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Morphological variability of the renal artery branching pattern: a brief review and an anatomical study

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Abstract

The segmental branches of the renal artery vary in number and origin. The 1998, *Terminologia Anatomica* homologates two branches of the renal artery (anterior, posterior) and five segmental arteries: four from the anterior branch and one from the posterior one. The purpose of this study is to evaluate the renal artery branching pattern, the number and origin of the segmental arteries, as well as to review data from similar studies. The study material consisted of 60 formalin-fixed adult kidneys. Dissections and microdissections were performed on the renal arteries and their branches. The branching of the renal artery was prehilar in 81.67% of cases, hilar in 10% and intra-sinusal in 8.33%. The number branches varied as follows: two branches in 42 cases (70%), three branches in 14 cases (23.33%) and four branches in four cases (6.67%). We subsequently analyzed the origin of the segmental arteries and found that in 53% of the cases the segmental arteries arose independently from the renal artery's branches, while in 47% of the cases they derived from common trunks of type I (85%) or II (15%). Type I trunks are those that originate directly from the main renal artery. They divide either into 2–3 segmental branches, or into just 1–2 branches and a smaller trunk (type II). The type II trunks further divide into 2–3 other segmental branches. These common trunks must be taken into account to avoid confusion with the segmental arteries. Knowledge of these variations is useful not only morphologically, but also clinically.

***Keywords*:** renal artery, branching pattern, segmental arteries, type I and II common trunks.

Introduction

Renal arteries are the largest collateral branches of the abdominal aorta. From their point of origin, they run obliquely, downward and laterally, towards the kidneys; they represent the main element of the renal pedicle, around which the other elements are grouped: the renal vein, the lymph vessels and the nerves [1–4]. The number of the terminal branches through which the artery approaches the kidney, as well as the artery branching point is very variable. *Terminologia Anatomica* (1998) [5] homologates two branches of the renal artery, one anterior and the other posterior. The superior segmental artery, the anterior superior segmental artery, the anterior inferior segmental artery and the inferior segmental artery derive from the anterior branch, while the posterior segmental artery derives from the posterior branch.

The hypothesis of the segmental character of the renal artery was first formed by Bertin in 1744, confirmed later by Hyrtl J (1882) [6] and Brödel M (1901) [7], whose studies encouraged the development of urological surgery.

Graves FT [8] developed the first renal segments classification in 1954, describing five segments: apical, encompassing the superior pole; upper, for the anterior-superior segment; middle, for the anterior-inferior segment; lower, for the inferior pole; and posterior, for the whole posterior region between the apical and inferior segment. Graves' terminology was quickly adopted by surgeons and served as a study model. However, Graves did not describe the vascular variants as well.

The importance of being familiar with the renal artery variability, which has become indispensable to urological surgery, has increased as a result of the large number of renal transplants and vascular reconstructions. Laparoscopic partial nephrectomy [9–13] has become a viable alternative to renal tumour patients [10, 14, 15]. Familiarity with the morphological types of renal artery branching allows better access to segmental renal arteries at the hilum level and safe laparoscopic partial nephrectomies. Segmental artery ligation reduces the risk for renal parenchyma during laparoscopic partial nephrectomies to a minimum [16].

Materials and Methods

The study was performed in the Anatomy and Embryology Department, on a group of 60 kidneys collected from both dissection areas and mortuaries, in compliance with the current legislation. The kidneys were collected after the post-mortem and evaluated by dissections and microdissections before, during and

after being fixed in formalin. Both the *in situ* dissections and those performed on the collected samples were carried out for the correct identification of the renal artery origin and the unaltered anatomical evaluation of the intrinsic relations of the renal pedicle vessels. The dissection of the renal pedicle towards the hilum allowed us to reveal the branching level and pattern of the renal artery trunk. The dissection continued deeply in the hilum for the identification of the anatomical elements. Then we sectioned the kidneys frontally and by microdissections we identified the morphology and topography of the elements of the renal sinus, based on the number and origin of the segmental arteries. For microdissections, we used a ×3÷×5 magnifying glass. Illustrative schemes were created for all pieces that were then grouped into morphological types.

Results

The following were analyzed on the study material: the renal artery branching point (extrahilar, hilar or intra-sinusal), the branching type, the number of the main branches and finally, the number and origin of the segmental arteries.

In most cases (49 – 81.67%), the branching of the renal artery was prehilar. In six cases (10%) it took place at the hilum, and in five cases (8.33%) was intra-sinusal.

The number of the renal artery branches varied between two and four. In 42 cases (70%), the renal artery split in two main branches (anterior and posterior). In 14 cases (23.33%), it divided into three branches: anterior, posterior and superior – seven cases (11.67%); anterior superior, anterior inferior and posterior in one case (1.67%); anterior posterior and inferior – six cases (10%). In four cases (6.67%) the renal artery divided into four branches: anterior, posterior, superior and inferior in two of these cases (3.33%), and anterior superior, anterior inferior, inferior and posterior in the other two (3.33%) (Figures 1 and 2).

As far as the origin point of the segmental branches is concerned, we noticed that in 53% of the cases the segmental arteries were independent branches derived from the division branches of the renal artery. In 47% of the cases, the segmental arteries arose from common trunks.

The common trunks were classified in two types, depending on origin and branching: common trunks of type I and type II. The former derive from the renal artery or its division branches and then branch in 2–3 segmental arteries or in 2–3 segmental arteries and a type II common trunk; the latter originate in a type I common trunk and divide in 2–3 segmental arteries.

The studied material revealed type I common trunks in 51 cases (85%) and type II common trunks in nine cases (15%). Type I common trunks arose most frequently from the anterior branch of the renal artery in 44 cases (86.27%). The correlation of the common trunks and the branching pattern of the renal artery revealed that of the 51 trunks, 46 (90.20%) were present in the pieces in which the renal artery split in two branches, while five of them occurred in the pieces in which the renal artery was divided in three branches.

The pieces in which the renal artery was divided in four branches did not have segmental arterial common trunks.

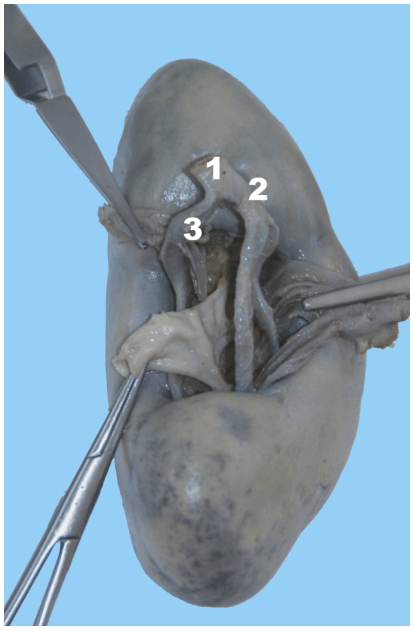

Figure 1 – ***Prehilar division into two branches: 1. Main renal artery; 2. Anterior branch; 3. Posterior branch.***

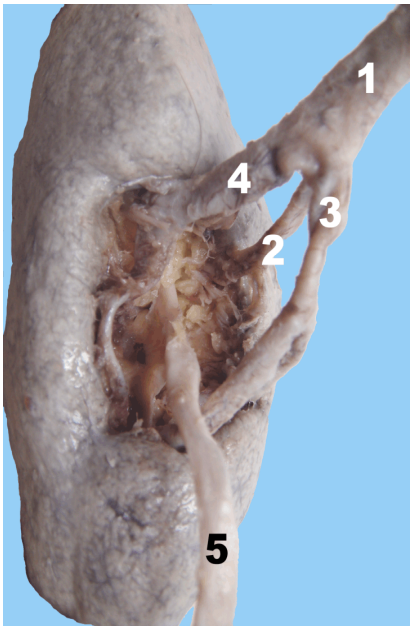

Figure 2 – ***Prehilar division into three branches: 1. Main renal artery; 2. Anterior superior branch; 3. Anterior inferior branch; 4. Posterior branch; 5. Ureter.***

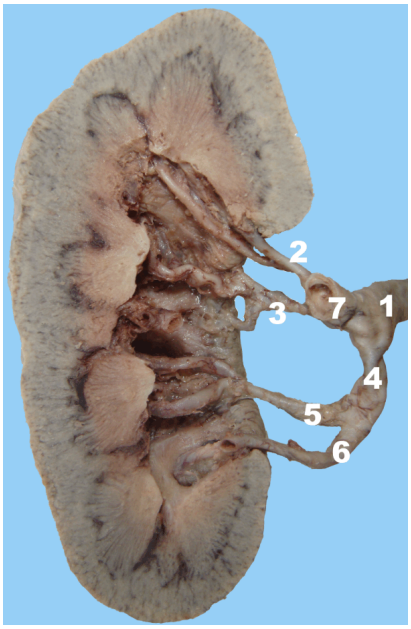

Figure 3 – ***Type I common trunk: 1. Main renal artery; 2. Superior segmental artery; 3. Anterior superior segmental artery; 4. Type I common trunk; 5. Anterior inferior segmental artery; 6. Inferior segmental artery; 7. Posterior branch.***

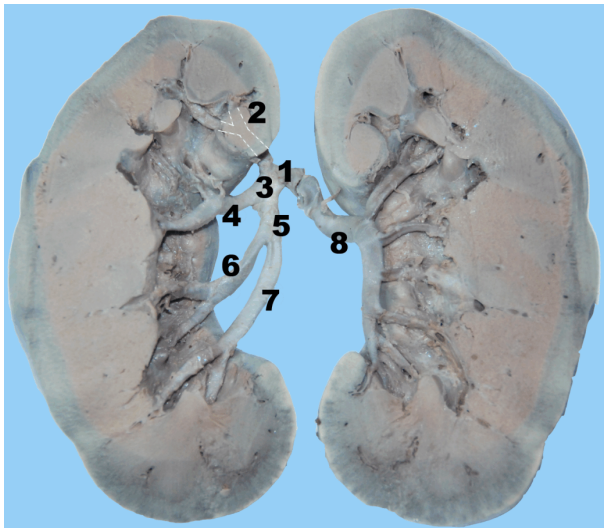

Figure 4 – ***Types I and II common trunks: 1. Anterior branch; 2. Superior segmental artery; 3. Type I common trunk; 4. Anterior superior segmental artery; 5. Type II common trunk; 6. Anterior inferior segmental artery; 7. Inferior segmental artery; 8. Posterior branch.***

Next, we analyzed the origin of each segmental artery (Figures 3 and 4).

The artery of the superior segment

The artery of the superior segment originated independently from the anterior branch of the renal artery in 25 cases (41.67%); in 32 cases (53.33%), it originated through a type I common trunk together with other segmental arteries: the artery of the anterior superior segment in 28 cases, the artery of the posterior segment in three cases, the artery of the anterior superior segment and the artery of the anterior inferior segment in one case; in three cases (5%) is derived from a type II common trunk together with the artery of the anterior superior segment.

The artery of the anterior superior segment

The artery of the anterior superior segment originated independently from the anterior branch of the renal artery in 24 cases (40%). The origin of the artery was through a type I common trunk in 33 cases (55%) together with: the artery of the superior segment – 28 cases, the artery of the superior segment and the artery of the anterior inferior segment – one case, the artery of the posterior segment – one case, and with a type II common trunk – three cases; through a type II common trunk together with the superior segment artery – three cases.

The artery of the anterior inferior segment

The artery of the anterior inferior segment originated independently from the anterior branch of the renal artery in 21 cases (35%); in 33 cases (55%) it was the branch from a type I common trunk together with: the artery of the inferior segment in 29 cases, the artery of the anterior-superior segment, the artery of the superior segment – one case and a type II common trunk in three cases; in six cases (10%) it detached itself as a branch from a type II common trunk together with the artery of the inferior segment.

The artery of the inferior segment

The artery of the inferior segment originated independently from the anterior branch of the renal artery in 10 cases (16.67%); in 32 cases (53.33%), it derived through a type I common trunk together with: the artery of the anterior inferior segment in 29 cases, the artery of the posterior segment in three cases; in six cases (10%), it originated from a type II common trunk, together with the artery of the anterior inferior segment.

The artery of the posterior segment

The artery of the posterior segment was the terminal branch of the posterior branch of the renal artery in 53 cases (88.33%); in seven cases (11.67%), it originated from a type I common trunk together with: the artery of the superior segment in three cases; the artery of the anterior segment in one case and the artery of the inferior segment in three cases.

Discussion

Along the time, the branching pattern of the renal artery has been described in many ways.

The classic authors described four branches: two anterior branches for the anterior side of the pelvis, the middle part of the kidney and the lower extremity of the kidney; a superior branch for the upper extremity of the kidney and a posterior branch that surrounds the pelvis and is distributed to the inferior two thirds of the posterior side (Cordier GJ, 1939) [17]. Also, Gérard G (1921) [18] showed that the renal artery ends most frequently in four branches, of which three are anterior – superior, middle and inferior, satellites of the large calices – and one is posterior, running along the superior edge of the pelvis or its internal edge.

Poirier P (1901) [1] described three branches of the renal artery: anterior for the anterior side of the kidney, superior for the upper extremity and posterior for the posterior side of the kidney. Testut L and Latarjet A (1958) [20] showed that irrespective of the length of the arterial trunk, it ends in three branches: anterior, posterior and polar superior (that can be derived from the posterior branch). Williams PL *et al.* (1989) [4] also described three branches: anterior, posterior and inferior. Besides these, frequently there may be two secondary branches: intermediary and middle.

Schmerber F (1895) [21] showed that the renal artery ends in two branches: one anterior and the other posterior, in relation to the excretory ducts. Grégoire R (1920) [22] described two branches as well: anterior or the common trunk of the anterior side and the inferior pole, and posterior or the common trunk of the arteries of the posterior sides and the upper pole. Paturet G (1958) [2] described an anterior trunk that quickly divides in three, four branches for the inferior pole and a posterior, less voluminous trunk that is distributed to the lower half and the upper pole of the kidney. Rouvière H (1970) [3] stated that in most cases, the terminal branches of the renal artery are two, anterior and posterior, that surround the renal pelvis and run down along its posterior side, up to the middle part of the hilum.

Ecoiffier J (1979) [23] also held that the renal artery ends in two branches, one anterior and the other posterior. *Terminologia Anatomica* (1998) [5] homologates two terminal branches of the renal artery: the anterior and the posterior branch.

In our study, in 70% of the cases, the renal artery divided in two branches, anterior and posterior). In 23.33% of the cases, it divided in three branches: anterior, posterior and superior – 11.67% of the cases; anterior superior, anterior inferior and posterior in one case (1.67%); anterior, posterior and inferior in 10% of the cases. In 6.67% of the cases, four branches derived from the renal artery: anterior, posterior, superior and inferior (3.33%), and anterior, superior, anterior inferior, inferior (3.33%).

As far as the renal artery branching point is concerned, the results of our study concur with those in the literature [2, 24, 25]. In 81.67% of the cases, a percentage that is comparable to that mentioned by the above authors, the branching was prehilar. The hilar branching occurred in 10% of the cases on both our study material and the comparative study. However, we noticed big differences concerning the intra-sinusal branching of the renal artery, which in our study occurred only in 8.33% of the cases, compared to 30% in the other authors' studies.

Paturet G (1958) [2] stated that the renal artery branching pattern depends on the form of the hilum:

- a narrow hilum is generally associated with intra-hilar or intra-sinusal branching;
- a large hilum, is almost always associated with extrahilar branching;
- there are intermediary situations between these two extremes.

We have found no correlation between the form of the renal hilum and the renal artery branching point.

Guntz M (1967) [25] described two branching patterns: dispersed, occurring in extrahilar branching, and condensed, characteristic of the intra-sinusal branching.

Shoja MM *et al.* (2008) [26] tried to identify a prehilar branching pattern in a study performed on 81 renal arteriographies. They classified the morphological types as follows: scalariform (7.4%) and divergent (92.6%), which in turn have two (80.2%) and three branches (12.4%). Based on their study, they generated two classes of morphological models: eight cardinal (82.7% of cases) and 10 less frequent (17.3% of cases), drawing the conclusion that although these models could be applied, the morphological variability of the prehilar branching was still high.

As far as the origin of the segmental branches is concerned, we found that in 53% of the cases, the segmental arteries originated as independent branches, while in 46% of the cases they originated from type I (85%) and type II (15%) common trunks.

In order to evaluate the selective segmental artery clamping during partial nephrectomies, Weld KJ *et al.* (2005) [16] analyzed the anatomical variants of the segmental arteries on 73 formalin-fixed kidneys. The authors underlined the possibility of the common origin of the segmental arteries and introduced the expression "presegmental arteries". They defined a presegmental artery as a branch of the renal artery that divides in two or several segmental arteries, while the segmental artery is the branch entering the parenchyma. In their study, the number of segmental arteries varied between three (21.9%) and five (31.5%). In 31.5% of the cases, a presegmental artery was present, in 9.2% of the cases, two presegmental arteries occurred, and in 49.3% of the cases, the presegmental arteries were missing.

In a study on 44 kidneys, Sarfraz R *et al.* [27] found presegmental trunks in 100% of the cases, most of them located at the prepielic and extrahilar level. Regarding the origin of segmental arteries, individual or through common trunks, and "presegmental arteries", the results of our study (in percentage points) are similar to those of Weld KJ *et al.* The difference is that we analyzed the origin of the segmental arteries taking into account the branching pattern of the renal artery (according to *Terminologia Anatomica*), while Weld KJ *et al.* considered that the segmental arteries derive directly from the "main" renal artery and ignored its branches.

In their study, Sarfraz R *et al.* [27] named "presegmental arteries" the renal artery anterior and posterior branches that later divide in segmental arteries. This explains the 100% presence of presegmental arteries.

The term "presegmental artery", introduced by Weld KJ *et al.* [16], defines a common origin branch of 2–3 segmental arteries.

We considered that in order to describe the common origin of the segmental arteries, the term "common trunk" is better, because not only segmental arteries can derive from a common trunk. There is the possibility to associate the origin of a segmental artery from a type I common trunk with a type II common trunk that subsequently divides in 2–3 segmental arteries.

Conclusions

The level and branching pattern of the renal artery are characterized by high morphological variability. Consequently, the morphology of the renal segmental arteries must not be regarded as a certainty model.

Arterial segmental control through clamping is anatomically possible, but difficult because of the high individual morphological variability. A primary or even secondary prehilar branch of the renal artery need not always be a segmental artery (only 53%); it may be a common trunk or even a lobar artery. The rate of segmental artery accessibility can influence the laparoscopic surgery approach.

References

[1] Poirier P, Charpy A, *Traité d'anatomie humaine*, 2e tome, fascicule II, Masson et Cie Editeurs, Paris, 1912.
[2] Paturet G, *Traité d'anatomie humaine. Appareil circulatoire*, tome III, fascicule I, Masson et Cie Editeurs, Paris, 1958.
[3] Rouvière H, *Anatomie humaine descriptive et topographique*, tome II, Masson et Cie Editeurs, Paris, 1970.
[4] Williams PL, Warwick R, Dyson M, Bannister LH, *Gray's anatomy*, Churchill Livingstone, Edinburgh–London–Melbourne–New York, 1989.
[5] ***, *Terminologia Anatomica*, Federative Committee on Anatomical Terminology, Thieme, Stuttgart–New York, 1998.

[6] Hyrtl J, Topographische Anatomie, Wien, 1882. In: Hureau J, Chevrel JP, Alexandre JH, Lassau JP, *Considérations sur le plan général d'organisation du rein des mammifères*, Bull Assoc Anat, 1966, 50:518–539.
[7] Brödel M, The intrinsec blood vessels of the kidney and their significance in nephrotomy, John Hopkin's Hosp Bull, 1901. In: Arvis G, *Anatomie pratique du sinus du rein*, 53 Congrès, Tours, 7–11 Avril, Bull Assoc Anat, 1968.
[8] Graves FT, *The anatomy of the intrarenal arteries and its application to segmental resection of the kidney*, Brit J Surg, 1954, 42(172):132–139.
[9] McDougall EM, Clayman RV, Anderson K, *Laparoscopic wedge resection of a renal tumor: initial experience*, J Laparoendosc Surg, 1993, 3(6):577–581.
[10] McDougall EM, Elbahnasy AM, Clayman RV, *Laparoscopic wedge resection and partial nephrectomy – the Washington University experience and review of the literature*, JSLS, 1998, 2(1):15–23.
[11] Kozlowski PM, Winfield HN, *Laparoscopic partial nephrectomy and wedge resection*, J Endourol, 2000, 14(10):865–870; discussion 870–871.
[12] Kozlowski PM, Winfield HN, *Laparoscopic partial nephrectomy and wedge resection for the treatment of renal malignancy*, J Endourol, 2001, 15(4):369–374; discussion 375–376.
[13] Kapoor A, Soon SJ, Birch DW, Zikman J, *Laparoscopic wedge resection of a renal mass in a solitary kidney*, Can J Urol, 2001, 8(3):1297–1299.
[14] Janetschek G, Daffner P, Peschel R, Bartsch G, *Laparoscopic nephron sparing surgery for small renal cell carcinoma*, J Urol, 1998, 159(4):1152–1155.
[15] Hoznek A, Salomon L, Antiphon P, Radier C, Hafiani M, Chopin DK, Abbou CC, *Partial nephrectomy with retroperitoneal laparoscopy*, J Urol, 1999, 162(6):1922–1926.
[16] Weld KJ, Bhayani SB, Belani J, Ames CD, Hruby G, Landman J, *Extrarenal vascular anatomy of kidney: assessment of variations and their relevance to partial nephrectomy,* Urology, 2005, 66(5):985–989.
[17] Cordier GJ, *Anatomie. Rein*, Encyclopédie medico-chirurgicale, 1939.
[18] Gérard G, *Manuel d'anatomie humaine*, 2e édition, Masson et Cie Editeurs, Paris, 1921.
[19] Poirier P, Charpy A, *Traité d'anatomie humaine*, 2e édition, Masson et Cie, Paris, 1901.
[20] Testut L, Latarjet A, *Tratado de anatomia humana*, 9a ed., Ed. Salvat, Barcelona, 1958.
[21] Schmerber F, Recherches anatomiques sur l'artère rénale (Thèse, 1895). In: Arvis G, *Anatomie pratique du sinus du rein*, 53 Congrès, Tours, 7–11 Avril, Bull Assoc Anat, 1968.
[22] Grégoire R, *L'appareille uro-génital*, Masson & Cie Editeurs, Paris, 1920.
[23] Ecoiffier J, *L'artériographie rénale*, Annales de Radiologie, Paris, 1972.
[24] Calas F, Martin R, Convert A, *Contribution a l'étude de la vascularisation du rein*, CR Assoc Anat (Nancy) 1963, 117.
[25] Guntz M, *Radio-anatomie de l'artère rénale. Déduction chirurgicales*, C R Assoc Anat, 1967, 148.
[26] Shoja MM, Tubbs RS, Shakeri A, Loukas M, Ardalan MR, Khosroshahi HT, Oakes WJ, *Peri-hilar branching patterns and morphologies of the renal artery: a review and anatomical study*, Surg Radiol Anat, 2008, 30(5):375–382.
[27] Sarfraz R, Tahir M, Sami W, *Presegmental arterial pattern of human kidneys in local population*, Ann Pak Inst Med Sci, 2008, 4(4):212–215.

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