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Morphological variability of arterial sources of the renal polar parenchyma and its clinical importance

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Abstract

A sample of 250 kidneys (200 corrosion casts and 50 dissection pieces) provided the basis for the analysis of the number, source, origin point and parenchymal penetration of the arterial branches supplying the two renal poles. Of the studied pieces, 76.80% had a single renal artery, while 23.20% had multiple renal arteries. The superior pole had only one arterial source in 95.20% of cases, and the inferior pole had only one arterial source in 97.20% of cases. The arteries supplying the superior pole originated from one of the renal artery's branches in 59.60% of cases and from its' main trunk in 17.20% of cases. They were also found to originate from branches of the multiple renal arteries in 18% of cases and from the abdominal aorta (5.20% of cases – inferior polar arteries). The arteries supplying the inferior pole arose in similar fashion – from the single renal artery's trunk in 9.20% of cases; from its division branches in 66.40% of cases; from the abdominal aorta in 9.60% of cases and from branches of multiple renal arteries in 14.80% of cases. Familiarity with the renal arteries' morphological variability is becoming increasingly important, as new urologic surgical and radiological techniques develop.

Keywords: renal poles, segmental arteries, polar arteries, branching pattern, morphological variability.

Introduction

Renal arterial vascularization is characterized by high morphological variability. With the diversification of imagistic methods (for diagnosis or intervention purposes) and the improvement of surgical techniques, awareness of and familiarity with this variability is becoming increasingly important.

The terminal aspect of the segmental branches of the renal artery has been demonstrated, confirmed and accepted through numerous research studies, creating a foundation for and bringing multiple improvements to the surgical techniques used in partial nephrectomies [1]. In anatomical literature, the number of renal segments described varies: two segments – Hyrtl as cited by Sampaio & Aragao [2], three segments [3, 4], four segments [5], five segments [6, 7], six segments [8, 9] and seven segments [10–12].

At present, the *Terminologia Anatomica* (1989) [13] acknowledges five renal segments: superior, anterior superior, anterior inferior, inferior and posterior.

According to this data and as listed in the *Terminologia Anatomica*, the renal polar parenchyma has one segment supplied by the homonymic artery (the superior segment's artery and the inferior segment's artery), originating from the anterior branch of the renal artery.

Following a wider study on renal vascular and ductal elements, this paper attempts to comparatively analyze the arterial vascularization of the two renal poles – both in cases with a single renal artery and in those with multiple renal arteries. In the literature reviewed, we have not come across a similar comparative study, and a number of the variants discussed here are either omitted or not presented in detail by other studies.

Materials and Methods

The study was conducted in the Department of Anatomy and Embryology, "Victor Babeş" University of Medicine and Pharmacy, Timişoara, Romania, on 200 renal corrosion casts and 50 formaldehyde-fixed kidneys. Dissections and microdissections of the renal artery and its branches were performed to the level of segmental arteries. All of the kidneys used in the study were from adults, who had deceased of unrelated causes and had no history of renal conditions. The study was conducted following all ethical guidelines set by the University.

The corrosion casts were obtained by injecting a plastic mass (based on nitrocellulose) into the vascular and ductal elements, followed by corroding the renal parenchyma with hydrochloric acid – as per current departmental methodologies. The number, origin and division pattern of the renal arteries in the dissection pieces were studied initially *in situ*. After the kidneys were sampled, the dissection of the renal pedicle continued into the hilum. Next, the kidneys were sectioned frontally. The elements of the renal sinus were identified through microdissection at 3–5× magnification. The pieces thus obtained were studied individually, catalogued and classified based on the morphological typologies of origin and distribution of segmental arteries.

Our study focused on the following aspects:

- the number of segmental arterial branches supplying the polar parenchyma;
- their sources and origin points;
- their origin type (individual or common trunks with other segmental branches);
- the way they enter the renal parenchyma (at the hilar or extrahilar level).

All of these aspects were first analyzed separately for each of the two renal poles, on all study pieces. Afterwards, the data was synthesized for the entire sample and the results were compared.

Results

Out of the current sample, 192 (76.80%) pieces had a single renal artery and 58 (23.20%) had multiple arteries. Of the latter, 49 (19.60%) had two arteries and nine (3.60%) showed three arteries.

Vascularization of renal poles in pieces with a single renal artery

In 174 (90.63%) cases, the renal artery divided into an anterior and a posterior branch. In 17 (8.85%) cases, the renal artery divided into three branches; the terminal branches were named according to their trajectory: anterior, posterior and superior (13 cases – 6.77%) (Figure 1) or anterior, posterior and inferior (four cases – 2.08%) (Figure 2). In a single case (0.52%), the renal artery gave birth to four branches: anterior, posterior, superior and inferior, each of them continued with a segmental artery.

Arterial supply to the superior polar parenchyma

In 184 (95.83%) of the single artery cases, a single segmental artery supplied the superior polar parenchyma. In 181 (94.27%) cases, the single segmental artery supplied both sides of the superior pole, while in three (1.56%) cases it supplied only the anterior side (with several smaller branches originating from the posterior branch of the renal artery to supply the posterior side).

The source of the superior segment's artery was the renal artery in 38 (19.79%) cases. The origins were between the aorta and the renal artery's division point in 27 (14.06%) cases, and at the division point itself in 11 (5.73%) cases.

Most frequently (139 cases – 72.40%), the superior segment's artery arose from the anterior branch of the renal artery.

As far as the origin type is concerned, the superior segment's artery arose as an individual branch in 79 (41.15%) cases, and shared a common trunk in 60 (31.25%) cases – with the anterior superior segmental artery in 52 (27.08%) cases, and with the anterior superior and anterior inferior segment's arteries in eight (4.17%) cases.

In seven (3.65%) cases, the superior segment's artery arose from the posterior branch of the renal artery (or a common trunk with the posterior segmental artery).

In eight (4.17%) cases, two distinct arterial branches supplying the superior polar parenchyma were revealed, one in the anterior and one in the posterior plane, each distributed to the homonymic side (Figure 3).

The anterior branch originated from: the renal artery in five cases [three cases – 1.56% before the division point (Figure 4) and two cases – 1.04% at the division point] and the anterior division branch of the renal artery in three (1.56%) cases (Figure 5).

In all eight (4.17%) cases, the posterior branch detached from the posterior division branch of the renal artery. In three (1.56%) cases, its origin was in the first half of the posterior division branch, the artery having an almost vertical path; in the other five (2.60%) cases, the branch arose from the same place as the posterior segmental artery, at the branching of the posterior division branch of the renal artery, having an oblique superior and medial path.

Arterial supply to the inferior renal parenchyma

In 187 (97.40%) cases, a single segmental artery supplied the inferior polar parenchyma. The origin of the inferior segment's artery was in the first part of the renal artery (before its' division) in 19 (9.90%) cases, at the division point in four (2.08%) cases and in its anterior division branch in 164 (85.42%) cases.

As far as the origin type is concerned, in 101 (52.60%) cases the inferior segment's artery derived as an individual branch from the anterior branch of the renal artery. In 60 (31.25%) cases, it derived from a common trunk with other segmental arteries: with the anterior inferior segmental artery in 52 (27.08%) cases, and the anterior superior and anterior inferior segmental arteries in eight (4.17%) cases.

The posterior branch had a similar origin type to that at the superior pole: in two (1.04%) cases this was in the first half of the posterior branch, the artery having an almost vertical path (Figure 6); in the other three (1.56%) cases, the branch arose from the terminus of the horizontal segment, as a branching of the posterior division branch of the renal artery.

As seen at the superior pole, the inferior polar parenchyma was also supplied by two arterial branches: anterior and posterior in five (2.60%) cases (Figure 7).

In all cases, the anterior branch arose from the anterior division branch of the renal artery.

Vascularization of renal poles in pieces with multiple renal arteries

Fifty-eight (23.20%) of the studied pieces were vascularized by multiple renal arteries, all of which arose from the abdominal aorta. We classified the arteries based on their level of origin: superior, middle and inferior.

The branching pattern of each artery was analyzed for these pieces as well.

Most frequently (34 cases – 58.62%), the superior renal artery branched into an anterior and posterior branch. The inferior renal artery remained mostly in a single branch (52 cases – 89.65%), and the middle renal artery even more so, having only one branch in all nine cases (anterior in four cases and posterior in five cases).

Arterial supply to the superior polar parenchyma

The superior polar parenchyma had one segmental artery in 54 (93.10%) cases. This artery arose from the superior renal artery in 50 (86.20%) cases, and from the inferior renal artery in four (6.90%) cases (Figure 8).

Regarding the superior segment's artery's origin type, in 13 (22.41%) cases it arose from the abdominal aorta, being the single branch of the superior renal artery (superior polar artery); in 34 (58.62%) cases it detached as an individual branch from the division branch of the superior renal artery; in three cases, it arose together with the superior anterior segment's artery.

In four (6.90%) cases, the superior segment artery originated from the anterior division branch of the inferior renal artery, after the latter crossed the superior renal artery at prehilar level.

In four (6.90%) cases, two distinct arterial branches (anterior and posterior) supplying the superior polar parenchyma were revealed.

The anterior branch was the terminal (anterior) branch of the middle renal artery that crossed the superior renal artery at the prehilar level.

The posterior branch arose from the posterior branching of the superior renal artery in three (5.18%) cases, and of the inferior renal artery in one case (1.72%).

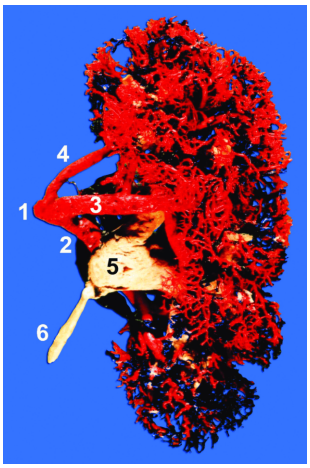

Figure 1 – *Corrosion cast. Posterior view. Renal artery divided into three branches: anterior, posterior and superior. 1: Renal artery; 2: Anterior branch; 3: Posterior branch; 4: Superior branch; 5: Renal pelvis; 6: Ureter.*

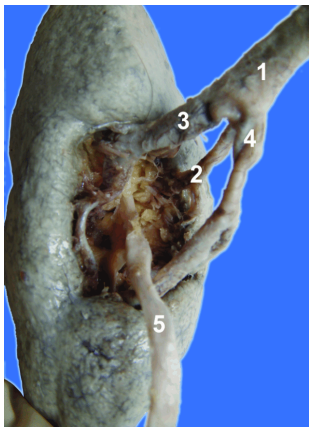

Figure 2 – *Dissection piece. Postero-medial view. Renal artery divided into three branches: anterior, posterior and inferior. 1: Renal artery; 2: Anterior branch; 3: Posterior branch; 4: Inferior branch; 5: Ureter.*

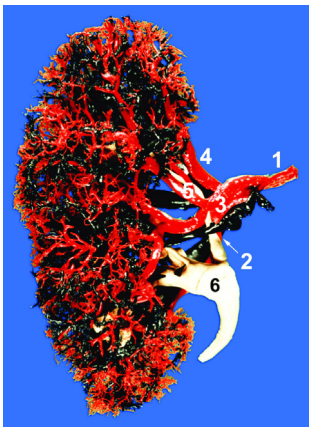

Figure 3 – *Corrosion cast. Posterior view. Superior polar parenchyma supplied by two arterial branches. 1: Renal artery; 2: Anterior branch; 3: Posterior branch; 4: Superior anterior branch; 5: Superior posterior branch; 6: Renal pelvis.*

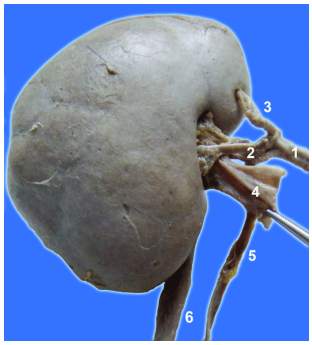

Figure 4 – *Dissection piece. Anterior view. Superior renal artery originating from the renal artery before the division point. 1: Renal artery; 2: Division point and anterior branch; 3: Superior polar artery; 4: Renal vein; 5: Right testicular vein; 6: Ureter.*

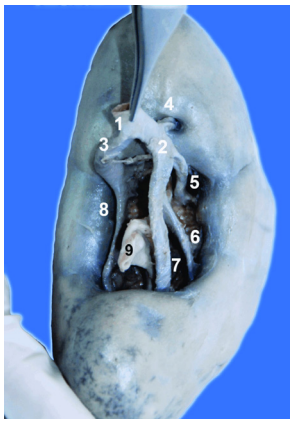

Figure 5 – *Dissection piece. Medial view. Superior renal artery originating from the anterior division branch of the renal artery and with an extrahilar penetration. 1: Renal artery; 2: Anterior branch; 3: Posterior branch; 4: Superior segmental artery; 5: Anterior superior segmental artery; 6: Anterior inferior segmental artery; 7: Inferior segmental artery; 8: Posterior segmental artery; 9: Renal pelvis.*

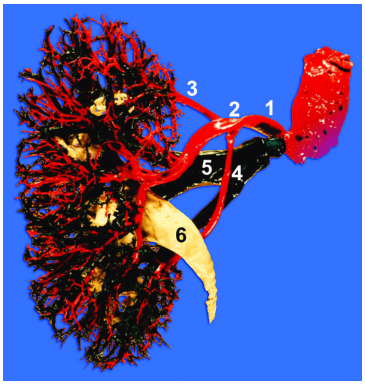

Figure 6 – *Corrosion cast. Posterior view. Inferior segmental artery originating from the posterior division of the renal artery. 1: Renal artery; 2: Posterior branch; 3: Superior segmental artery; 4: Inferior segmental artery; 5: Renal vein; 6: Renal pelvis.*

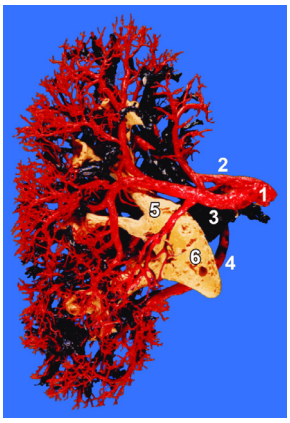

Figure 7 – *Corrosion cast. Posterior view. Inferior polar parenchyma supplied by two arterial branches: anterior and posterior. 1: Renal artery; 2: Anterior branch; 3: Posterior branch; 4: Inferior anterior branch; 5: Inferior posterior branch; 6: Renal pelvis.*

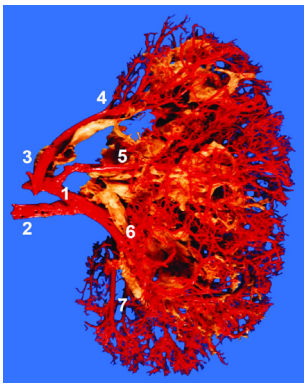

Figure 8 – *Corrosion cast with three renal arteries. Anterior view. Inferior renal artery crossing superior renal artery and with a single branch, supplying the superior pole. Middle renal artery with a single posterior branch. Superior renal artery branching into anterior superior artery and a common trunk for the anterior inferior renal artery and inferior segmental artery. 1: Superior renal artery; 2: Middle renal artery; 3: Inferior renal artery; 4: Superior segmental artery; 5: Anterior superior artery; 6: Anterior inferior renal artery; 7: Inferior segmental artery.*

Arterial supply to the inferior renal parenchyma

The inferior polar parenchyma had only one arterial source in 56 (96.55%) cases; this arterial source originated from the inferior renal artery in 52 (89.66%) cases, and the superior renal artery in four (6.89%) cases.

The origin pattern of the inferior segment's artery varied as follows: in 24 (41.38%) cases, it was in the abdominal aorta, as a single branch of the inferior renal artery (inferior polar artery); in 18 (31.03%) cases, it arose as an individual branch from the anterior division branch

of the inferior renal artery; in four (6.90%) cases it arose from a trunk shared with the anterior inferior segment's artery; in six (10.43%) cases, it detached from the posterior division branch of the inferior renal artery (through a common trunk with the posterior segment's artery); in four (6.89%) cases, the inferior segment's artery detached from the anterior division branch of the superior renal artery.

When two arterial sources were present (two cases – 3.45%), the anterior branch arose from the anterior branching of the inferior renal artery in one case, and from the anterior branching of the superior renal artery in the other case; in both cases, the posterior branch detached from the posterior branching of the inferior renal artery.

In seven (2.80%) cases – six with a single renal artery and one with two renal arteries – the superior and the inferior polar parenchyma each had two arterial sources, one anterior and one posterior, so the two arterial planes were separated completely: anterior and posterior.

The general analysis of the study material reveals the following aspects: in 238 (95.20%) cases, the superior renal pole was supplied by a single segmental artery; of these, in 235 cases the single segmental artery was distributed to both sides, while in three (1.20%) cases only to the anterior side. In 12 (4.80%) cases, the superior polar parenchyma had two distinct arterial branches, one anterior and one posterior.

The arteries supplying the superior pole originated in the single renal artery in 38 (15.20%) cases: before its division site in 27 (10.80%) cases; at its division site in 11 (4.40%) cases; in the anterior division branch in 139 (55.60%) cases and in the posterior division branch of the single renal artery in 15 (6%) cases; in 13 (5.20%) cases, in the abdominal aorta (superior polar arteries), in 45 (18%) cases from branches of the multiple renal arteries.

The inferior renal pole had a single artery in 243 (97.20%) cases, and two arterial branches (anterior and posterior) in seven (2.80%) cases.

The arteries supplying the inferior pole originated in the single renal artery in 23 (9.20%) cases: before its division point in 19 (7.60%) cases; at its division point in four (1.60%) cases; in the anterior division branch in 161 (64.40%) cases and in the posterior division branch in five (2%) cases; in 24 (9.60%) cases, in the abdominal aorta (inferior polar arteries), in 37 (14.80%) cases from branches of the multiple renal arteries (Figure 9, a and b).

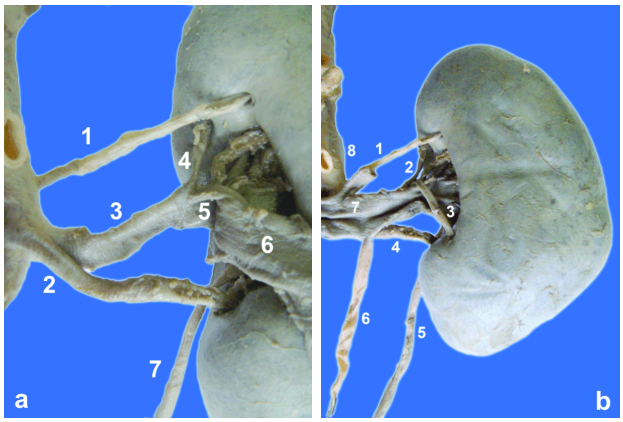

Figure 9 – ***Dissection piece with three renal arteries. Anterior view. (a) Middle renal artery crossing the inferior renal artery. 1: Superior renal (polar) artery; 2: Middle renal artery; 3: Inferior renal artery; 4: Superior branch from inferior renal artery; 5: Inferior branch from inferior renal artery; 6: Renal vein repositioned; 7: Ureter. (b) Superior and inferior poles supplied by two branches each – one originating from the aorta and one from the inferior renal artery. 1: Superior renal artery; 2: Superior branch from inferior renal artery; 3: Inferior branch from inferior renal artery; 4: Middle renal artery; 5: Ureter; 6: Left testicular vein; 7: Renal vein.***

The last aspect we analyzed was how the segmental arteries supplying the two renal poles entered the parenchyma.

Arteries entered the superior polar parenchyma through the renal hilum in 194 (77.60%) cases, and at an extrahilar level in 56 (22.40%) cases. The extrahilar branches originated in the abdominal aorta in 13 (5.20%) cases and in the renal artery in 43 (17.20%) cases.

Arteries entered the inferior polar parenchyma through the hilum in 205 (82%) cases, and at an extrahilar level in 45 (18%) cases. The extrahilar branches originated in the abdominal aorta in 24 (9.69%) cases and in the renal artery in 21 (8.40%) cases.

Discussion

The great variability of the branching pattern of the renal artery is reflected not only in the division point and pattern, but also the number of branches. Similarly, the number of segmental arteries, their source, origin type (individual or common trunks) and manner of parenchymal penetration (through the hilum or extrahilar) are subject to high morphological variability.

The morphological variability of segmental arteries has been the subject of many studies, all conducted to reveal the segmental arterial areas and to facilitate the performance of partial nephrectomy.

Our study points out that the number of the renal arterial branches varies between two (90.63%) and four (0.4%). Our results differ from those of Sampaio *et al.* [14], who describes two branches in all cases.

As we have already mentioned, when describing the branching pattern of the renal artery, we took into consideration the branches that arise from the same site and named them based on their path: anterior, posterior, superior and inferior [15].

Irrespective of their number and association, the anterior and posterior division branches have always been present, our results matching those reported in the academic literature and in the *Terminologia Anatomica* [13].

In 8.85% of cases, the single renal artery divided into three branches, with the superior branch three times more frequent than the inferior branch, a percentage significantly higher than that reported by Budhiraja *et al.* [16] – 3%.

In only one case, the renal artery produced four branches, each constituting a segmental artery in itself.

The division pattern of the multiple arteries was different. Most of the times, the superior renal artery divided in two branches – anterior and posterior – (58.62%), while the inferior renal artery had a single branch in most cases (89.52%) and the middle renal artery had two branches (anterior and posterior) in all cases.

None of the studied pieces showed three or four branches of the renal artery.

With regard to the number of arterial sources supplying the superior polar parenchyma, in most cases (94.27% of the single artery cases and 93.10% of the multiple artery cases), the parenchyma was supplied by a single segmental artery distributed to both parts.

In 1.56% of cases (only for the single renal artery pieces), one arterial branch (similar to the other segmental arteries) originated in the anterior division branch of the renal artery and supplied only the anterior side of the superior polar parenchyma.

In 4.80% of cases, the superior polar parenchyma had two distinct arterial sources, one originating in the anterior arterial plane and the other in the posterior plane. These cases were more common in multiple (6.19%) artery pieces, than in the single (4.17%) artery cases.

The presence of two segmental arteries that supply the superior polar parenchyma is more rarely reported and analyzed in the anatomic literature. Sykes [12] shows that in 20.3% of cases there can be two superior (apical) segmental arteries, each arising from one of the division branches of the renal artery. This percentage is higher than the one we reported in our studies [17].

The arteries supplying the superior polar parenchyma had three sources: various parts of the renal artery's trunk, its division branches or the abdominal aorta (the latter in pieces with multiple renal arteries).

In 10.80% of cases, the origin of the segmental arteries was on the path of the single renal artery, between its aortic origin and the division point, a smaller proportion than described by Saldarriaga *et al.* [18] – 15.4%, Talović *et al.* [19] – 12.82% and Raghavendra *et al.* [20] – 11.66%.

In 4.40% of cases, the segmental arteries arose at the division point of the single renal artery. This percentage is higher than that of Raghavendra *et al.* [20] (1.66%).

Most frequently, the origin of the superior segment arteries was the anterior division branch of the renal artery (55.60% of cases). This percentage is closer to that of Raghavendra *et al.* [20] – 51.66%, higher than Saldarriaga's *et al.* [18] – 46.4% and lower than Sampaio's *et al.* [14] – 73.5%.

The superior segment's artery arose from the posterior branch of the renal artery in 6% of cases. This percentage is much lower than the percentages reported by Sampaio *et al.* [14] – 26.5% and Raghavendra *et al.* [20] – 8.33%.

As far as the origin type is concerned, in 68.75% of cases, the superior segment's artery arose as an individual branch, and in 31.25% cases, it arose through a common trunk with other segmental arteries. Most frequently, in 27.08% of cases, it arose through a common trunk with the artery of the anterior superior segment. Our results are similar to those reported in other studies: Raghavendra *et al.* [20] gives a 25% origin of the superior segment artery (apical segmental artery) in the upper segmental artery. Weld *et al.* [21] also shows that in 21.4–26.1% the artery of the superior segment arises together with the artery of the anterior superior segment through a pre-segmental artery. However, Sarfraz *et al.* [22] describes the presence of pre-segmental arteries in 100% of cases.

When we described the origin type of the segmental arteries, we used the term "common trunk" or "together with", and not from another segmental artery, given the meaning of the term renal "segment" [15].

The inferior polar parenchyma had one segmental artery in a high percentage (97.40%) of cases. This artery always supplied both sides. As with the superior pole, most frequently (64.40%) this artery arose from the anterior branch of the single renal artery; our results are close to those of Sampaio & Aragao [2] at 62.2%, but greater than those reported by Saldarriaga *et al.* [18] – 55.9% and Raghavendra & Telkar [23] – 51.33%; in 2% of cases, the origin was the posterior division branch, the percentage being much lower than that in Raghavendra & Telkar's study (8.33%) [23].

The origin of the inferior segment's artery was in different parts of the renal artery trunk in 7.60% of cases (a percentage lower than Raghavendra & Telkar's – 10% [23]); in 1.60% of cases, the inferior segment artery arose from the division site in a percentage lower than that reported by Saldarriaga *et al.* [18] (3.4%). The origin pattern was an individual branch (67.19%) and a common trunk with the artery of the inferior anterior segment (28.65%) – similar to Raghavendra & Telkar's results (28.33% origin from or with the artery of the inferior anterior segment) [23]; it detached from a common trunk with the arteries of the anterior superior and anterior inferior segments in 2.60% of cases, a percentage higher than that reported by Raghavendra & Telkar (1.66% origin from or common with the artery of the anterior superior segment) [23].

In the inferior polar parenchyma, two arterial sources were more frequent in pieces with multiple renal arteries (3.45%) than in pieces with a single renal artery (2.60%), a lower percentage than the 5% found by Rani *et al.* [24].

In 1954, Graves [6] described the variability of the origin of the inferior segment's arteries and indicated the possibility that the inferior polar parenchyma might be supplied by two branches, both with aortic origin. He considered that in this case, the artery in the anterior plane is the artery of the inferior segment, and the artery in the posterior plane is the posterior branch of the inferior segment's artery. Although both arteries have aortic origin, Graves does not consider that the second inferior artery is segmental (in line with his classification of five renal segments).

Familiarity with the morphological types in which the polar parenchyma has two arterial sources is important, in order to minimize the risks of hemorrhage during surgery or erroneous interpretations of radiological data.

Our study shows that the frequency of a single segmental artery supplying the polar parenchyma is higher in pieces with single renal artery than in pieces with multiple renal arteries: 95.83/93.10% for the superior pole and 97.40%/96.55% for the inferior pole.

The comparison of the two poles revealed that the inferior pole is more frequently supplied by one artery, compared to the superior pole; the difference increased

from 1.57% in pieces with a single renal artery to 3.45% in pieces with multiple renal arteries.

Regarding the origin types, the superior segment's artery arises most often as an individual branch (68.75% of cases) with a single renal artery and increases to 72.41% in pieces with multiple renal arteries.

For the inferior segment's artery however, the proportion of cases in which it originates as a single branch is slightly higher in pieces with a single renal artery (72.41%) and decreases to 51.72% in pieces with multiple renal arteries.

In our study, the incidence of the multiple renal arteries was 23.20% – 19.68% double and 3.62% triple, comparable to the data in the literature: Vilhova *et al.* [25] (double 18.7%; triple 3%); Özkan *et al.* [26] (24%), Çiçekcibaşi *et al.* [27] (25%), Weld *et al.* [21] (12.3%, double), Khamanarong *et al.* [28] (double 17.43%; triple 0.93%), Saldarriaga *et al.* [18] (25.1%), Satyapal *et al.* [29] (28.2%), Sampaio & Passos [30] (30.4%), Talović *et al.* [19] (33.33%), Palmieri *et al.* [31] (61.5% multiple). The percentage differences are caused by a number of factors, such as racial or gender differences, study method and evaluation criteria – as also highlighted by Natsis *et al.* [32] in their extensive literature review.

A correct description of the sources and origin types of the segmental arteries must take into consideration all the morphological types of renal artery division. Also, one should use a uniform terminology, such as that homologated in *Terminologia Anatomica*, to name the segmental arteries and the renal segments. *Terminologia Anatomica* reflects a better correspondence between the name and the site of the renal segments. The concurrent use of the terms introduced by Graves to define the renal segments and those homologated in *Terminologia Anatomica* can lead to confusions (especially the term "superior segment" used by Graves, which in *Terminologia Anatomica* is called the superior anterior segment).

We use the term "multiple renal arteries" to name the arteries originating from sources other than the renal artery (the abdominal portion of the aorta is the only morphological variant in this study) and entering the parenchyma through the hilum. We use the term "polar arteries" to name the arteries with aortic origin, supplying only the superior or the inferior pole, and with extrahilar penetration.

We consider that the segmental arteries (superior and inferior) originating from the renal artery or its division branches cannot be called supernumerary, additional or multiple arteries, since they represent the usual branches and the only arterial sources of the respective segments, and not additional/supplementary sources. We treated these cases as segmental arteries having different origin and penetration patterns.

In our study, the superior polar arteries were found in 5.20% of cases. This percentage is almost similar to that reported by (5.1%), higher than that reported by Raghavendra *et al.* – 1.66% [20] and Çiçekcibaşi *et al.* – 3.3% [27] and lower than those reported in studies conducted by Sampaio & Passos – 6.80% [30], Weld *et al.* – 9.6% [21], Saldariaga *et al.* – 15.4% [18], Khamanarong *et al.* – 7.32% [28], Palmieri *et al.* – between 7.14 and 11.6% [31] or Budhiraja *et al.* – 22.6% [16]. As we have already mentioned, these differences result from the fact some authors include the segmental arteries originating in the renal artery and its division branches in this category.

The inferior polar arteries were more common (9.60%) than the superior ones. Our results are closer to those of Sampaio & Passos – 8.70% [30], Çiçekcibaşi *et al.* – 10.5% [27] or Sykes [12], who gives a 11:3 ratio favoring the inferior arteries; our percentage is higher than that reported by Khamanarong *et al.* – 3.56% [28], Vilhova *et al.* – 4.4% [25], Palmieri *et al.* – between 2.9 and 3.7% [31] and lower than that of Weld *et al.* – 15.1% [21] and Talović *et al.* – 20.51% [19].

As for the parenchymal penetration patterns, the inferior segment arteries enter the parenchyma through the hilum in 82% of cases, while the superior polar arteries do so in only 77.60% of cases.

The arteries with extrahilar penetration supplying the superior pole had aortic origin in 5.20% of cases, but most frequently they arose directly from the renal artery (10.40%), before its branching point, and from its branches (6.8%).

The arteries with extrahilar penetration supplying the inferior pole had aortic origin in most cases (9.6% – almost double than the arteries of the superior pole); however, the percentage of the arteries arising from the renal artery decreased by almost 1/3 (3.6%), and the percentage of those originating in the renal artery branches is also smaller (4.8%).

Conclusions

Arterial vascularization of the renal polar parenchyma is characterized by high morphological variability. This is reflected in the number of arterial branches, their sources, origin types and parenchymal penetration. The most common origin of the segmental arteries is the anterior division branch of the renal artery. The segmental arteries arose either as individual branches or from common trunks shared with other segmental arteries. In most cases, the segmental arteries of the renal poles entered the parenchyma through the hilum. The presence of two arterial sources is more common in the superior pole and the pieces with multiple renal arteries. Detailed knowledge of the morphological variability of renal polar vascularization is important not only from the anatomical, but also from the clinical perspective. As it reveals the incidence of different variants, it provides useful data both for diagnostic purposes and for surgical interventions. Given the development and improvement of urological surgery methods, vascular reconstruction and radiological procedures, such knowledge will help reduce potential accidents or incorrect diagnoses.

Conflict of interests

The authors declare that they have no conflict of interests.

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