Review of the supernumerary renal arteries by dissection method

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Introduction. A thorough knowledge of the variations of the renal artery has grown in importance with the increasing numbers of renal transplants. The literature indicates that multiple renal arteries are found in 9-76% cases. The purpose of this study was to establish the incidence and characteristics in cadavers. **Methods.** The examinations were performed on 39 cadavers dissected in the Department of Anatomy Faculty of Medicine University of Sarajevo. **Results.** The anatomical findings included the presence of multiple renal arteries in 18 (46.15) cases. Most often the hilar and lower polar arteries were found, while the upper polar artery was present in only 5.1% cases. **Conclusions.** In preparation for interventions, such as live renal donation, vascular reconstruction, renovascular hypertension, or radical nephrectomy, preoperative renal imaging is necessary and operative techniques should be considered with attention to multiple renal arteries. The recognition of multiple renal arteries is both anatomically significant and in surgical and radiological practice.

Key words: multiple renal artery, variations, renal dissection.

Introduction

The frequency of renal diseases, and the increase of the need for renal transplants, increase the need for research aimed at a better knowledge of the variations of the blood vessels in the kidneys.

The problem with transplantation is the lack of available organs, and the increasing number of patients on the waiting lists leads to increasing interest in live kidney donors. However, the presence of excessive numbers of renal arteries results in technical limitations in kidney transplantation (1).

The first anatomical findings on the renal artery, and the fact that one kidney can be provided with more than one renal artery, were shown by Eustachius on 1552, in anatomy illustrations engraved in copper. Since then, until today, the vascularisation of the kidney has been researched, with the special attention paid to variations in the arterial provisioning of this organ. The kidney can be provided with several renal arteries,

which part, enter and are located in different ways within the organ itself. They represent am important morphological fact, influencing the size and number of the vascular segments of the kidney. This has not only theoretical but also practical significance.

For the development and improvement of surgical approaches to the kidney, along with the development of diagnostic methods, we also need anatomical research in terms of the more precise definition of evaluation of the course, starting point and the division (parting) of the renal artery, and the morphological variations of the relations in its flow (2, 3, 4, 5, 6) A better knowledge of the variations in the artery vascularisation of the kidney has begun to play an important role in recent years in relation to the issue of renal transplantation (7). There is wide range of variations in the supernumerary renal arteries, which is the consequence of observation of this problem from different points of view, for different clinical purposes and due to the use of different research methods.

Also, we cannot find unified terminology for the supernumerary renal arteries (5, 6). Different terms have been used, such as: abnormal blood vessels, accessory, extra-hilar, multiple or aberrant blood vessels. All this creates a statistical gap in terms of their accurate type, number and the point of separation (parting point) (8, 9).

The knowledge of variations of the number and type of renal arteries is not only anatomical data but also represents also important clinical data, especially for surgery and radiology.

The objective of this paper is to explore through the dissection method as follows:

– Existence and localization (site) of supernumerary renal arteries,

– Types of supernumerary renal arteries using Merklin's classification (9),

– The separation point of these arteries from many arterial sources,

– Their courses and the ways of branching within the kidney itself,

– By the statistical processing of the results gained to define their frequency.

Methods

By the dissection method we processed 78 kidneys from 39 cadavers of delivered stillborns, previously fixed in 5% dissolution of formalin. The research was carried out in the Institute of Anatomy of the Medical School in Sarajevo University.

With the careful dissection of the region we accessed the blood vessels and the fat shell of the kidney. With the dissection we liberated the kidney from the fat shell and we separated the blood vessels from it towards the large blood vessels. The attention was focused on the origin and the number of the renal arteries, their relation and the separation in the hilus itself. With special care we dissected the blood vessels within the hilus of the kidney in order to notice the variations in the separation of the segmental renal arteries and their relations with the pelvis of the kidney. With the method of dissection we prepared the segmental arteries within the kidney itself and their ramification was followed up. However, this method did not provide the possibility of liberation deep inside the renal parenchyma, due to the exuberance of the blood vessels of the kidney.

All dissected preparations were photographed and documented, and we analyzed in them:

– The appearance of more than one renal artery (supernumerary renal arteries),

– Types of supernumerary renal arteries by the Merklin classification:

1. supernumerary renal arteries of the aorta origin, which can be hilar, upper and lower polar artery ,

2. supernumerary renal arteries originating from the renal artery that can be upper and lower polar artery.

3. supernumerary renal arteries that can originate from other arteries, for instance: lower phrenical artery, testicular, iliac, etc.

– The course and direction of the arteries' location and the place of entrance into the renal parenchyma.

The method of statistical analyses used in this paper is the arithmetic mean, then t- test of the differences of arithmetic mean. Statistical significance is considered important for $p < 0.05$. In our case we used Windows software statistics for biomedical research (SPSS version. 13.0).

Results

In the overall research we were led by the fact of the importance of renal transplantation, especially due to the continually increasing needs for donors of this organ in the last few years. Considering the very exuberant vascular network and the large number of variations in the vascularisation, and especially in the arterial provisioning of this organ, we examined the arterial visualization of the kidney and the potential variations on the available material.

In the preparations from the delivered still-borns we dissected the kidney, the kidney, urethra and the tree of the abdominal aorta together with the blood vessels belonging to these organs.

At the beginning of dissection we also prepared (liberated) the vena cava inferior with the accompanying veins towards the organs (Figure 1), in order to show the anatomical relationship of the arteries and the veins. After that, in order to have better insight into the positioning and separation of the segmental renal arteries within the hilus itself and further on in parenchyma of the kidney, we liberated the vena cava inferior with the accompanying veins.

39 preparations from delivered still-borns were prepared by the method of classical dissection, and the prepared organs

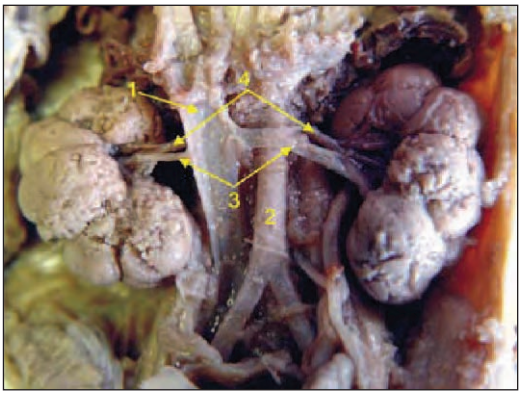

Figure 1 Review of the renal blood vessels:
1. Inferior vena cava, 2. Abdominal aorta, 3. Left and right renal vein, 4. Left and right renal artery

with the blood vessels were not taken out of the abdomen.

Of the total number, 20 preparations are male and 19 female. In all preparations the kidneys are located in the anatomic position within the abdomen.

We did not notice the lack of a kidney in any of the preparations.

For the analyses of the supernumerary renal arteries we used the classification by Merklin, of:

1. Supernumerary renal arteries originating from the aorta,

2. Supernumerary renal arteries from the kidney artery,

3. Supernumerary arteries that can come from other arterial sources.

The supernumerary renal arteries regardless of their origin, were found in 18 dissected preparations (46.15%) of 39 delivered still-borns.

In 12 preparations (30.76%) there were only the supernumerary renal arteries of aorta origin present. Five preparations (12.82%) had supernumerary renal arteries from the renal artery.

In one preparation (2.56%) we noticed both side presences of both groups of the supernumerary renal arteries. The supernumerary artery of the aorta origin was placed on the left side, and supernumerary artery

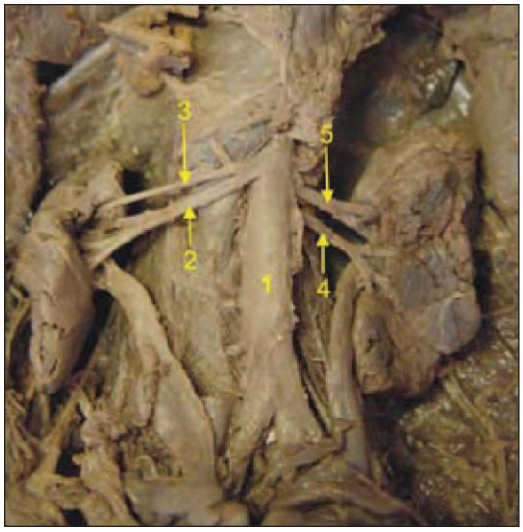

Figure 2 Both side presence of both types of the supernumerary renal arteries: 1. Abdominal aorta, 2. Right renal artery, 3. Upper polar artery from right renal artery, 4. Left renal artery, 5. Hilar artery of aorta origin from the left side

Figure 3 The right kidney provided with three renal arteries of aorta origin: 1. Abdominal aorta, 2. Right renal artery, 3. Lower polar artery of aorta origin on the right side, 4. Upper polar artery of aorta origin on the right side, 5. Left renal artery, 6. Ureters

from the renal artery on the right side (Figure 2).

In the second case we noticed that the right kidney was provided with three renal arteries of aorta origin. The upper polar supernumerary artery of aorta origin separates from the thoracic aorta, pushing its way through under the diaphragm and enters the kidney through the hilus on its upper part and provides for the upper part of the kidney.

The lower polar supernumerary renal artery of aorta origin starts from the aorta somewhere above the place of bifurcation of the abdominal aorta into two iliac arteries, flows behind the ureters and enters the hilus of the kidney in the lower part and provides for lower pole of the kidney (Figure 3)

Analysis of supernumerary renal arteries of aorta origin

Supernumerary renal arteries of aorta origin were found in 13 (33, 33%) preparations.

In ten preparations there one-sided arteries present.

The supernumerary renal arteries of aorta origin are more frequent on the right side. Nine of them were found on the right side, and five on the left side (Figure 4a and 4b.)

In three preparations (7.69%) we found the bilateral presence of supernumerary renal arteries of aorta origin (Figure 6). In one preparation the right kidney was provided with three arteries, which are described above. Also, in one preparation, the left kidney, beside the supernumerary renal artery of aorta origin had a supernumerary artery originating from the renal artery (Figure 2).

Analyzing the types of supernumerary renal arteries, using Merklin classification, we found the following results in dissection processed preparations:

– 7 (17.95%) hilar supernumerary renal arteries of aorta origin, which together with the renal artery enter the hilus of the kidney. Three arteries were found on the right side, four on the left. The bilateral presence of

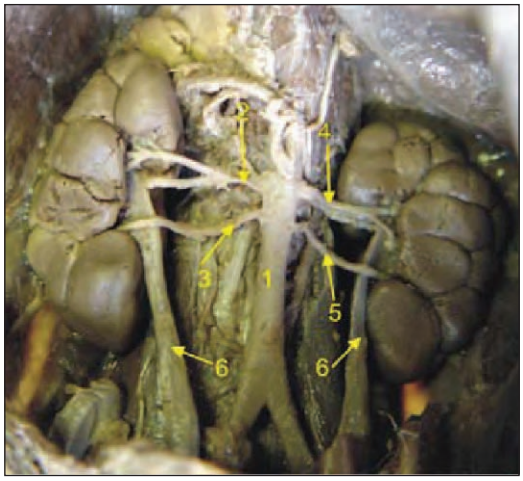

Figure 4a The both-side presence of supernumerary renal arteries of the aorta origin: 1. Abdominal aorta, 2. Right renal artery, 3. Lower polar artery of aorta origin on the right side, 4. Left renal artery, 5. Lower polar artery of aorta origin on the left side , 6. Ureters

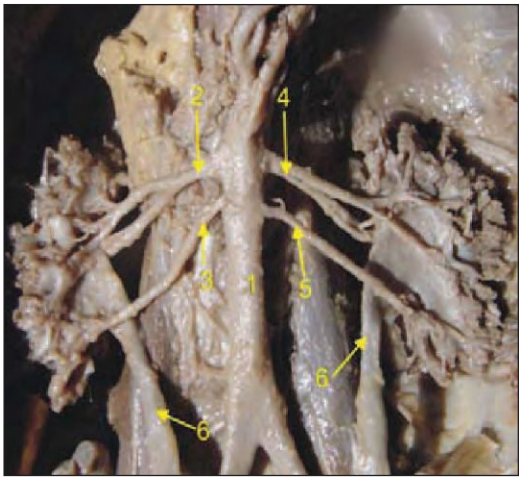

Figure 4b The bilateral presence of supernumerary renal arteries of aorta origin (the parenchyma of kidney removed): 1. Abdominal aorta, 2. Right renal artery, 3. Lower polar artery of aorta origin on the right side, 4. Left renal artery, 5. Lower polar artery of aorta origin on the left side, 6. Ureters

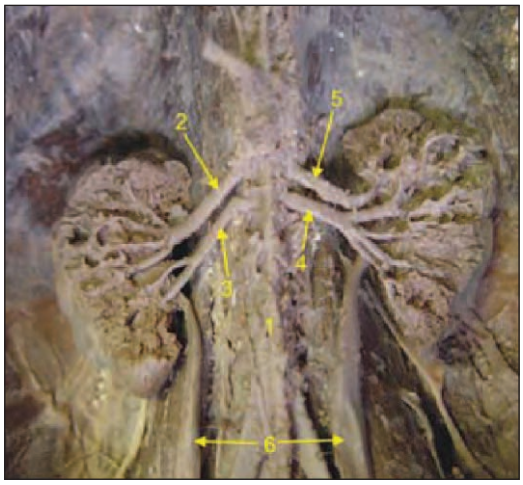

Figure 5 The bilateral presence of supernumerary renal arteries of the aorta origin (the parenchyma of kidney removed): 1. Abdominal aorta, 2. Right renal artery, 3. Lower polar artery of aorta origin on the right side, 4. Left renal artery, 5. Hilar artery of aorta origin on the left side, 6. Ureters

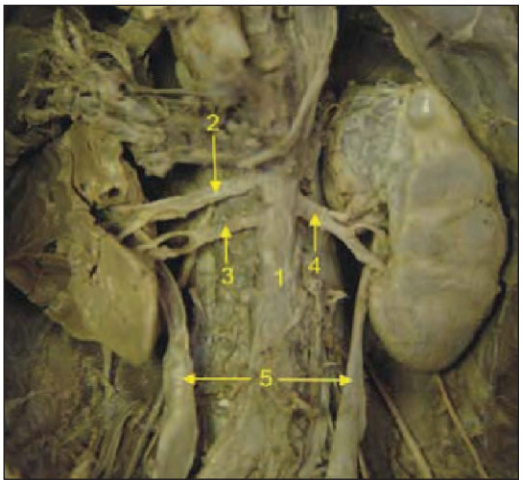

Figure 6 Right hilar supernumerary renal artery of aorta origin: 1. Abdominal aorta, 2. Right renal artery, 3. Hilar artery of aorta origin on the right side, 4. Left renal artery, 5. Ureters

this kind of supernumerary renal arteries of aorta origin was not found in the dissected preparations analyzed (Figure 6).

– In the dissection processed material, we found only 2 (5.13%) upper polar supernumerary renal arteries of aorta origin, en-

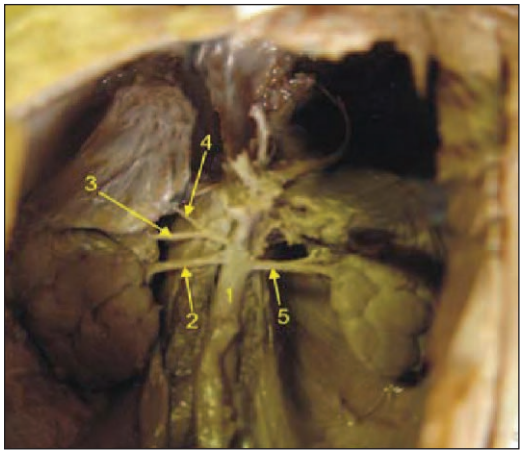

Figure 7 The right upper polar supernumerary renal artery of aorta origin: 1. Abdominal aorta, 2. Right renal artery, 3. Upper polar artery of aorta origin on the right side, 4. Inferior suprarenal artery, 5. Left renal artery

Figure 8 The left lower polar supernumerary renal artery of aorta origin (the parenchyma of kidney removed): 1. Abdominal aorta, 2. Right renal artery, 3. Left renal artery, 4. Lower polar artery of aorta origin on the left side

Table 1 Number and percentage of types of supernumerary renal arteries of aorta origin

Number of renal artery	Right kidney	(%)	Left kidney	(%)	Total	(%)
One artery	28	72	32	82	60	77
Two arteries	10	26	7	18	17	22
Hilar supernumerary renal artery	3	8	4	10	7	9
Upper supernumerary renal artery	2	5	0	0	2	2
Lower supernumerary renal artery	5	13	3	8	8	10
Three arteries	1	2	0	0	1	1
t-test	1,812					
Degree of variations	5					
Level of the significance (p)	0.05					

tering directly into the kidney parenchyma in its upper pole (Figure 7).

– We found 8 (20.51%) lower polar supernumerary renal arteries of aorta origin. Five arteries from the right side and three arteries from the left side and in two cases we found the bilateral presence of these arteries (Table1). Those arteries directly enter the renal parenchyma in its lower pole (Figure 8).

Analysis of the supernumerary renal arteries with renal artery origin

We have found in 6 (15.38%) dissected preparations a group of renal supernumerary arteries of renal artery origin, in five preparations on the right side and in one case on the left side.

Analyzing by Merklin classification the supernumerary renal arteries originating

Figure 9 The upper right polar supernumerary renal artery from the renal artery: 1. Abdominal aorta, 2. Right renal artery, 3. Upper polar artery originating from the renal artery on the right side, 4. A. renalis sinistra

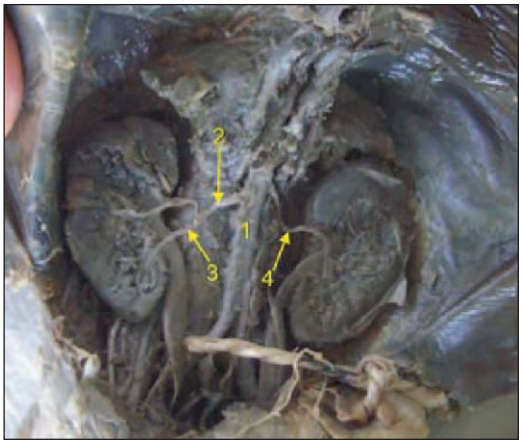

Figure 10 The lower right polar supernumerary renal artery from the renal artery: 1. Abdominal aorta, 2. Right renal artery, 3. Lower polar artery of renal artery origin from the right side, 4. Left renal artery

Table 2 Supernumerary renal arteries originating from the renal artery

Number of renal arteries	Right	(%)	Left	(%)	Total	(%)
Upper supernumerary polar artery	4	10	1	2	5	6
Lower supernumerary polar artery	1	2	0	0	1	1
t-test	2,919					
Degree of variations	1					
Level of the significance (p)	0,05					

from the renal artery, we found the existence of the upper and lower polar supernumerary renal artery (Table 2).

In 5 (12.82) preparations, we found the upper polar artery of the kidney with its origin in the renal artery (Picture 9). Only in one preparation (2.56%) did we find a lower supernumerary artery of renal artery origin (Figure 10).

According to Merkin there is no hilar supernumerary renal artery originating from the renal artery, but in that case we bear in mind one pre -hilar branching of the renal artery.

Discussion

The anatomical variations of the renal artery are frequent in number, course and the place of origin. The literature data illustrate that beside the renal artery, there can be supernumerary renal arteries. These appear on average from 26-30% and they have a different starting point, course and allocation in the renal parenchyma compared to the renal artery. The fact that these arteries may be neglected during surgical procedures on the kidney or its environment is an important

morphological element, which has not only theoretical but also practical importance.

The generally accepted and precise terminology for these arteries has not been unified in the majority of the authors (8). Many call them accessory blood vessels, especially in the earlier literature. This term is not acceptable, because they occupy a certain vascular area within the kidney and there is no anastomosis, either with the branches of the main, or with branches of the segmental renal arteries (3). This fact is backed up by other authors (4) while analyzing arteriovenosus anastomoses in the human kidney and the arterial distribution within the segments of the kidneys. We can talk about the segmentation of the kidneys only when they are provided with only one renal artery.

The term aberrant arteries (8) also does not suit these renal arteries. We agree with the authors who define them as the supernumerary renal arteries, because they represent the exclusive source of provision of blood to certain parts of the kidney. They are divided into two groups according to the part of the kidney they are providing and according to their origin.

One group is the supernumerary renal arteries originating from the aorta. In this group we have three types of supernumerary renal arteries: upper polar, hilar and lower polar supernumerary artery of aorta origin.

The second group is the supernumerary renal arteries originating from the main renal artery, to which two types of supernumerary renal arteries belong: the upper and lower polar supernumerary artery.

This distinction of the supernumerary arteries is the most acceptable. The majority of the authors, recently researching this issue, agree with this distinction and they use it in their researches. The interest in supernumerary renal arteries has increased also recently due to the increase in the frequency of kidney transplantation and the need for living kidney donors (10). The development of the methods in urological surgery, as well as the development of new radiological techniques have enhanced the interest in renal artery anatomy (11). Kidney transplantation is a permanent and safe treatment for patients with chronic kidney failure. However, the presence of supernumerary renal arteries increases the complexity of the procedure of kidney transplantation (12).

The existence of supernumerary renal arteries is a challenge for the surgeons, performing the kidney transplantation, since each renal artery is a terminal blood vessel and its injury causes segmental ischemia with delayed hypertension and leads to a direct link between essential hypertension and the presence of supernumerary renal arteries, without the existence of other pathological changes (13, 14).

In the material we analyzed, we more frequently found supernumerary arteries originating from the aorta. In the dissected preparations we found 28. 2% cases. There is a high degree of concordance of our results with the values found in the literature and they are in close relation to the results of other authors in from 25% to 30% cases (15, 16, and 17).

We found 15.36% supernumerary renal arteries originating from the renal arteries in the analyses of the preparations. This group of supernumerary renal arteries has not received much attention by other authors. In the literature we only found data for types of renal supernumerary arteries originating from the renal artery.

The supernumerary renal arteries were analyzed according to their place of entrance into the kidney as: upper polar, hilar and lower polar supernumerary arteries. In cases when the kidney is provided by two arteries, along with the main renal artery, we mostly found a lower polar or hilar supernumerary renal artery of aorta origin. The supernumerary renal arteries from the aorta can be separated at any location from the Th11 vertebra to the aorta bifurcation. We found

this high starting point of supernumerary renal arteries from the aorta in one case in the dissected material with the presence of three arteries providing the right-hand kidney (18).

We found three arteries providing the kidney on average in 1-3% (5). Our results, being 0.9% in the dissected material, agree with the data from literature. Bergman points out that in the case of triple renal arteries one supernumerary artery is always hilar, and other one is either an upper or lower polar renal artery. We did not find this ratio in our material.

The hilar supernumerary artery is a kind of supernumerary renal artery coming only from the aorta. Our results show that it appears with the same frequency as the lower polar artery originating from the aorta.

Upper polar arteries are a type of supernumerary renal arteries, directly entering the renal parenchyma at its upper pole. They are one-fold. They separate from the aorta or from the renal artery. In the dissected preparations we found them in 5.1% cases, and they mostly originate from the renal artery in 12.8% cases. Before entering the renal parenchyma they often divide into smaller branches, which pass through the upper pole of the kidney.

From the surgical point of view, upper polar arteries represent a huge risk, especially from the aorta, and due to the high place of separation from it they are masked during the surgical procedure.

Since they have smaller caliber, they are often mistaken for the capsular and lumbar artery. The percentage of supernumerary renal arteries is higher in the dissection method, because the negatives are difficult to read and smaller polar arteries are neglected and they are grouped in the lumbar or capsular arteries. We only found out their origin from kidney by dissection (19).

This kind of supernumerary renal artery is less present in terms of percentages, which is also confirmed by our findings. There are more upper polar arteries compared to the lower polar arteries originating from the aorta and also there were more upper polar arteries originating from the renal artery in the dissection analyses (13,20,21). We agree with this fact completely, since the we found the most arteries of this kind in the dissection analyses originating from the renal artery.

Lower polar renal arteries are the second largest group of supernumerary renal arteries. They are present in 6% to 7% cases (2, 5, 21). This is the most numerous kind of supernumerary renal artery. Lower polar supernumerary renal arteries are found in a smaller percentage in 2.6% cases.

Our data are in accord with the data from the literature regarding the more frequent appearance of these arteries in the dissection analyses and also in kidneys during intra surgery findings. They can appear individually or together with the upper polar artery with triple arterial provision of the kidney.

Lower polar arteries are often present on both sides, whether they come from one or two different sources (18). This is also recorded in our paper.

Clinically and surgically seen, lower polar arteries are of extreme importance. In many cases, they are the direct cause of the hydronephrosis. Many cases are described, where the lower polar artery causes the constriction of the upper part of the ureter or the ureter - pelvic link. The feeding of the ureter of the transplanted kidney directly depends on the lower polar artery, and the long-term necrosis of the ureter leads to complications. Then the surgeon has to think about operative revision of the necrotic part of the ureter (13).

A lower supernumerary renal artery is alsorepresent an obstacle during other surgical procedures on the kidney. Long-term consequences occur with the accidental

ligature of these arteries (22). Although, the kidney heals spontaneously, the consequences remain the same as with the injury of segmental renal artery. It is necessary to follow up kidney function and blood pressure, since hypertension is the only long-term risk for these patients (14). The author considers the supernumerary renal arteries to be the direct cause of essential hypertension in younger patients. With the injury of the segmental renal arteries it is necessary to remove part of the parenchyma they provide with blood, because they are terminal arteries and they provoke ischemia and hypertension. The same happens with the cutting of supernumerary renal arteries, especially, with the cutting of the lower polar artery, because it provides a much larger surface than the upper polar supernumerary renal artery, so the consequences are much more prominent. The supernumerary lower polar renal artery is evident and it is easy to avoid. However, it is difficult to find it especially when it has a low starting point from the aorta or an earlier separation from the renal artery, when it is subject to injuries due to inattention.

Conclusions

From all the above-mentioned enclosed in this paper we can conclude the following:

– The kidney, in most of the cases, is vascularised by one renal artery, with the dissection method in 53.85% preparations.

– Our results confirm that there is a large number of anatomical variations in the vascularisation of the kidney. The most often incidence is the occurrence of supernumerary renal arteries.

– The most frequent are lower polar and hilar supernumerary arteries originating from the aorta.

– We more rarely found supernumerary arteries originating from the renal artery.

– This knowledge should serve as a caution in the approach to each surgical procedure on the kidney, and especially donated organs, in order not to lose precious time and the source of donation, due to the frequent impossibility of performing preoperative arteriography in the time interval of obtaining the organ from the cadaver.

– On the basis of the t-test and the probability p = 0,05 we conclude that all parameters found are at the level of significance.

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