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Artículos

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Análisis tridimensional del lecho arterial del riñón humano

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Abstract:

The aim of the research was to conduct a three-dimensional and quantitative analysis of the human kidney arterial system to identify sources of segmental arteries. 116 corrosive preparations of the human kidney arterial system were made, followed by 3D scanning to obtain digital models. Morphometric analysis data were processed by variation statistics methods. It has been established that on the basis of the fractal structure principles of the intra organic arterial kidney bed and the dichotomous branching of its links in the kidneys, identification and specific designation of the links is not possible, since there is only one link in the main branch, and interlobular arteries in the loose branch of 1st and 2nd orders, which determine the level of segmental arteries. As a result of this, these arteries are not designated in the International Anatomical Nomenclature and their number varies from 6 to 10, depending on the types of branching of the kidney arterial vessels.

Keywords: kidney, renal arteries, 3D-stereometry.

Resumen:

El objetivo de la investigación fue realizar un análisis tridimensional y cuantitativo del sistema arterial renal humano para identificar las fuentes de arterias segmentarias. Se realizaron 116 preparaciones corrosivas del sistema arterial renal humano, seguido de escaneo 3D para obtener modelos digitales. Los datos del análisis morfométrico se procesaron mediante métodos estadísticos de variación. Se ha establecido que en base a los principios de estructura fractal del lecho renal arterial intraorgánico y la ramificación dicotómica de sus enlaces en los riñones, no es posible la identificación y designación específica de los enlaces, ya que solo existe un enlace en el rama principal y arterias interlobulillares en la rama suelta de 1º y 2º orden, que determinan el nivel de las arterias segmentarias. Como resultado de esto, estas arterias no están designadas en la Nomenclatura Anatómica Internacional y su número varía de 6 a 10, dependiendo de los tipos de ramificación de los vasos arteriales renales.

Palabras clave: riñón, arterias renales, estereometría 3D.

Author notes

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Introduction

Variant anatomy of the human kidney arterial bed has been studied by many researchers [1-7,9-15] . The researchers were especially interested in issues related to the segmental structure of this organ, namely their number, location [1-7,9-25] . For the first time, the term or concept “renal segment” was introduced by Graves and Samb in the mid-1950s [15] . According to these authors, the "renal segment" includes a separate section of the kidney parenchyma with its own system of arterial blood supply and urination [7] . A review of the literature shows us that the number of renal segments is quite variable. Thus, according to S.G. Eremeev [7] in 88% of cases, the kidney has a five-segment structure, in 12% of cases a four-segment structure. The author identifies the upper pole, upper anterior, lower anterior, posterior, and lower pole segments in the presence of five segments in the kidney. The author identifies the upper-pole, lower-pole, anteropulmonary and post-lank segments, if the kidney has four segments. the sources and options for blood supply to the renal segments are also of great interest. According to S.G. Eremeev [7] , the upper and lower segments differ in great variability with respect to blood supply sources. Thus, according to the author, in the kidneys with four and five segments, one segmental artery is involved in the blood supply to the posterior papillary and anteropulmonary segments [7] . Moreover, in 53% of cases, it departed from the pelvic anterior pit, and in 18% of cases - from the lower pole [7] .

Rubinov [16] obtained similar data. The author also identified kidneys with four segments (18.4% of cases) and (81.6% of cases) with five segments. Observations of V.V. Serov [16] differ from studies of the above authors, the author distinguished five segments of the kidney: these are the upper pole, the upper anterior, then the lower anterior, posterior and lower segments. According to this author, the segment of the upper pole may have several options for blood supply. So, the segment of the upper pole in the first embodiment is supplied with a single artery (45% of cases), departing from the anterior pit. In 32% of cases, this segment is supplied with two arteries, extending from the anterior and posterior branches of the renal artery.

Serov [18] also established several options in the blood supply to the segment of the kidney lower pole: in the first embodiment, the segment of the lower pole is supplied with a single artery, departing from the heart anterior pit, which was detected in 47% of cases; in the second variant, the lower pole segment is supplied with two arteries from the ventral and dorsal branches of the renal artery, which was found in 45% of cases; in the third variant, the nutrition of the lower pole segment occurs due to the lower pole artery, departing from the posterior pit of arteries, which was met in 8% of cases.

The variant anatomy of the blood supply to the renal segments was dealt with by Ajmani [19] According to a study by this author, the main renal artery is divided into the ventral and dorsal branches in 98% of cases before entering the kidney hilum. The author has established 5 options for dividing the ventral and 3 options for dividing the dorsal branches of the renal artery and the upper pole segment can have several options for blood supply (about 7 options).

According to this author, the kidney has 4 segments (3.5% of cases), in 72.6% of cases the kidney has 5 segments, and in 23.9% of cases there are up to 6 segments in the kidney. Sh.R. Sabirov [21] revealed 4 segments of the kidney in 35% of cases, 5 segments of the kidney in 38.5% of cases and 6 segments in 26.5% of cases [14,17] . Of course, both domestic and foreign scientists dealt with questions of the segmental structure of the kidney. According to Longia [21] , the kidney has a five-segment structure in 53% of cases. In 46% of cases, the kidney has a four-segment structure and 1% of cases is a three-segment one. The author also identified kidney variants with less than five segments: for example, in 15% of cases, the upper segment is absent in the kidneys; in 14% of cases, the anteropulmonary segment represented the combined upper and lower segments; in the third variant, the lower pole segment is absent in the kidney, which was found in 17% of cases [21] . Sampaio [23] was also involved in variants of the segmental structure of the kidneys. According to him, in

61.2% of cases, the kidney has 5 segments, and in 38.8% of cases - 4 segments. In 73.5% of cases, the kidney has an upper segment, occupying an area of 13%. In 61.2% of cases in the kidney there are upper and lower anteropulmonary segments, with an area of 21.4% and 17.2%, respectively. In 38.8% of cases, kidneys were identified with one anterior pit of the segment and occupied an area of 28.4%. In the author's studies, kidneys were identified with the presence of the lower pole and posterior papillary segments, occupying an area of 22.2% and 33.8%, respectively [24].

From a literature review it can be noticed that many domestic and foreign researchers [1-7,9-25] were involved in the issues of kidneys segmental structure and blood supply to the segments. According to researchers, the kidney is divided into segments relative to the branching of the renal artery system [6-10] and the number of kidney segments varies from 3 to 6. According to some other researchers, their number can reach up to 10 [6-8,17,18]. Today we know the classic division of the kidney into five renal segments: upper, upper front, lower front, lower and rear segments. According to many authors, the segmental arteries branching, namely their pools that feed isolated sections of the kidney, determine the segments.

The International Anatomical Nomenclature [10] does not distinguish segmental arteries. According to this nomenclature, the angioarchitectonics of the kidney and its structural units are presented as follows: “renal artery” (I) “interlobar artery” (II) “arc artery” (III), “interlobular artery” (IV) and “bringing artery” (V). If to consider that segmental arteries are the third level, that is, branches of the third order, then they are “interlobar" according to the International nomenclature. Morphologically “interlobar arteries" are vessels located in the kidney parenchyma and in quantitative terms their number can reach from 10 to 16. If to give further, only segments of the poles can have two sources of blood supply from the renal artery branches [18]. Given the fact that in most cases (88%) the kidney has five segments, where the poles have two sources of blood supply in the upper and lower pole segments, it has only 7 segmental arteries. The question arises what the fate is of the remaining 9 interlobar "segmental" arteries. Even if we take into account that each segment of the kidney feeds on two arteries, we get 10 segmental arteries, and the 6 ones remain again. That is, ambiguities arise, nevertheless, which arteries are called “segmental”, what is the level and their number, which became the aim of our research.

Scope of the Research: Conduct a three-dimensional and quantitative analysis of the human kidney arterial system to identify sources of segmental arteries.

Materials and Methods

116 corrosive preparations of the human kidney arterial system were manufactured. Corrosion preparations of the kidney arterial vessels of the were further subjected to 3D scanning to obtain digital models.

1) In the computer program "Mimics-8.1" was determined: - 3D projection of the kidneys’ main arteries in relation to the planes; - 3D projection of renal artery extraorgan branches;

- the number of renal arteries main branches of the at the kidney hilum;

2) In 3D projection, we determined: - the types of branching of the renal artery main branches inside the kidney, depending on the division in the gates of each of its branches: - with the main: - with loose

3) In 3D projection, we determined: - the vessels number of the renal artery’s main branches of different orders: - with the main branching type; - with loose branching type;

Depending on the branching types of each main branch: - the number of 1st order arteries (I); - the number of 2nd order vessels (II); - the number of 3rd order vessels (III); - the number of 4th order vessels (IV).

4) Among them we determined the segmental arteries, their number depending on the intraorgan branching types: - with the main branching type; - with loose branching type

Morphometric analysis data were processed by variation statistics methods on a personal computer using the Excel (Ver.10.2701) and Statwin programs (Ver.5.1).

Results

According to the research results, in 84.6% of cases (73 of 116 preparations), the renal artery relative to the facies anterior is divided into the ventral and dorsal branches, which are distributed in the corresponding zones of the kidney parenchyma. In 9.8% of cases (8 preparations), the division of the main renal artery relative to the horizontal plane occurs into the upper pole and lower pole, the branches of which were distributed in the corresponding zones of the kidney poles. Of the 35 corrosive preparations in 42.8% of cases (15 preparations), the division of the main renal artery relative to the frontal and horizontal plane occurs on the ventral, dorsal and upper pole branches, which were distributed in the corresponding areas of the kidney. In 31.4% of cases (11 preparations), the division of the main renal artery relative to the frontal and horizontal plane occurred on the ventral, dorsal and lower pole branches, distributed in the corresponding zones of the kidney. In 17.1% of cases (6 preparations), the division of the main renal artery occurs relative to the facies anterior into two ventral branches and one dorsal branch, distributed in the corresponding areas of the kidney. In 8.5% of cases (3 preparations), the division of the main renal artery occurs into the upper pole, central and lower pole branches, distributed in the corresponding zones of the renal parenchyma.

As a result of a three-dimensional analysis of the links of the human kidney arterial system, depending on the types and variants of vascular branching, it was found that 84.6% of cases more often there is a variant in which the main renal artery is divided into the ventral and dorsal branches, distributed in the corresponding areas of the renal parenchyma where they were analyzed.

It was found that in the first type of intraorgan branching of the kidney arterial system, the ventral branch was branching according to the loose type, distributed in the facies anterior of the renal parenchyma, and the dorsal branch – according to the main one, supplying the corresponding sections of the renal parenchyma, which was detected in 46.2% of cases. In the first type of intraorgan branching of the kidney arterial system, the ventral branch was branching according to the loose type, distributed in the facies anterior of the renal parenchyma, and the dorsal branch according to the main one, supplying the corresponding sections of the renal parenchyma, which was detected in 46.2% of cases. Moreover, the hierarchy of the arterial links of the renal arterial system was as follows: «A. renalis» (I), - «A. ventralis» (II), - «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V), - «A. interlobulares» (VI), - «A. afferentis» (VII); «A. dorsalis» (II), - «A. interlobares - 1» (III), - «A. arcuatae» (IV), - «A. interlobulares» (V), - «A. afferentis» (VI). It was revealed that with this variant of intraorgan branching of the kidney arteries, the number of vessels of the first (I), second (II), third (III) and fourth (IV) orders was - 1; 2; 7±1 and 12±1 in the indicated order. That is, the average number of interlobar arteries with this type and branching variant of the arterial vessels of the kidney was 7±1.

In 23.8% of cases, with the same variant of division, there is a branching of both arterial branches according to the loose type - the second type of arterial vessels branching. Moreover, the level organization of the arterial links of the renal artery system was presented in the following order: «A. renalis» (I), - «A. ventralis» (II)», - «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V), - «A. interlobulares» (VI), - «A. afferentis» (VII); «A. dorsalis» (II), - «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V)», - «A. interlobulares» (VI), - «A. afferentis» (VII). The number of vessels of the first (I), second (II), third (III) and fourth (IV) orders was - 1; 2; 9 ± 1; 14 ± 1, respectively. It was found that with this option and the branching type of the kidney arterial vessels, the average number of "segmental" arteries was 9±1.

In 19.4% of cases with the same variant of division, a third branching type of the renal artery system was found, in which both branches were distributed according to the main branching type. The structural organization of the arterial links was as follows: «A. renalis» (I), - «A. ventralis» (II), - «A. interlobares» (III), - «A. arcuatae» (IV), - «A. interlobulares» (V), - «A. afferentis» (VI); «A. dorsalis» (II), - «A. interlobares» (III), - «A. arcuatae» (IV), - «A. interlobulares» (V), - «A.

afferentis» (VI). The number of vessels of the first (I), second (II), third (III) and fourth (IV) orders was - 1; 2; 6±1 and 11±1, respectively. Further, the number of "segmental" arteries with this variant and branching type averaged 6±1.

In 11.1% of cases, a fourth branching type of the renal arterial system was observed, with the same variant of the main kidney artery division. In this case, the branching of the dorsal branch is of the loose type, and the branching of the ventral branch is of the main type. Moreover, the level organization of the arterial links of the renal artery system was presented in the following order: «A. renalis» (I), - «A. ventralis» (II), - «A. interlobares» (III), - «A. arcuatae» (IV), - «A. interlobulares» (V), - «A. afferentis» (VI); «A. dorsalis» (II), - «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V), - «A. interlobulares» (VI), - «A. afferentis» (VII). The number of vessels of the first (I), second (II), third (III) and fourth (IV) orders was 1; 2; 7±1; 12±1 in the indicated order. The average number of interlobar arteries was 7±1.

In 8 corrosion preparations, which accounted for 9.8% of cases, the main renal artery division with respect to the facies horizontal occurred on the upper and lower pole branches. It was also established that these branches (lower pole and upper pole) in 76.4% of cases with this variant of division have a loose branching character. The structural organization of arterial links in this case was as follows: A. renalis» (I)», «A. superius polus (II)», - «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V), - «A. interlobulares» (VI), - «A. afferentis» (VII); «A. inferior polus» - (II), - «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V)», - «A. interlobulares» (VI), - «A. afferentis» (VII). It was found that with this variant of intraorgan branching of the arterial system of the kidney, the number of vessels of the first (I), second (II), third (III) and fourth (IV) orders was –1; 2; 9±1 and 14±1, respectively. The number of "segmental" arteries averaged 9±1.

It was established that in the second branching type of this variant of the renal arterial system division, in 16.1% of cases the lower pole branch has the main branching type, and the upper pole branch has the loose one. Moreover, the hierarchy of the arterial links of the renal arterial system was as follows: «A. renalis» (I)», «A. superius polus (II)», - «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V), - «A. interlobulares» (VI), - «A. afferentis» (VII); «A. inferior polus» (II), - «A. interlobares» (III), - «A. arcuatae» (IV)», - «A. interlobulares» (V), - «A. afferentis» (VI). Further, the number of vessels of the first (I), second (II), third (III) and fourth (IV) orders was - 1; 2; 7±1; 14±1, respectively. The average number of interlobar arteries of the third order, that is, "segmental", was 7±1.

In the third branching type of the same variant of the main renal artery division, in 7.5% of cases, the upper pole branch distributed in the main type, and the lower pole branches in the loose type. The structural organization of arterial links for this branching type is presented in the following order: «A. renalis» (I)», - «A. superius polus (II)», - «A. interlobares» (III), - «A. arcuatae» (IV)», - «A. interlobulares» (V), - «A. afferentis» (VI); «A. inferior polus» (II), «A. interlobares - 1» (III), - «A. interlobares - 2» (IV), - «A. arcuatae» (V), - «A. interlobulares» (VI), - «A. afferentis» (VII). The number of vessels of the first (I), second (II), third (III) and fourth (IV) orders was 1; 2; 8±1 and 15±1, respectively. Thus, with this option and the type of branching of the renal arterial system, the number of "segmental" arteries averaged 8 ± 1.

According to a stereo-anatomical research results of the structure and links of the renal artery system, it was found that the interlobar arteries of the third order, that is, "segmental" arteries, have differences in numbers depending on the branching variants and types of the intraorgan arterial vessels of the kidney. Also, for different branching types of the arterial kidney system, a quantitative and qualitative difference is observed with respect to the number of vessels of the third and fourth links, that is, interlobar vessels of the first and second orders, depending on the branching types of individual branches of the renal artery and the hierarchy of its individual links and dichotomy. Thus, the amount of these blood vessels, taking into account the division of the upper and lower pole, ventral and dorsal branches (3rd level of dichotomies) in most cases is 10 or more. Further, a quantitative analysis shows that with the loose branching type of intraorgan arterial

vessels, the number of "segmental" arteries (vessels of the 3rd order) is greater (from 8 to 10 arteries) than with the main branching type.

Discussion

Studies show that the range of individual variability of the kidney intraorganic arterial bed depends on both the division of the main renal artery and the branches types of intraorgan branching of the renal artery. So, with the loose branching type in the kidney arterial bed, there are 7 links with interlobular arteries of the 3rd (segmental) and 4th order. In the main branching type, the level organization of the kidney intraorganic arterial bed is represented by six links: «A. renalis» (I), - «A. ventralis» (II), - «A. interlobares» (III), - «A. arcuatae» (IV), - «A. interlobulares» (V), - «A. afferentis» (VI). The variant anatomy of the kidney segmental structure, that is, the topography of the renal segments, their number, and area in different kidneys depends on the presence or absence in the kidney arterial bed of the 3rd order links (segmental arteries), which, as mentioned above, are more numerous with a loose branching type than with the main one. Depending on the branching and dichotomies types, each particular segmental arterial vessel, or even two vessels, has its own vascular pool, providing a strictly defined area of the kidney with blood supply. According to the results of this study, on average, there are from 6 to 10 segmental arterial vessels. These vessels, independently or together, form the vascular pools of the kidney that feed a particular segment of the renal parenchyma, and thereby determine the features and variants of the kidney segmental structure. Thus, the results of this work show that the number of renal segments or individual sections of a kidney depends on the number of arterial vessels with a loose branching nature, that is, the more vessels with a loose branching type, the more kidney segments. A kidney with a classic five-segment structure most often has 7 segmental arteries, two of which branch in the upper pole segment, two in the lower pole, and the remaining segments have one artery each.

Conclusion

Thus, we can conclude that, based on the fractal structure principles of the kidney intraorganic arterial bed and the dichotomous branching of its links in the kidneys, identification and specific designation of the links is not possible, since there is only one link (interlobar artery) in the main branching, and interlobular arteries of the 1st and 2nd orders in loose branching, which determine the level of segmental arteries. As a result, these arteries are not indicated in the International Anatomical Nomenclature and their number varies from 6 to 10, depending on the kidney arterial vessels branching.

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