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Characteristics of a few observed variants of renal arteries, and their prehilar branching with kidneys morphometry

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Abstract. Human renal arteries are characterized by a wide range of variability. This study aimed to detect the variations of the renal arteries, make measurements in cadaveric samples and, based on a review of the literature, to compare results with those already published. *Materials and Methods.* At the Department of Morphology, kidneys of the formalin-fixed five cadavers were used for this study. Renal arteries and kidneys were explored, measured, and anatomical variations were noted. *Results.* Main renal arteries originated from the aorta, mainly at the L2 level. The right main renal arteries' mean length, diameter, and angle were 40.4 mm, 6.1 mm, and 75.6°, but the left - 32.2 mm, 6.0 mm, and 84.0°. The right accessory renal artery's mean length, diameter, and angle were 65.0 mm, 3.5 mm, and 115°, but left - 68.0 mm, 1.3 mm, and 74°. The mean length and width of the right kidney were 11.6 cm and 6.5 cm, and the left - 11.8 cm and 7.5 cm. The origins of the renal segmental arteries and prehilar branching patterns were variable. *Conclusions*. Detection of anatomy of the renal arteries may affect pathogenesis, clinical manifestations of various diseases, and the choice of methods of treatment.

Keywords: cadavers, kidney, renal artery, prehilar branching, variants.

1. INTRODUCTION

In the classical case, each kidney is supplied by a single renal artery, which arises as a lateral visceral branch of the abdominal aorta between the 1st and 2nd lumbar vertebrae levels. Related to the lumbar vertebra, the right main renal artery originates above the left renal artery. Determining any possible early branching of the main renal artery is essential. The pre-hilar or early branching pattern is a standard variant, and the main renal artery divides into segmental branches at a more proximal level than the renal hilum. Related to this, the component that diverges within 1.5 to 2.0 cm from the lateral wall of the aorta is named the pre-hilar branch [1].

In the kidney, the distribution of the arteries forms a unique pattern and division of the renal parenchyma into five segments (the apical, the upper (anterior), the middle (anterior), the lower and the posterior segment), where every segment supplies its artery [2]. The first details of the renal pattern were described in the 1950s by Graves using the corrosion cast method [3]. The available literature data indicate that the investigation of renal artery variations prevalence is based on autopsy results [4].

Variations of renal arteries are seen more frequently than variations of renal veins [5]. Anatomical variation is defined as normal flexibility in the topography and morphology of body structures [6]. It differentiates from anomalies, abnormalities, and malformations commonly presented in the literature. Although the exact distinction between these terms has not been made, the latter should be applied when structural changes negatively influence body functions [7]. Variations may significantly influence predisposition to an illness, the course of a disease, the findings of clinical examinations, or patient management [8]. Knowledge of this type of anatomical variation of renal vascularization has etiological, diagnostic, and therapeutic importance [9].

The morphological aspect of this problem concerns the establishment of individual features and variants of anatomy, topography of the renal arteries, their quantitative and morphometric characteristics, spatial location, and sources of origin of the renal arteries.

Knowledge about variants and anomalies in the kidney's blood vessels is one of the essential tasks of morphology, as it represents a significant interest in practical medicine, which determines the relevance of such studies. In the past decade, researchers have provided a wealth of genetic and phenotypic information, questions, and tolls that are now well-defined. Still, despite this, a straightforward program of work for the next decade will lead to new insights into how the kidney develops and how the molecular basis of nephrogenesis goes away in congenital kidney disease [10].

According to available data, renal vessels, particularly arteries, are characterized by an extensive range of variability in sources of origin, topography, branching, spatial relationships of branches, and syntopy with other anatomical structures, by number and morphometric characteristics [11]. Due to clinical significance, questions about the anatomy of the renal vessels are constantly attracting the attention of researchers. For different specialists, it is necessary to understand and detect variations, abnormalities, levels, and expressions of them. Anatomical and clinical medical literature describes numerous and diverse variants of the structure of the arterial vascular system concerning the place of discharge, direction, type of branching of vessels, their relationships with surrounding authorities, and blood supply areas [12]. At present, interest in possible variants and anomalies of the vascular system is still considerable since they may not affect only pathogenesis and clinical manifestations of various diseases but also the choice of treatment methods. In most cases, knowledge of morphological variants of kidney blood supply is significantly helpful in laparoscopic operations and transplantation surgeries where microvascular techniques are employed to reconstruct the renal blood vessels [13]. Variations of the renal arteries have been studied by different authors and published across various population groups [14].

Despite that, the literature is silent regarding morphometric data of renal arteries for cadaveric studies in Latvia, and information about it needs to be included. Therefore, this study aims to detect the variations of the renal arteries, make their and kidneys measurements in our cadaveric samples, and, based on a literature review, correlate the results with those already published.

2. MATERIALS AND METHODS

Under the supervision of an experienced dissector, the routine abdominal retroperitoneum standard anterior dissection was conducted for medical undergraduates at the Department of Morphology. This study was approved by Research Ethics Committee at the Rīga Stradiņš University and a permit was issued in April 2023 (11 April 2023; Nr. 2-PĒK-4/373/2023). The Laboratory of Anatomy of the Institute of Anatomy and Anthropology of Rīga Stradiņš University provided the material. The kidneys of the formalin-fixed five adult cadavers were used for the investigation. Only cadavers with two kidneys were selected for dissection, ensuring the relevant renal anatomy was not distorted. The specimens were placed supine position with their arms lying alongside them.

Perirenal fat and surrounding tissues were removed, and kidneys and the adjacent part of the aorta and arteries were cleared and explored using a Vernier measuring device, roller, and a protractor. For each cadaver, the following parameters were determined and evaluated for each side: the number of renal arteries; the length of the main renal artery; the diameter of the main renal artery at emergence from the aorta; the number of accessory arteries; the presence of early branching; angles between the lateral side of the abdominal aorta and the lower side of the renal artery; kidney length and width. The length of the renal artery was measured from the point of origin to the point of branching as well as from the point of origin to the hilum of the kidney. The diameters of arteries were measured at a distance of 15 mm from their origin in the abdominal aorta. Schematic diagrams were prepared by the authors and visualized all cases of renal arteries.

Quantitative variables were determined by mean, minimum, and maximum. The analysis included descriptive statistical methods.

Also, this study focused on making out the differences in the variations by comparing them with the previous studies undertaken.

3. RESULTS

The findings of five cadavers' cases concerning the number of renal arteries on both sides, origin, length, diameter, and angle are represented in Table 1 and Table 2.

3.1. Number of renal arteries

In cadaveric cases no. 1-4, one main renal artery (a. renalis) was present on the right side, but in cases no. 1-3 and 5, one main artery was detected on the left side. There was found one main renal artery and one accessory renal artery (a. renalis accessoria) in case no. 5 on the right side and in case no. 4 on the left side.

Table 1. Right renal arteries characteristics in five cadaver cases.

Values of renal arteries	Case no. 1	Case no. 2	Case no. 3	Case no. 4	Case no. 5	
Number	1 MRA	1 MRA	1 MRA	1 MRA	1 MRA	1 ARA
Origin[1]	L2 (inf)	L1 (inf)	L2 (inf)	L2 (inf)	L1 (inf)	L4 (inf)
Length (mm)	56.0	47.0	21.0	42.0	36.0	65.0
Diameter (mm)	6.5	4.8	7.5	5.6	6.2	3.5
Angle	81°	83°	80°	76°	58°	115°

[1] MRA = main renal artery; ARA = accessory renal artery; L = lumbar vertebra; inf = inferior border.

Table 2. Left renal arteries characteristics in five cadaver cases.

Values of renal arteries	Case no. 1	Case no. 2	Case no. 3	Case no. 4		Case no. 5
Number	1 MRA	1 MRA	1 MRA	1 MRA	1 ARA	1 MRA
Origin[1]	L2 (inf)	L1 (med)	L2 (inf)	L2 (inf)	L2 (med)	L1 (inf)
Length (mm)	37.0	28.0	28.0	32.0	68.0	36.0
Diameter (mm)	6.0	4.2	7.8	5.8	1.25	6.2
Angle	71°	110°	107°	74°	74°	58°

[1] MRA = main renal artery; ARA = accessory renal artery; L = lumbar vertebra; inf = inferior border; med = middle.

3.2. Origin of renal arteries

In all our cases, the renal artery starts from the abdominal aorta. There was no case where the renal artery originated from the common iliac, testicular, ovarian, suprarenal artery, or any other source. On the right side, most main arteries originated at the level of the inferior border of L2 and L1. The detected right accessory renal artery started at the level of the inferior border of L4. On the left side, in cases no. 2 and 5, main arteries originated at the level of the middle or inferior border of L1, but in cases no. 1, 3, and 4, these arteries started at the level of the inferior border of L2. The left accessory renal artery began at the level of the middle of L2.

3.3. Length of renal arteries

The length of the right main renal artery fluctuated from 21.0 to 56.0 mm, averaging 40.4 mm, but on the left side, was ranged from 28.0 up to 37.0 mm, averaging 32.2 mm. in case no. 5, the length of accessory renal arteries varied more pronounced (65.0 mm on the right and 68.0 mm on the left) than the length of the main renal arteries (36.0 mm on the right and 32.0 mm on the left).

3.4. Diameter of renal arteries

The diameter of the main right renal artery ranged from 4.8 to 7.5 mm, averaging 6.1 mm, but the diameter of the main left renal artery ranged from 4.2 to 7.8 mm, also averaging 6.0 mm. In the presence of one accessory artery, the diameter of the main renal artery varied from 5.8 to 6.2 mm. In case no. 5, the mean diameter of the presented accessory renal artery was 3.5 mm on the right side, and in case no. 4, it was 1.3 mm on the left side.

3.5. Angle between aorta and renal arteries

The angle between the aorta and the main renal arteries varied from 76° to 83° on the right side, averaging 75.6°, while that angle on the left side was from 58° to 110°, with a mean of 84.0°. The angle between the aorta and right accessory artery was 115° (case no. 5), but the angle between the aorta and left accessory artery was lesser and reached 74° (case no. 4).

3.6. Length and width of the kidneys

Morphometrical measurements of the kidneys are presented in Table 3 and Table 4.

Table 3. Right kidney morphometry.

Values of kidneys	Case no. 1	Case no. 2	Case no. 3	Case no. 4	Case no. 5
Length (cm)	13.0	9.5	10.2	13.0	12.3
Width (cm)	7.6	6.0	5.9	5.4	7.5

Table 4. Left kidney morphometry.

Values of kidneys	Case no. 1	Case no. 2	Case no. 3	Case no. 4	Case no. 5
Length (cm)	15.3	9.1	11.1	11.4	12.2
Width (cm)	7.1	10.7	5.8	6.3	7.7

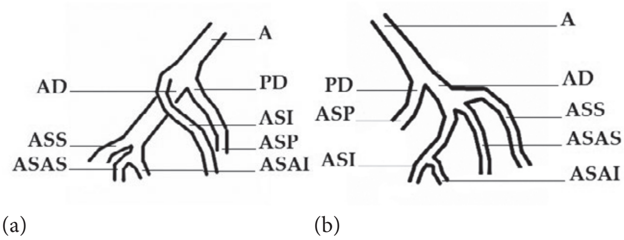


Figure 1. A diagram demonstrating renal artery prehilar branching, case no. 1: (a) a. renalis dextra; (b) a. renalis sinistra. A = a. renalis; AD = anterior division; PD = posterior division; ASS = a. segmenti superioris; ASAS = a. segmenti anterioris superioris; ASAI = a. segmenti anterioris inferioris; ASI = a. segmenti inferioris; ASP = a. segmenti posterioris.

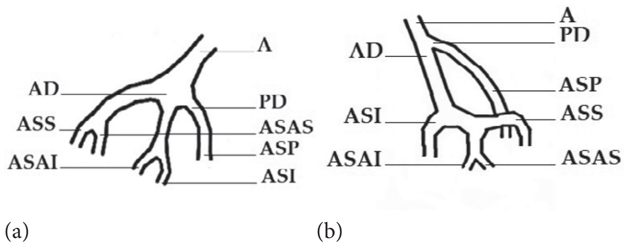


Figure 2. A diagram demonstrating renal artery prehilar branching, case no. 2: (a) a. renalis dextra; (b) a. renalis sinistra. A = a. renalis; AD = anterior division; PD = posterior division; ASS = a. segmenti superioris; ASAS = a. segmenti anterioris superioris; ASAI = a. segmenti anterioris inferioris; ASI = a. segmenti inferioris; ASP = a. segmenti posterioris.

The length of the kidney varied from 9.5 cm to 13.0 cm with an average value of 11.6 cm on the right side and from 9.1 cm to 15.3 cm with an average value of 11.8 cm on the left side. In cases no. 1 and 4, the length of the right kidney was equal to 13.0 cm. On the left side of all five cases, the values of renal length differed from each other. In cases no. 1 and 3, the left side kidneys were longer than the right kidneys, and the difference was 2.3 cm and 0.9 cm between both sides' length values. In cases no. 2 and 4, the right kidney length values were more prominent than the left side. In these cases, the right kidneys were 0.4 cm and 1.6 cm larger than the kidneys on the left side. In case no. 5, the difference was minimal and only 0.1 cm between the length of the right and left side kidneys.

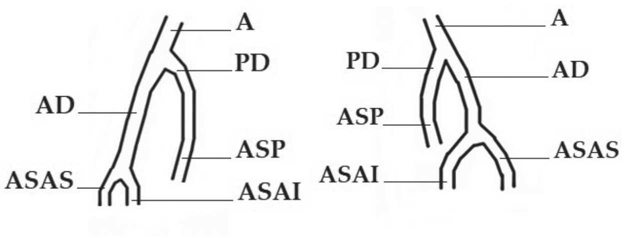
The values of the renal width varied from 5.4 cm to 7.6 cm with an average value of 6.5 cm on the right side and from 5.8 cm to 10.7 cm with an average value of 7.5 cm on the left side. Compared renal width values between sides, right kidneys were detected wider in cases no. 1 and 3, but left kidneys were wider in cases no. 2, 4, and 5. The renal width differences were 0.5 cm (in case no. 1), 4.7 cm (in case no. 2), and 0.9 cm (in case no. 4). Minimal differences between both side renal widths were in case no. 3 and 5, accordingly 0.1 cm and 0.2 cm.

3.7. Prehilar branching

In case no. 1 (Figure 1), the right renal artery divided into anterior (AD) and posterior (PD) divisions. From the AD straight away after bifurcation started a. segmenti inferioris (ASI). Independently from AD originated a. segmenti superioris (ASS). A. segmenti anterioris superioris (ASAS) and a. segmenti anterioris inferioris (ASAI) started from the common trunk of the AD. PD terminated with a. segmenti posterioris (ASP). The left kidney artery was also divided into AD and PD. From one common and short trunk of AD started two branches (ASS and ASAS). ASAI and ASI originated together from another common bifurcated and long trunk of the AD. ASP also was a terminal end of the PD.

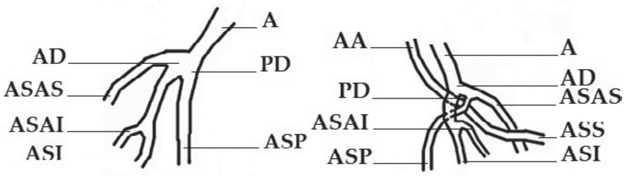
In case no. 2 (Figure 2), anterior (AD) and posterior (PD) divisions with their branches started from the trunk of the right kidney artery. At the same level, AD bifurcated again into two other trunks. A. segmenti superioris (ASS) and a. segmenti anterioris superioris (ASAS) together originated from the first common trunk, where a. segmenti anterioris inferioris (ASAI) and a. segmenti inferior (ASI) started from the second common trunk. The left kidney artery branched into AD and PD. ASS and ASI originated from the bifurcation of AD independently, whereas ASAS and ASAI started from the following common and bifurcated trunk of AD. PD terminated with a. segmenti posterioris (ASP) on both sides of renal arteries.

Case no. 3 (Figure 3) had similar branching of the right and left renal arteries into anterior (AD) and posterior (PD) divisions. A. segmenti anterioris superioris



(a) (b)

Figure 3. A diagram demonstrating renal artery prehilar branching, case no. 3: (a) a. renalis dextra; (b) a. renalis sinistra. A = a. renalis; AD = anterior division; PD = posterior division; ASAS = a. segmenti anterioris superioris; ASAI = a. segmenti anterioris inferioris; ASP = a. segmenti posterioris.

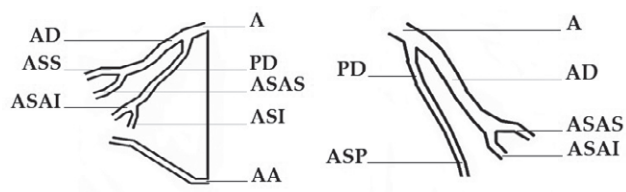


(a) (b)

Figure 4. A diagram demonstrating renal artery prehilar branching, case no. 4: (a) a. renalis dextra; (b) a. renalis sinistra. A = a. renalis; AA = a. renalis accessoria; AD = anterior division; PD = posterior division; ASS = a. segmenti superioris; ASAS = a. segmenti anterioris superioris; ASAI = a. segmenti anterioris inferioris; ASI = a. segmenti inferioris; ASP = a. segmenti posterioris.

(ASAS) and a. segmenti anterioris inferioris (ASAI) originated from AD after its bifurcation and on both sides of renal arteries. PD's right and left a. segmenti posterioris (ASP) terminal ends had no branching.

In case 4 (Figure 4), the difference between the right and left kidney arterial systems was detected. On the right side, the anterior (AD) and posterior (PD) divisions, with their branches, started from the trunk of the renal artery. A. segmenti anterioris superioris (ASAS) moved away independently, but a. segmenti anterioris inferioris (ASAI) and a. segmenti inferior (ASI) originated from another following common and bifurcated trunk. The left renal artery had a more complicated branching, where this kidney was supplied by two arteries: a. renalis (A) sinistra and a. renalis accessoria (AA) sinistra. The second artery moved behind the first artery and terminated as a. segmenti superioris (ASS). The renal artery divided into AD and a short, bifurcated trunk into ASAI and ASI in its following course. PD started shortly after the division place of the renal artery, and it moved away from AD. PD terminated with a. segmenti posterioris (ASP) on both sides of renal arteries.



(a) (b)

Figure 5. A diagram demonstrating renal artery prehilar branching, case no. 5: (a) a. renalis dextra; (b) a. renalis sinistra. A = a. renalis; AA = a. renalis accessoria; AD = anterior division; PD = posterior division; ASS = a. segmenti superioris; ASAS = a. segmenti anterioris superioris; ASAI = a. segmenti anterioris inferioris; ASI = a. segmenti inferioris; ASP = a. segmenti posterioris.

Case no. 5 was the most interesting occurrence in this study (Figure 5). The right kidney had additional a. renalis accessoria (AA), derivate from embryonic development during metanephros formation in the pelvic region and after ascending to L2-Th12. During this process, there temporary kidney artery that supplied the kidney during its ascending was formed. Commonly this artery was degenerated, but in this case, it was saved. The right renal artery divided into the anterior (AD) and posterior (PD) divisions, bifurcating again into different branches. A. segmenti superioris (ASS) and a. segmenti anterioris superioris (ASAS) started from AD, but PD divided into a. segmenti anterioris inferioris (ASAI) and a. segmenti inferior (ASI). The left kidney artery divided into AD and PD, where the last one had a lesser diameter than AD. After AD bifurcation, ASAS and ASAI originated, but PD terminated with a. segmenti posterioris (ASP).

4. DISCUSSION

Renal vasculature plays an essential role in several fields of medicine, including introductory study courses like human anatomy, histology, and physiology until clinical study courses in pathology, nephrology, and surgery.

Several anatomic variants of the renal blood supply and their clinical relevance motivate numerous researchers to find a reliable method of visualizing the renal arteries [15]. One of the noninvasive preoperative planning methods for evaluating anatomic variations is multidetector computed tomography (MDCT) angiography [16]. In the case of multiple arteries, it means accurately detecting either incidental kidney pathology or even disease of the artery itself [17]. Kidneys with double arterial supply are involved in a higher percentage of transplant failures than normal kidneys because double renal arteries can also increase the complexity of renal transplantation [18]. All renal arteries must be anastomosed during this procedure since it appreciates that intrarenal crossegmental anastomoses between arteries are non-existent except for extracapsular and small capsular anastomoses [19]. In the visualization of the relationship between the damaged parenchyma and the architecture of the renal vessels, more advantages are for selective renal angiography [20]. Combining the two investigation methods allows a more complex analysis of morphological parameters, trajectories, and vascular territories of kidneys [21]. Related to this, knowledge of the patterns provides essential data to the radiologists and preoperative information to the surgeons in better planning, the safety of the procedures, and limiting significant complications [22,23]. Nowadays, any info about vascular anomalies is of utmost importance as it influences technical aspects of surgery, results of donor nephrectomy, renal transplant, repair of abdominal aorta aneurysm, urological procedures, and angiographic interventions [24].

The complexity of the topographic and anatomical relationships of the vascular organs of the human retroperitoneal space attracts the attention of researchers. The anatomical configuration of the kidney arteries has a high value in kidney transplantation, nephrology, and different diagnostical manipulations of these fields. Analysis of the literature indicates that the coverage of various aspects of the anatomy and topography of the renal vessels, their variability, and anomalies is still sometimes unambiguous and sometimes contradictory.

The structure of the blood supply is very closely connected in a way to the functional significance of the organ and also depends on the characteristics of its development in embryogenesis. The more complex the organo- and organ histogenesis is in prenatal development, the more its vessels' morphological and topographic features are more pronounced. In the case of abnormal topography or extra artery formation due to adaptation to renal location or due to different embryological aberrations, it may be associated with other clinically significant complications as renal artery thrombosis, stenosis, which can lead to segmental parenchymal necrosis and increased chance of bleeding [25,26]. Mohammed et al. [27] stated that variations in the kidney arterial supply reflect how the vascular supply continually changes during embryonic and early fetal life. Stojadinovic et al. [28] underlined that variations of the main renal artery and vein are common due to several mesonephric arteries during fetal life.

After entering the hilum, each artery divides into five segmental arteries that do not freely anastomose with each other. The study by Shakeri et al. [29] reports that the apical, upper, middle, and lower segmental arteries usually are from the anterior division of the main renal artery, while the posterior segmental artery originates from the posterior division.

The abdominal part of the aorta is a primary source of kidney supply due to the central and accessory renal arteries. According to the literature, these arteries can be single or multiple. Changes in the number of them are common, ranging from 9% to 76% [30]. In different studies, the branching of the main renal artery varies between 4.3% and 13% [31]. In the current investigation, ten main renal arteries, of which five were on the right side and five on the left side, originating from the aorta, were observed in all cadavers. In the study of 356 kidneys, Abdessater et al. [32] detected 69% a single artery and 31% multiple arteries, including 26% with two arteries and 5% with three or more. Results of other authors showed that the frequency of numerous kidney arteries is about 30% [33,34].

The percentage of frequency of multiple kidney arteries varies from study to study, which can be the reason for complications in its classification and interpretation of results. As reported by Tardo et al. [35], 93.1% of cadavers have one kidney artery, 5.6% have two arteries, and only 1.4% have three kidney arteries. The situation is complicated by the confusion of the terminology that various researchers propose when covering this problem. According to some authors, in the presence of the main arterial trunk and one or more additional arteries, discussing multiple renal arteries, one of them is the main one, and the other (others) - is additional (different) [36]. Other authors consider that it is necessary to distinguish between the concepts of "multiple mains," "accessory," and "perforating" arteries of the kidney [37]. Related to VonAchen et al. [38], accessory renal arteries were markedly more prevalent in hypertensive patients compared to normotensive renal donors. The accessory arteries perfuse anatomically equivalent kidney regions and vary in number from two to six. Under multiple arteries, it is proposed to understand the presence of more than two vessels that follow from the aorta to the hilum of the kidney. These kidney arteries can originate from other sources: common iliac, external iliac, celiac, middle suprarenal, right colic, right branch of the hepatic artery, lumbar arteries, etc. In two our study cases, one right and one left accessory renal artery also arose from the aorta.

The renal artery's typical origin is at the L1-L2 intervertebral discs. Kadir et al. [39] observed that in 75% of the general population, the main renal artery arises at the level of the L1-L2 intervertebral discs and in 25% between T12 and L2 intervertebral discs. Özkan et al. [40] described a single main renal artery as a direct branch of the aorta, originating from the superior edge of L1 and inferior edges of L2 in 98% of individuals. 23% of the right renal arteries and 22% of the left renal arteries appeared between the L1 and L2 intervertebral discs. However, some authors testify that this level is lower and corresponds to the L3 vertebra [41]. In rare cases, on the contrary, a more cranial origin of the renal arteries exists Th12 vertebrae or even supradiaphragmatically. Some authors report that the most typical site of origin of renal arteries from the abdominal aorta is lateral, but less commonly are anterolateral and posterolateral at the level of L1-L2 [42]. In three specimens of this study, the origin of the main renal artery was at the lower border of L2 on both sides. Two right main renal arteries had an origin at the lower border of L1. The left main renal artery in one cadaver started at the lower border of L1. In other cadavers, the left main renal artery originated from the middle level of L1.

The level of origin of the accessory renal arteries from the abdominal part aorta is also variable [43]. It ranges from the lower half of the body of the Th12 vertebra to the lower half of the L3 vertebral body. In this study, the accessory renal artery had a more inferior origin on the right than the left side (lower border of L4 and middle level of L1, accordingly).

Current data showed that the lengths of arteries were not highly different from other studies, but kidney lengths were variable compared to the reported results by El-Reshaid et al. [44]. We found that the mean length of the right main renal arteries was 40.4 mm, and for the left main renal arteries, it was 32.2 mm. The length of the right-sided main renal artery varied from 21.0 to 56.0 mm, whereas the length of the left-sided main renal artery ranged from 28.0 mm to 37.0 mm. The right accessory renal artery length was 65.0 mm, and the left accessory renal artery was 68.0 mm.

The next aspect, important for practical medicine, is a complex of studies of the diameter of the renal artery. Typically, each kidney receives one renal artery with a diameter of about 6-8 mm, but this varies depending on the size of the kidneys [45]. In a study by Bouzouita et al. [46], the renal artery's mean diameter (caliber) was detected as 4.67 mm. The diameter of the right renal artery was 4.83 mm, whereas the left renal artery measured 4.70 mm, but in casts with multiple renal arteries, the mean diameter was 3.40 mm. In this study, results showed that the mean diameter of the right main renal arteries was 6.1 mm but on the left side, for the main renal arteries, it was 6.0 mm. The diameter of the right accessory renal artery was 3.5 mm, and the diameter of the left accessory renal artery was 1.3 mm.

Tarzamni et al. [47] demonstrated that the origination angle of the main renal artery from the aorta did not play a role in the development of the accessory renal artery or its early branching. The authors indicated that the angle ranged from 23° to 110° (mean 57.5°). In current study, the mean angle between the aorta and the main renal arteries was 75.6° on the right side, but on the left, it was 84.0°. Detected 115° angle between the aorta and one right accessory artery was more prominent than the 74° angle in one left accessory artery. In studied case no. 5, on the right side, the angle was the largest, but the diameter of the accessory renal artery was small.

Values of normal renal morphometry are essential for understanding the presence or progression of the disease. The average length usually reaches 12 cm, while the width is approximately 6 cm [48]. Renal size varies and relates to age, gender, height, weight, body mass index, and diseases [49]. Data from this study showed that the mean length of the kidney was 11.6 cm on the right side and 11.8 cm on the left side. In two cadavers, on the right side was seen that the length of the kidney was equal to 13.0 cm. These kidneys were more prolonged in comparison with other right side kidneys. On the left side, one kidney was seen as the longest (15.3 cm), but one kidney was the shortest (9.1 cm), comparing this side to other specimens. As a result, the mean values of the renal width were lesser on the right side than the mean value on the left side (6.5 cm and 7.5 cm, respectively). Compared renal width values between sides, the widest kidney (10.7 cm) was detected in one case on the left side. The narrowest kidney (5.4 cm) was present on the right side. In three cases, the values of the renal widths were almost equal on both sides.

In 2019, Terminologia Anatomica included two branches of the renal artery (anterior, posterior) and five segmental arteries: four from the anterior branch (a. segmenti superioris (ASS), a. segmenti anterioris superioris (ASAS), a. segmenti anterioris inferioris (ASAI), a. segmenti inferioris (ASI)) and one from the posterior one (a. segmenti posterioris (ASP) renis) [50]. In this study, prehilar branching based on the origins of these segmental arteries was analyzed. The segmental branches arose from the main renal artery some distance before it reached the hilum. The number of the prehilar branches varied between two and four. Mostly, the segments were supplied by their arteries, which arose from the anterior and posterior divisions of the main renal artery. These segmental arteries were end arteries. Weld et al. [51] underlined the possibility of the segmental arteries' common origin and introduced the expression "segmental arteries." In all cases, there were observed different prehilar branching patterns of the renal artery. In some cases, the segmental arteries originated as independent branches, while in other cases, they originated from common trunks with similarities or differences between sides. The prehilar branching of the renal artery has a high level of variation, and it has been discussed previously by several authors [52]. In 1954, the standard classification of kidney blood supply by Graves didn`t include all variations, and Shoja systematized them into 8 "cardinal" and 10 "infrequent" groups [53]. Generally, analyzed data of this study can be included in these prehilar branching patterns, except for the combinations of main and accessory renal arteries together.

There were some main limitations of this study. First, the sample size was small, resulting in a low range of variations. Second, these results can be compared only with a few cadaveric studies.

According to the detection of significant clinical significance, the unique direction of research on variant anatomy and topography of arteries aims to study the topography of these vessels concerning the hilum of the kidney and the features of their branching options.

5. CONCLUSION

Based on a small sample analysis, renal arteries vary according to their number, level of origin, length, diameter, angle, and precise relations. All cadavers have one dominant renal artery originating from the abdominal aorta. In the course near the renal hilum, each artery divides into an anterior and a posterior division, which split into segmental arteries supplying the renal segments. Two cadavers have accessory renal arteries from the aorta above or below the main renal artery. They follow it to the renal hilum, the predominant termination point for renal arterial variations. The accessory renal arteries are smaller in diameter compared to the main renal artery. In the measurements of the length, diameter, angle, length, and width of kidneys, there are differences depending on the side of the body (right / left) in the same cadaver and between them.

Results of this study also show that these cases can be systematized and added to renal branching patterns, but some exceptions exist.

Detection of anatomy of the renal arteries may affect pathogenesis, clinical manifestations of various diseases, and the choice of methods of treatment. In Latvia, further studies are recommended to help better understand the detailed anatomy and the architecture of the renal vasculature.

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Conceptualization, D.T.; methodology, D.T., D.K.; software, D.T.; validation, D.T., D.K.; formal analysis, D.T., D.K.; investigation, D.T., D.K.; resources, D.T., D.K.; funding Acquisition, M.P.; writing—original draft preparation, D.T., D.K.; writing—review and editing, D.T., D.K., M.P.; visualization, D.T., D.K., M.P.; supervision, D.T; D.K. All authors have read and agreed to the published version of the manuscript.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Rīga Stradiņš University (number 2-PĒK-4/373/2023, 11 April 2023).

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