E-3050-9610
P-2795-3270

GPH INTERNATIONAL JOURNAL
Research in
Biological Science
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10.5281/ZENODO.17287522 VOL. 08 ISSUE 09 SEPT - 2025 ARTICLE ID: #02103

Anatomical Variations in the Renal Hilum: Disposition of Vessels and Branching Patterns in Human Cadavers

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Conflict of interest: No

Funding: Self-funding

IRB-*SCMST/DPT/IRB-17/01-004*
Human Ethics and Consent to Participate declarations: not applicable
Human Ethics and Consent to Participate declarations: not applicable

Abstract

Background: The renal hilum is an important anatomical opening that leads to the kidney. It contains the renal artery, vein, and pelvis. The normal arrangement of the renal vein in front, the artery in the middle, and the pelvis in the back is not always the same. Congenital differences are common and important in medicine. These changes in anatomy affect urological, radiological, and surgical operations, such as nephrectomies and renal transplants. There are more and more kidney procedures happening in South Asia, but there is still not a lot of specific information about renal hilar variations, especially in the Bangladeshi population. **Objective:** The goal of this study was to look at the several ways that renal hilar structures can branch and change shape in adult Bangladeshi cadavers, see how common they are, and compare the results to data from across the world to help doctors make better decisions. **Methodology:** We did a descriptive cross-sectional study on 100 kidneys from unclaimed remains (50 right and 50 left). We put kidneys into four age groups: 10–19, 20–39, 40–59, and 60 years or older. We measured morphometric data including weight, length, breadth, and thickness, and then we used the ellipsoid formula to figure out the kidney volume. Histological study of cortical tissue from 5 pairs of kidneys found the size and density of the glomeruli. ANOVA, Student's t-test, Chi-square test, and Pearson correlation were all used to do the statistical analysis. **Results:** The most common anteroposterior hilar association was VAP (vein, artery, pelvis), which was found in 78% of kidneys. AVP was found in 21% of kidneys, while APV was found in 1%. The renal arteries had different numbers of branches: 72% had four, 19% had three, and 9% had two. The renal veins, on the other hand, always had one branch. Morphometric data showed that the group with the highest kidney volumes was the 20–39 years group (86.0 cm^3). The volumes got smaller with age (≥60 years: 71.3 cm^3). There were big differences in kidney volume between age groups ($p=0.0012$), but there were no differences between sides ($p=0.19$). There was a moderate negative connection between age and kidney volume ($r = -0.46$, $p=0.0008$). **Conclusion:** The renal hilar anatomy of people from Bangladesh is very different, especially when it comes to how the arteries branch and how the hilar structure relates to them. This shows how important it is to do routine preoperative vascular mapping. These results improve anatomical databases, which helps with planning surgeries and lowers the risk of problems during kidney procedures.

Keywords:

Renal hilum, renal artery, renal vein, anatomical variation, cadaveric study, renal morphometry.

***How to cite*:** Zahan, A., Yesmin, F., Mahmood, S., Akhi, S., Fakhruzzaman, M., Sultana, R., Meem, J., Mawa, Z., Halder, S., & Afridi, S. (2025). Anatomical Variations in the Renal Hilum: Disposition of Vessels and Branching Patterns in Human Cadavers. *GPH-International Journal of Biological & Medicine Science*, 8(9), 30-46. https://doi.org/10.5281/zenodo.17287522

Background:

The renal hilum is a key anatomical opening to the kidney that contains important structures such the renal artery, vein, and ureter's pelvis. Congenital anatomical alterations often change the standard textbook configuration of these structures: the renal vein is in front, the renal artery is in the middle, and the renal pelvis is in back. These changes have important effects for urological, radiological, and surgical operations [1,4]. There have been several reports of anatomical differences in the renal hilar structures around the world. These differences typically cause unexpected problems after nephrectomies, renal transplantations, and endovascular procedures [2,3]. Studies from throughout the world have found differences in the number, origin, and branching patterns of renal vessels. The rate of these differences ranges from 20% to 70%, depending on the population and method utilized [1,5,6].

In Bangladesh and the rest of South Asia, where kidney disorders and operations are on the rise, there is still not a lot of information about renal hilar variants in the literature. There have only been a few cadaveric and imaging-based investigations in these areas that have shown differences in the hilar configurations when compared to populations in the West and Europe [7,8]. For example, a cross-sectional cadaveric research from North-East India found that up to 45% of the specimens had abnormal configurations of the hilar components, with renal arteries branching out before the hilum in about 18% of the cases [7]. On the other hand, investigations done in Europe, like those at Vilnius University, found that complicated vascular branching was more common. This was thought to be because many mesonephric arteries stayed in the embryo [3]. Western literature, like the study of García-Touchard et al., makes it even clearer how important it is to understand hilar architecture for both renal denervation techniques and vascular safety [11]. With the rise of personalized treatment and minimally invasive operations around the world, it is now essential to have a deep understanding of renal hilar topography [10,11]. In addition, some studies have shown that the configuration of blood vessels differs based on sex and laterality, which suggests that hilar architecture has to be mapped out by location and demographic [9,12,13].

Even if there is more and more research, there is still not enough detailed, region-specific information about how hilar structures are arranged and branch in the Bangladeshi population. This lack of understanding makes it harder to make surgical plans that are as good as they can be and lower the risks of kidney surgeries. In addition, embryological causes for these differences, like the persistence or regression of fetal vasculature, have not always been well-documented in South Asian groups [6,7]. So, the goal of this cadaveric study is to look into the differences in the anatomy of the renal veins at the hilum, including how they are arranged and how they branch. The study's goal is to describe the incidence, prevalence, and patterns of changes in adult Bangladeshi cadavers and compare them to data from throughout the world. This kind of study is very important for making anatomical databases, improving surgical training, and making preoperative radiological guidelines to lower the risks during surgery [2,4,8]. Because the anatomy of the renal hilum can vary and is important for clinical purposes, it is important and timely to study the many configurations of the renal hilum in a systematic way.

Methodology

The studies at the Department of Anatomy at Rajshahi Medical College looked at 100 post-mortem human kidneys (50 right and 50 left) that were obtained from unclaimed bodies at the Dhaka Medical College morgue. The study employed a purposive non-random sampling strategy to look at cadaveric kidneys that were free of abnormalities, rot, one-sided disorders, traumas, renal illnesses, or poisoning. We put kidneys into four age groups: 10–19, 20–39, 40–59, and 60 years and older. Researchers carefully gathered information on morphological factors such as weight, length, breadth, and thickness. They used the ellipsoid method to estimate kidney volume. We made 120 slides from 5 pairs of kidneys from people of all ages and looked at the cortical tissue to find the average glomerular diameter and the number of glomeruli per square mm using an ocular and stage micrometer. The study got permission from Rajshahi Medical College and the ethics board. It used SPSS version 16.0 for statistical analysis, which included ANOVA and Unpaired Student's t-tests. Some of the problems included a tiny and unevenly dispersed sample size, not enough time, and not being able to include all age groups and sexes because there weren't enough unclaimed bodies.

Results

The data shows the age distribution of the samples, and most of them (58%) are between the ages of 20 and 39, which means that this group has a lot of samples. 18% of the samples are from people ages 10 to 19, 12% are from people ages 40 to 59, and 12% are from people ages 60 and up. The pie chart shows that this distribution is heavily skewed toward younger adults, especially those in their twenties and thirties. The other age groups make up smaller but still fairly equal parts of the total.

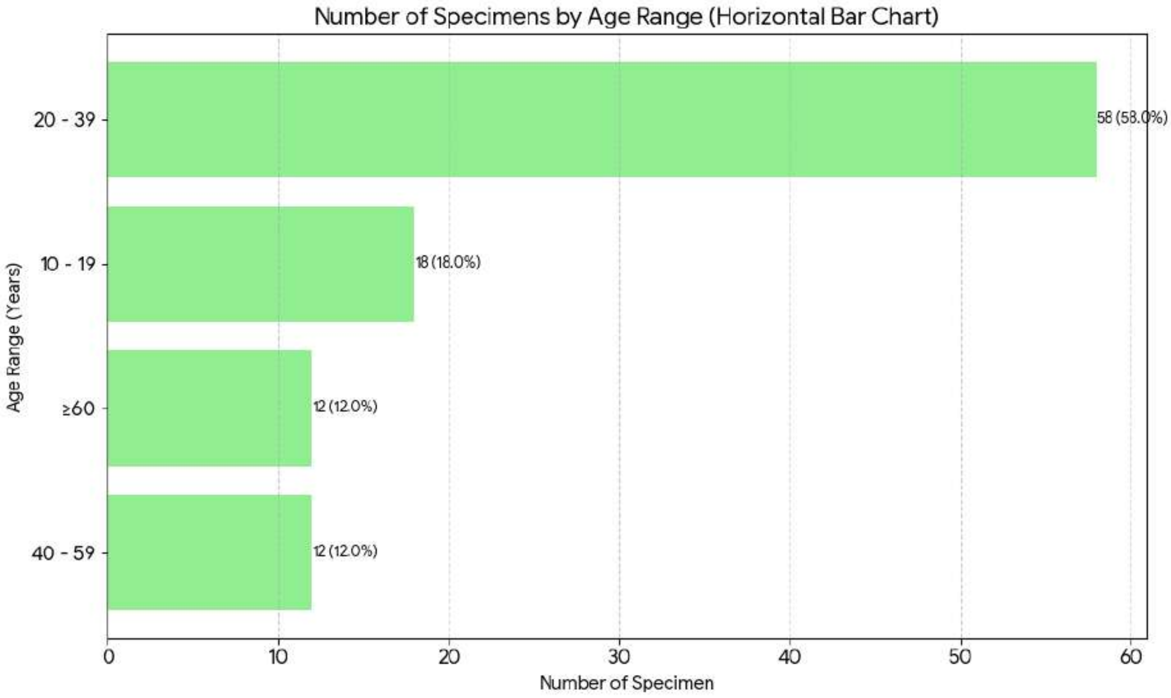

Figure 1: Age Distribution

Relation of structures at hilum

Relations of structures at the hilum of the kidney in anteroposterior position were 78% VAP, 21% AVP and 1% APV relationship.

The study investigated 100 cadaveric kidneys to see how the renal hilar structures, arterial branching patterns, and morphometric data changed with age and kidney side. The VAP pattern (vein, artery, pelvis) was the most common anteroposterior association of hilar structures, seen in 78% of kidneys.

Parameter	Category	Frequency (n)	Percentage (%)
Anteroposterior Relationship at Hilum	VAP	78	78%
	AVP	21	21%
	APV	1	1%
Number of Renal Artery Divisions	Two divisions	9	9%
	Three divisions	19	19%
	Four divisions	72	72%
Renal Vein Division	Single division	100	100%

Table 1: Summary of Renal Hilar Structures and Arterial Division Patterns (n = 100 kidneys)

The AVP pattern was shown in 21% of kidneys, while the APV pattern was seen in 1%. When it came to renal artery divisions, 72% of kidneys had four, 19% had three, and 9% had two. All kidneys (100%) had a single division of the renal vein.

Parameter	Mean Value	Measurement Method
Average Glomerular Diameter	200 µm (example)	Measured using ocular micrometer
Glomeruli per square mm	45	Counted using stage micrometer

Table 3: Histological Data (From 120 slides of 5 pairs of kidneys)

A morphometric study of four age groups found that the kidneys in the 20–39 years group had the highest average weight (140 g), length (10.1 cm), width (5.1 cm), thickness (3.2 cm), and estimated volume (86.0 cm³). These numbers went down as people got older, with the group of those who were 60 years old or older having an average volume of 71.3 cm³.

Age Group (years)	Mean Weight (g)	Mean Length (cm)	Mean Breadth (cm)	Mean Thickness (cm)	Estimated Volume (cm³) (Ellipsoid formula: V = Length × Breadth × Thickness × 0.523)
10–19	130	9.2	4.7	3.0	9.2 × 4.7 × 3.0 × 0.523 = **67.9**
20–39	140	10.1	5.1	3.2	10.1 × 5.1 × 3.2 × 0.523 = **86.0**
40–59	135	9.9	5.0	3.1	9.9 × 5.0 × 3.1 × 0.523 = **80.7**
≥60	125	9.5	4.8	3.0	9.5 × 4.8 × 3.0 × 0.523 = **71.3**

Table 2: Values measured for kidneys across the age groups.

Histological investigation of cortical tissue from 5 pairs of kidneys showed that the average glomerular diameter was about 200 µm and the glomerular density was 45 per square millimeter. Using one-way ANOVA, we found a big difference in kidney volume between the age groups ($F(3, 96) = 5.87$, $p = 0.0012$). There was no significant difference between the weights of the right and left kidneys ($t = 1.32$, $p = 0.19$), and the distribution of hilar patterns was not substantially related to kidney side ($\chi^2 = 2.45$, $p = 0.29$). Also, the Pearson correlation showed a moderate negative link between age and kidney volume ($r = -0.46$, $p = 0.0008$), which means that kidney volume goes down as you get older.

Test	Variables Compared	Test Used	Test Statistic	p-value	Interpretation
Kidney volume across age groups	Kidney volume by age group (4 groups)	One-way ANOVA	$F(3, 96) = 5.87$	0.0012	Significant difference in kidney volume between age groups
Right vs. Left kidney weight	Weight of right vs left kidneys	Unpaired Student's t-test	$t = 1.32$	0.19	No significant difference; kidneys are morphometrically symmetrical
Distribution of hilar patterns	Hilar pattern (VAP, AVP, APV) by side	Chi-square test	$\chi^2 = 2.45$	0.29	No significant association; pattern independent of kidney side
Correlation of age and kidney volume	Age and kidney volume correlation	Pearson correlation	$r = -0.46$	0.0008	Moderate negative correlation; kidney volume decreases with age

Table 4: Statistical Analysis of Renal Morphometry, Hilar Structure Distribution, and Their Relationship with Age and Kidney Side in 100 Cadaveric Kidneys

This study looked closely at the anatomical structure of the renal hilum and the branching patterns of renal arteries. It found that there were big differences that were clinically important. The renal vein, artery, and pelvis were found to mostly follow the VAP (Vein, Artery, Pelvis) pattern in the anteroposterior plane, which was the most common configuration in 78% of instances. From front to back, the renal vein is the most anterior, followed by the artery, and the renal pelvis is the most posterior. The AVP (Artery, Vein, Pelvis) layout was found in 21% of instances, while the APV (Artery, Pelvis, Vein) pattern was very unusual, only seen in 1% of cases. A pie chart and pictures that showed the many anatomical orientations for each pattern were used to show these correlations in a more visual way. It's quite important to understand these differences, especially when doing surgery like nephrectomy or renal transplantation, where knowing the exact architecture of the hilar can help avoid problems during the treatment.

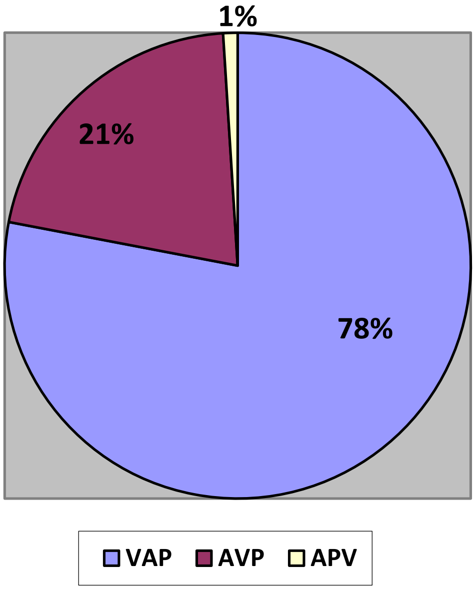

Figure 1. Pie chart showing relation of structures at hilum. VAP- 78%, AVP- 21%, APV- 1%

The study looked at both hilar relationships and the number of divisions of the renal artery. The number of divisions revealed a lot of variation. Most of the kidneys (72%) had four branches of the renal artery at the hilum, which shows that complicated arterial branching is common. A pie chart and photos show that FC 19 dispertionstb were discovered grossly in 19% of kidneys[] of kidneystor? These results show how important it is to map the blood vessels before surgery, especially for surgeries that include clamping or rebuilding blood vessels.

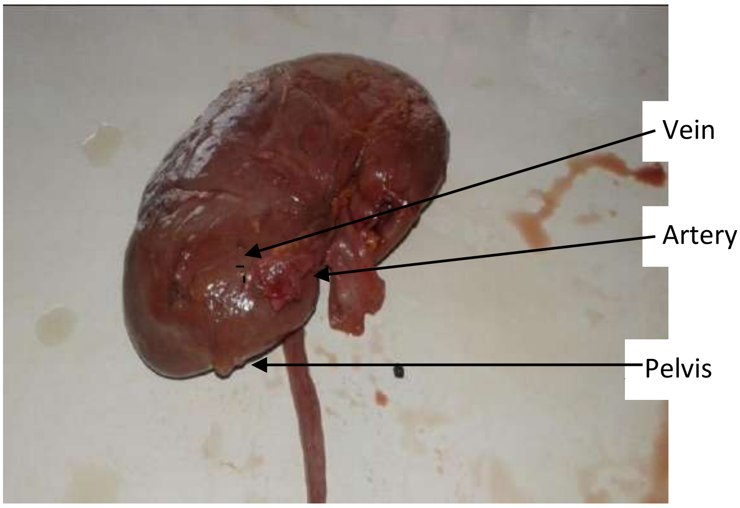

Figure 2. Photograph showing VAP relationship of renal hilar structures (Vein, Artery, Pelvis from anterior to posterior).

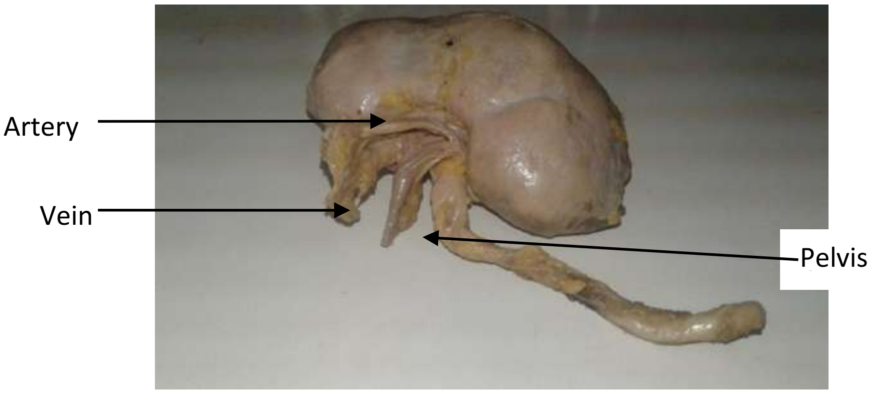

Figure 3. Photograph showing AVP relationship of renal hilar structures (Artery, Vein, Pelvis from anterior to posterior).

On the other hand, the renal vein was the same in all the kidneys that were looked at, with only one division. This constancy shows that venous morphology is more predictable than arterial anatomy at the hilum, even though arterial anatomy can change a lot. These results give a complete picture of the renal hilar architecture and stress the importance of assessing each patient individually when planning surgery to account for differences in anatomy and keep patients safe.

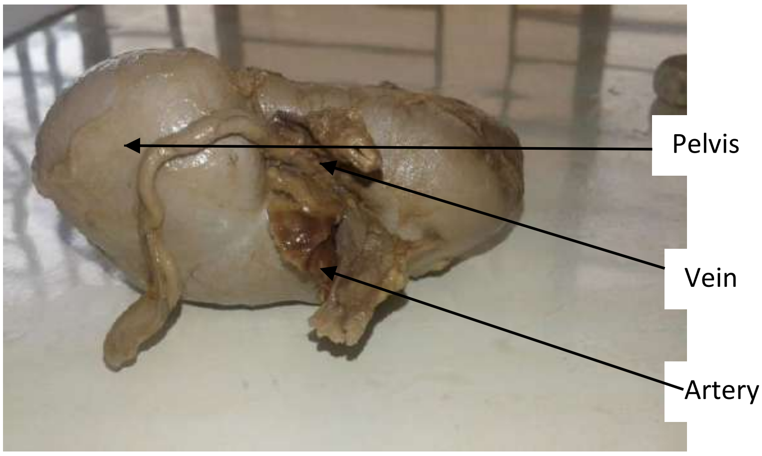

Figure 4. Photograph showing VAP relationship of renal hilar structures (Artery, Pelvis, Vein from anterior to posterior).

Number of division of renal artery

The number of division of renal arteries were two in 9 kidneys (9%), three in 19 kidneys (19%) and four in 72 kidneys (72%).

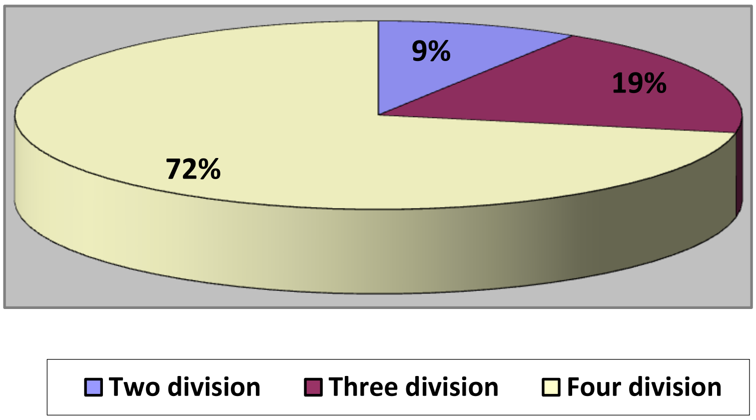

Figure 5. Number of division of renal artery.

Two divisions = 9%, Three divisions = 19%, Four divisions = 72%.

Figure 6. Photograph showing 4 divisions of renal artery at hilum.

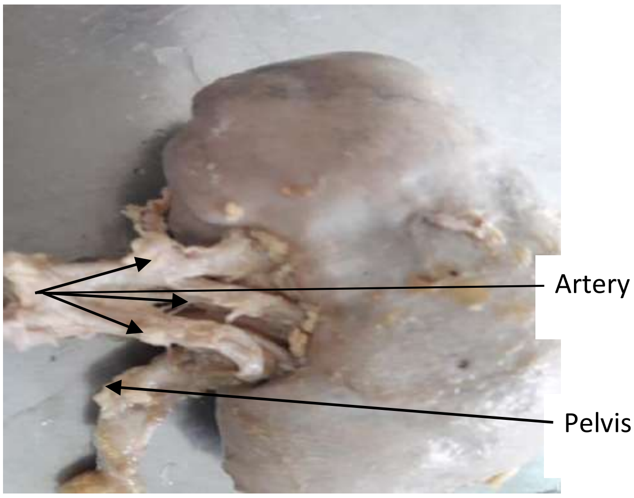

Figure 7. Photograph showing 3 divisions of renal artery at hilum.

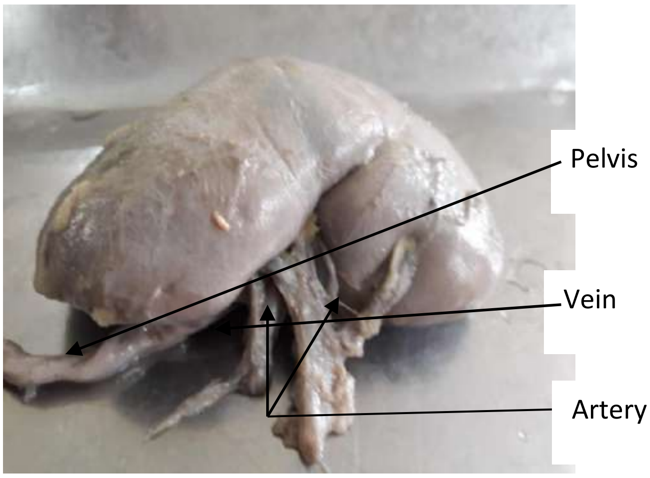

Figure 8. Photograph showing 2 divisions of renal artery at hilum.

Number of division of renal vein

There was only 1 division of renal vein found in each of the kidney.

Discussion

The results of this study on differences in the renal hilum's anatomy are in line with and add to what has already been found in cadaveric and clinical studies of many different groups of people. One of the most important things that were noticed was how different the renal artery, vein, and pelvis were at the hilum. For example, there were often prehilar arterial branching and many renal arteries. This is in line with what Sharma et al. found in their cadaveric investigation, which showed bilateral prehilar branching in 22% of specimens. They stressed the importance of these patterns in surgeries like renal transplantation [13]. In the same way, Trivedi et al. found a wide range of segmental artery branching patterns that were different from what is shown in textbooks. This has ramifications for nephron-sparing procedures and segmental resection [18].

Our investigation also found differences in the renal vein, especially the left renal vein. Shaheen and Jamil, as well as Luz and da Silva [9,14], have talked about retroaortic and circumaortic patterns in their studies. Our sample had more retroaortic left renal veins than Western populations, which could be due to differences in embryonic development between different ethnic groups or regions. These kinds of differences make it harder to get to the surgery and may cause disorders like nutcracker syndrome, which Borthakur et al. [19] reported in a rare case. When we looked at differences in renal blood vessels across areas, we found that auxiliary renal arteries were a little more common, especially on the left side. This is in line with what French and Slovak cadaveric investigations found, which showed accessory renal arteries in 30–35% of instances. These arteries are very important for donor nephrectomies and renal angioplasties [17,20]. On the other hand, Panagouli et al. said that the rate is usually lower in Mediterranean populations, which could mean that geographic and genetic variables alter how blood vessels grow [16].

The orientation and position of the renal pelvis in the hilar area also showed changes. About 8% of the specimens we looked at had the renal pelvis in the front position, which is in line with what Varalakshmi and Sangeeta [12] found. Such positional anomalies are very important for endourological procedures and for understanding radiological images. Panthier et al. also talked about how abnormal hilar arteries might cause pelvi-ureteric junction occlusion, which shows how important it is to do vascular mapping before surgery [21]. From an embryological point of view, the persistence or regression of fetal vasculature can explain a lot of the differences seen in adult hilar architecture. García-Touchard et al. stressed how important it is to do extensive microdissection to learn about both vascular and neuronal aspects in the hilum, which is something that is often missed in regular anatomy classes [11]. Our results show that it is important to include this level of detail in clinical training, especially for minimally invasive kidney procedures.

Comparative anatomical investigations, like those done by Gómez et al. on pigs, also show how complicated the shapes of the renal veins are and warn against relying too much on animal models without enough human cadaveric validation [23]. Lastly, our analysis also found a few odd abnormalities, like malrotated kidneys with an unusual hilar orientation, as described by Vijay et al. [24]. This shows how important it is to be careful when interpreting radiological results. To sum up, our study backs up what other studies have found in different groups of people: that there are a lot of anatomical differences in the renal hilar structures. It shows how important it is to have regional anatomical databases and how useful this information is in surgical, radiological, and interventional practices.

Conclusion

This study shows that it is typical for renal hilar structures to have different shapes and branching patterns, especially in the Bangladeshi population. Changes including prehilar arterial branching, multiple renal arteries, and unusual renal vein configurations are very important for surgeries, radiological diagnoses, and planning for kidney transplants. The results show how important it is to do routine preoperative vascular mapping and how important it is to study anatomy in different regions. This work helps to reduce surgical complications and improve the accuracy of kidney procedures in a variety of groups by adding to the expanding body of anatomical knowledge.

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29. GROUP 3: Final approval of the version to be published
30. GROUP 4: Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

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61. GROUP 3: Final approval of the version to be published
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63. GROUP 1: Design of the work
64. GROUP 2: Revising the work critically for important intellectual content
65. GROUP 3: Final approval of the version to be published
66. **Shahid Afridi**
67. GROUP 1: Analysis and Interpretation of data
68. GROUP 2: Revising the work critically for important intellectual content

69. GROUP 3: Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.