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Original Article

Anatomy Section

Anatomical Variations in Arrangement of Renal Hilar Structures and its Applied Importance: A Cadaveric Cross-sectional Study among North East Population of India

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ABSTRACT

Introduction: The hilum of the kidney leads into a central renal sinus filled with the renal pelvis and renal vessels. The classical arrangement of the structures present is the renal vein, renal artery, and renal pelvis, from anterior to posterior. Previous studies have shown many variations in the arrangement of the structures in the renal hilum; however, there is a lack of literature on this topic in the North-east region of India, where many communities and tribes reside.

Aim: To evaluate both the classical and anatomical variations in the arrangement of the renal hilar structures in human cadavers.

Materials and Methods: The present study was a cadaveric cross-sectional study conducted in the Department of Anatomy at Assam Medical College, Assam, India, involving 160 specimens from 80 cadavers, both adult and foetal (≥36 weeks), from July 2013 to June 2014. Among these, 15 were adult cadavers and 65 were perinatal cadavers (11 male and 4 female adults; 28 male and 37 female perinates). The relations of the structures, i.e., renal artery, renal vein, and renal pelvis present in the renal hilum, were studied in an anterior-posterior manner after meticulous dissection.

Results: In the present study, the majority of specimens exhibited hilar structures arranged in a VAP pattern (67 kidneys, 41.88%), with a higher occurrence on the left-side (37 kidneys, 23.1%) compared to the right-side (30 kidneys, 18.7%). This was followed by a VAPA pattern (28 kidneys, 17.5%). Variations in the arrangement of hilar structures other than the classical arrangement were observed in more than 59% (93 kidneys) of the specimens. It was noted that the anterior and posterior divisions of the renal artery and the anterior and posterior tributaries of the renal vein occupied the pre-hilar and hilar regions rather than the main trunks.

Conclusion: It was observed that the arrangement of the structures present in the renal hilum exhibits a wide spectrum of variations. Knowledge of these variations may be beneficial not only for anatomists but also for urologists and radiologists, as it may help prevent or at least minimise the incidence of intraoperative injuries and post-operative complications. Urological procedures such as nephrectomy and renal transplant operations require careful dissection and separate ligation of the renal vessels present in the renal hilum to prevent arteriovenous fistula and massive haemorrhage. Prior knowledge of unusual arrangements of the hilar structures may assist surgeons in avoiding inadequate ligation of vessels and minimising complications.

Keywords: Kidney hilum, Kidney pelvis, Partial nephrectomy, Renal artery, Renal vein

INTRODUCTION

The kidney is a bean-shaped, paired retroperitoneal organ that plays a crucial role in maintaining body homeostasis. Each kidney consists of nephrons that produce urine, as well as a pelvicalyceal system that transports urine to the urinary bladder. The renal hilum is the concave fissure located on the medial border of the kidney, where the renal vein exits, the renal artery enters, and the renal pelvis exits the kidney. The hilum leads into a central renal sinus, which is lined by the renal capsule and is almost entirely filled by the renal pelvis and vessels; the remaining space is occupied by fat. The classical arrangement of structures is vein, artery, and renal pelvis, from anterior to posterior. The posterior division of the renal artery and the posterior tributary of the renal vein generally enter the kidney tissue posterior to the pelvis [1]. Hollinshead WH found that the renal artery typically divides into anterior and posterior rami, usually close to and in relation to the pelvis before entering the kidney [2]. Sinnatamby CS stated that each renal artery usually divides into two branches that enter the hilum of the kidney, one in front of and one behind the renal pelvis [3]. Moore KL and Per Sand TVN noted that at the hilum, the renal vein, renal artery, and renal pelvis are arranged in an anterior-to-posterior relationship [4].

A thorough understanding of variant hilar anatomy is of utmost importance for surgeons and interventional radiologists to ensure safe procedures. However, there is limited literature available on this topic from North-east India. Many studies regarding the variations in the arrangement of structures present in the hilum of the kidney have been conducted in other countries and different states of India, but the results are not consistent with one another [5-12].

Thus, the present study aimed to contribute to the existing knowledge in this field, providing insights into the variant renal hilar anatomy in the North-east region of India. This information could help reduce the incidence of injury during kidney surgeries and radiological interventions in this area. The aim of this study is to examine the normal relationships between the structures of the renal hilum, while the objective is to investigate the variations in these relationships.

MATERIALS AND METHODS

This cross-sectional cadaveric study was conducted in the Department of Anatomy at Assam Medical College and Hospital (AMCH), Dibrugarh, Assam, India, from July 2013 to June 2014. Specimens were dissected from adult cadavers (15 in total)

designated for undergraduate dissection, as well as from foetal cadavers over 36 weeks of gestation (65 in total), which were obtained from the Department of Obstetrics and Gynaecology. In total, 160 kidney specimens were dissected for the study.

Among these, 30 were from adult cadavers (11 male and 4 female), and 130 were from perinatal cadavers (28 male and 37 female). Perinatal specimens (greater than 36 weeks gestation) were utilised alongside adult cadavers to encompass all age groups representing the entire population. The authors were unable to collect cadavers of children during the study period; therefore, the authors used perinatal specimens, as there are no alterations in renal hilar anatomy after birth.

Ethical clearance was obtained from the Institutional Ethics Committee (H) prior to data collection (No. AMC/EC/PG/13/12742). Informed consent does not apply in this case, as the study was conducted on cadavers.

Inclusion criteria: Adult cadavers are provided for the academic dissection of undergraduate and postgraduate students, as well as stillborn perinates after 36 weeks of gestational age (weight >2 kg).

Exclusion criteria: Perinates born before the 36th week of gestation and weighing less than 2 kg, as well as cadavers with a previous history of renal surgery, were excluded from the present study due to the presence of gross congenital malformations.

Procedure

After fulfilling all the required official formalities, the cadavers were received in the Department of Anatomy. The details of the cadavers and the specimens collected from them were recorded. The adult cadavers were embalmed with embalming fluid using the gravity method [13]. The foetal cadavers were dissected immediately, if possible. The specimens collected from them were fixed in 10% formalin for 15 days before dissection was carried out.

Method of dissection: The abdomen was opened using a median longitudinal incision on the anterior abdominal wall, and the intestine was retracted superiorly. First, the psoas major muscle was identified, followed by the pelvis and ureter, which were found partly in front of and just medial to it. The morphology and position of the ureter, as well as its relation to the renal artery, were observed. The relations of the hilum of the kidneys were examined. The kidneys, ureters, and urinary bladder were then removed. The specimens were thoroughly washed in running tap water and transferred to a jar containing 10% formalin. They were numbered accordingly, dissected, and studied. The renal vessels and loose areolar tissues from both the anterior and posterior surfaces of the pelvis were removed and cleaned. The relationships of the hilar structures were studied. The topographic arrangements of the structures in the renal hilum were analysed at approximately 0.5 cm (0.2 inches) from the anterior lip of the renal hilum and painted with colours. The relationships of the structures were documented antero-posteriorly, specifically considering the renal artery, renal vein, and renal pelvis. Photographs of the specimens were taken. The data collected from the study were recorded and tabulated accordingly.

STATISTICAL ANALYSIS

The data collected from the study was recorded, and the results and observations were evaluated using tables. Descriptive statistics were employed.

RESULTS

Different patterns observed during the study were-:

VAP [Table/Fig-1,2a,b],

VAPA [Table/Fig-1,3a,b],

AVP [Table/Fig-1,4a,b],

AVP-A [Table/Fig-1,5a,b],

AVP-A-V [Table/Fig-1,6],

VAAP [Table/Fig-1,7],

V-AVP-A [Table/Fig-1,8],

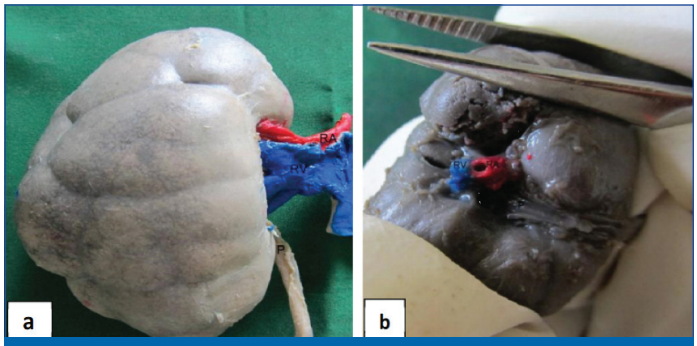
V-A-VAP [Table/Fig-1,9],

A-VAP [Table/Fig-1,10],

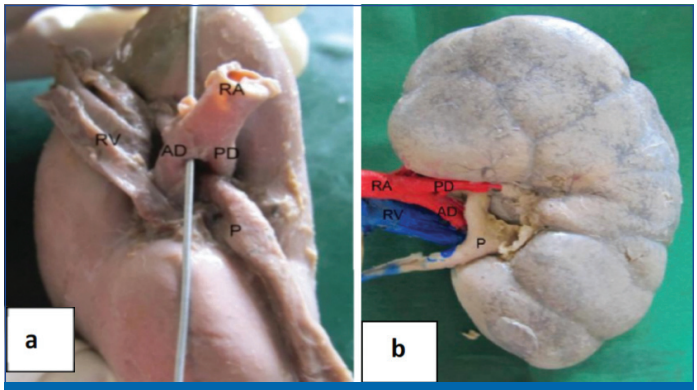
VAPA-V [Table/Fig-1,11],

Types/pattern	Right n=80 (50%)	Left n=80 (50%)	Total n=160 (100%)
V-A-P	30 (18.75)	37 (23.12)	67 (41.88)
A-V-P	8 (5.0)	17 (10.62)	25 (15.63)
VAAP	2 (1.25)	3 (1.87)	5 (3.13)
A-VAP	2 (1.25)	2 (1.25)	4 (2.50)
V-AVP-A	3 (1.88)	0 (0)	3 (1.88)
VAPA-V	2 (1.25)	0 (0)	2 (1.25)
VAPA	13 (7.5)	15 (10)	28 (17.50)
AVP-A	18 (11.25)	5 (3.12)	23 (14.38)
V-P-A	0 (0)	0 (0)	0 (0)
AVP-V	0 (0)	0 (0)	0 (0)
V-A-VAP	1 (0.63)	0 (0)	1 (0.63)
A-V-P-A-V	1 (0.62)	1 (0.62)	2 (1.25)

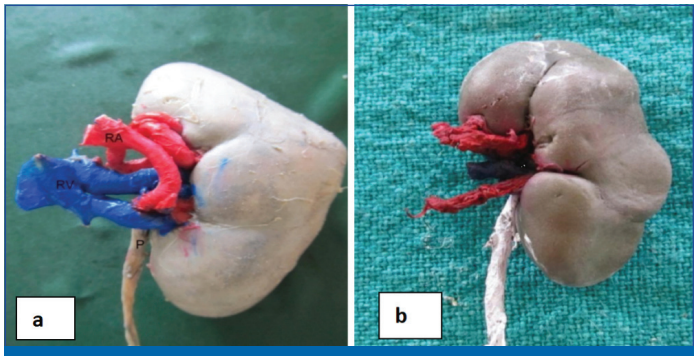
[Table/Fig-1]: Patterns of arrangement of the hilar structures.
A: Artery; V: Vein; P: Pelvis



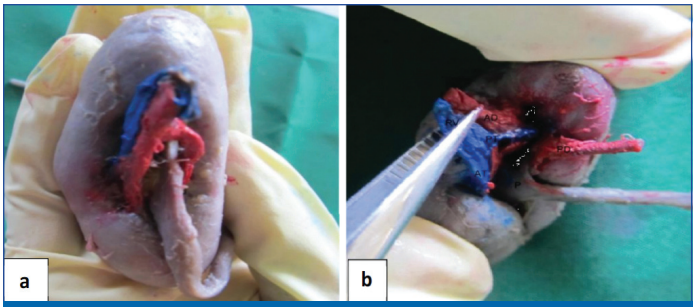
[Table/Fig-2]: Vein–Artery–Pelvis (VAP) Pattern in: a) Adult (Medial view); b) Perinate (Anterior view).



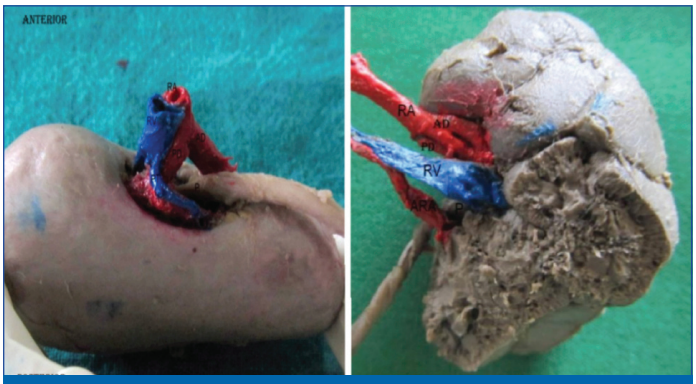
[Table/Fig-3]: Vein-Artery (AD)-Pelvis–Artery (PD) (VAPA) pattern: a) Adult (Medial view); b) Perinate (posterior view).



[Table/Fig-4]: AVP pattern: a) Adult; b) Perinate (Anterior view).

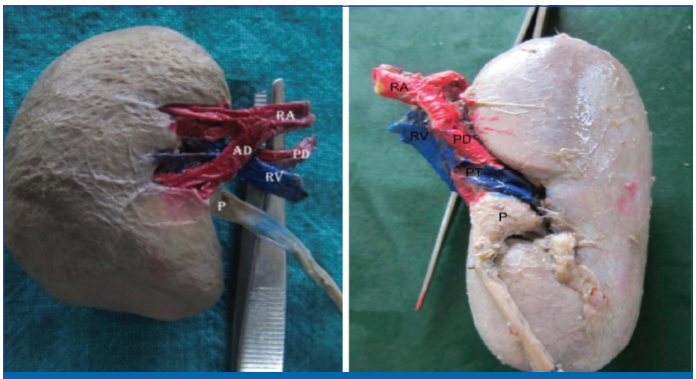


[Table/Fig-5]: AVPA Pattern: a) Adult (medial view); b) Perinate (medial view).



[Table/Fig-6]: VPAV (Adult) (Posterior view). **[Table/Fig-7]:** VAAP (perinate) (Anterior view). (Images from left to right)
ARA: Accessory renal artery

[Table/Fig-8]: VAVPA (Adult) (Posterior View). **[Table/Fig-9]:** VAVAP (Perinate). (Images from left to right)
ARA: Accessory renal artery



[Table/Fig-10]: AVAP (Anterior view) adult. **[Table/Fig-11]:** VAPAV (posterior view) adult. (Images from left to right)

The present study shows that 41.88% (67 specimens) exhibit the classical arrangement (VAP). This arrangement is more prevalent on the left-side (37 specimens, 23.12%). The VAPA pattern is observed in 28 specimens (17.50%) with a higher occurrence on the right-side (16 specimens, 10%). Additionally, an accessory renal artery was noted in 2 specimens. (A=artery, V=vein, P= pelvis, AD= anterior division of artery, PD= posterior division of artery, AT= anterior tributary, PT= posterior tributary.)

Patterns of arrangement of the Hilar structures individually in adults and perinates is described in [Table/Fig-12 and 13].

Types/pattern	Adult (n=30)		Total (n=30)
	Right (n=15)	Left (n=15)	
VAP	6	5	11
AVP	1	4	5
VAAP	0	0	0
A-VAP	1	0	1
V-AVP-A	0	0	0
VAPA-V	0	0	0
VAPA	3	4	7
AVP-A	4	1	5
V-P-A	0	0	0
AVP-V	0	0	0
V-A-VAP	0	0	0
AVP-A-V	0	1	1

[Table/Fig-12]: Patterns of arrangement of the Hilar structures in adult.

Types/pattern	Perinate		Total (n=130)
	Right (n=65)	Left (n=65)	
VAP	24	32	56
AVP	7	13	20
VAAP	2	3	5
A-VAP	1	2	3
V-AVP-A	3	0	3
VAPA-V	2	0	2
VAPA	10	11	21
AVP-A	14	4	18
V-P-A	0	0	0
AVP-V	0	0	0
V-A-VAP	1	0	1
AVP-A-V	1	0	1

[Table/Fig-13]: Patterns of arrangement of the hilar structures in perinate.
A: Artery; V: Vein; P: Pelvis; AD: Anterior division of the artery; PD: Posterior division of the artery; AT: Anterior tributary; PT: Posterior tributary

DISCUSSION

An anatomical, surgical, radiological, and paediatric literature review has emphasised a wide spectrum of variations associated with the arrangement of hilar structures [6-9,11,12]. The importance and implications of these variations have also been highlighted quite often. It is evident that a thorough understanding of the normal arrangement, as well as the wide range of variations associated with these structures, is essential for medical professionals performing interventions in this field.

Sampaio FJ and Aragão AH described that in 40.4% of cases, a large inferior tributary of the renal vein is in close relation to the anterior aspect of the ureteropelvic junction [5]. In 69.2% of cases, there is a renal vein posterior to the pelvis; in 48.1% of cases, the vein has a close relation to the junction of the pelvis with the upper calyx; and in 21.1% of cases, it crosses the middle posterior surface of the renal pelvis. Arvindhan K and Srinivasan KR reported a case of bilateral variation in the relations of the hilar structures of the kidney [6]. They observed that the artery, vein, and pelvis of the ureter were arranged in the anterior, intermediate, and posterior positions, respectively. In another case, they noted that in the left kidney, the posterior segmental artery and apical segment arteries arose as separate branches from the aorta, while the main renal artery supplied the other three segments. The renal vein was located between the artery and the pelvis of the ureter, which is a rare configuration. Joao A et al., observed that variant patterns were more commonly seen on the left-side [7]. They classified the arrangements of the hilar structures into five patterns: Pattern 1: RV-RA-P; Pattern 2: RA (AD)-RV-RA (PD)-P; Pattern

3: RA (AD)-RV-P-RA (PD)-RV (PT); Pattern 4: RV-RA (AD)-P-RA (PD); and Pattern 5: RA (AD)-RV-P-RA (PD). (RA=renal artery, RV= renal vein, P= pelvis, AD= anterior division, PD= posterior division, AT= anterior tributary, PT=posterior tributary) [8]. Kumar N et al., observed 12 patterns of arrangements [9]. The present study has demonstrated 10 patterns of Hilar arrangements. The majority of specimens showed 41.88% of the classical arrangement of hilar structures, i.e., the VAP pattern, which was found to be more prevalent on the left-side (23.12%). The classical pattern was followed by the VAPA pattern (17.50%), which was more common on the right-side (10%) [Table/Fig-14] [7-9, 10-12].

Hilar- structure arrangement pattern (antero- posterior)	Joao A et al., [7] (2009) (Brazil)	Trivedi S et al., [8] (2011) (MP-India)	Naveen Kumar et al., [9] (2013) (South India)	Divya C et al., [10] (2018) (South India-Karnataka)	Chabra N [11] (2020) (UP-India)	Trivedi S et al., [12] (2023) (North India-Raipur)	Present study (North East India)
VAP	83%	19%	45.8%	32%	25.5%	9.3%	41.88%
AVP	3%	NA	28.1%	3%	5%	NA	15.3%
VAAP	NA	8%	NA	8%	5.9%	22%	3.13%
A-VAP	NA	23%	2.1%	14%	13.7%	41%	2.50%
V-AVP-A	NA	NA	NA	2%	9.8%	NA	0.63
VAPA-V	NA	NA	2.1%	2%	NA	NA	1.88%
VAPA	NA	20%	8.3%	12%	15.7%	3.4%	17.50
AVP-A	NA	8%	4.2%	8%	17.6%	NA	14.38
V-P-A	3%	NA	2.1%	2%	NA	NA	0
AVP-V	NA	NA	3.1%	NA	NA	NA	0
V-A-VAP	NA	NA	NA	3%	NA	NA	0.63%
AVP-A-V	NA	NA	1%	9%	NA	NA	1.25%

[Table/Fig-14]: Showing pattern of arrangement of hilar structures [7-9,10-12].

In comparison to other studies, the authors observed that the hilar structures in the majority of specimens were arranged in a VAP pattern (41.88%), which is similar to the findings of previous studies conducted by Joao A et al., (2009), Kumar N et al., (2013), and Divya C et al., (2018) [7,9,10]. This was followed by the VAPA pattern (17.50%), as described in standard anatomy textbooks [1]. However, present findings do not align with those of Trivedi S et al., (2011) and Chabra N (2020) [8,11]. The V-A-VAP pattern (0.63%) observed in the present study was the least common variety, previously reported only by Divya C et al., (3%) [10]. Other patterns, such as VAPA-V were found in 1.88% of cases, as reported by Naveen K et al., Divya C et al., who noted frequencies of 2.1% and 2%, respectively [9,10]. The findings of Trivedi S et al., such as A-V-AVP (26.3%) and VAP-V-A (30.3%), were not observed in the present study [12]. The author reported that A-VAP was the most common pattern at 41%, while in this study found it to be only 2.5%.

It was observed that the arrangement of hilar structures was highly variable compared to standard textbooks. Knowledge of variations in hilar arrangement is a crucial prerequisite for any procedure in this field. The variant anatomy of the hilum may pose challenges for urologists when clamping the vessels during laparoscopic nephrectomy and renal transplantation, as well as for radiologists in interpreting radiological imaging and renal angiograms. Rouviere O et al., reported that 29-65% of cases of ureteropelvic obstruction were caused by anomalous courses of the renal vessels that crossed the renal pelvis in their study [14]. It is advisable to make a lateral deep incision alongside the ureteropelvic junction rather than approaching its anterior or posterior aspects during endopyelotomies if there is an anomalous hilar structural arrangement [15]. Dissection and ligation of the renal hilar structures are the most important steps in laparoscopic procedures. Ligation/clamping of the renal vein and artery separately are preferable to the en bloc approach, as the latter may lead to the development of arteriovenous fistulas and massive haemorrhage as surgical complications later on. Difficult hilar dissection may result in the conversion of a laparoscopic operation to an open procedure [16].

The pathologies affecting the kidneys, such as calculi, renal carcinoma, and renal failure, often requires surgical interventions. Understanding these conditions can help surgeons identify potential anatomical variations that may be encountered during laparoscopic partial nephrectomy and renal transplant procedures. Knowledge of these variations benefits not only surgeons but also radiologists, as it enables them to make more accurate interpretations of renal angiography.

Limitation(s)

As this is a hospital-based cadaveric study, it has certain limitations. The authors conducted the study over a one-year period and attempted to collect as many samples as possible within that short timeframe. A more detailed study with a larger number of samples may be necessary to identify additional anatomical variations in this region.

CONCLUSION(S)

The present study concluded that the arrangement of structures present in the renal hilum exhibits a wide spectrum of variations in the North East region of India. Only 41.88% of the cases showed the classical pattern (VAP), while the others displayed variations. Renal vascular accidents during surgical procedures may pose an immediate threat to a patient's life. Therefore, a proper understanding of both normal and variant anatomy of these structures is a key to ensuring safe radiological and urological interventions.

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