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Original Research Article

Renal artery variants: a comprehensive cadaveric comparative study using morphological and corrosion casting technique

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ABSTRACT

Background: Kidneys, crucial excretory organs, receive substantial blood supply through renal arteries. Variations in their anatomy are common, warranting detailed investigation. This study aims to comprehensively examine renal artery patterns using both gross dissection and the corrosion cast method.
Methods: Thirty kidney pairs from cadavers were meticulously dissected at Subharti Medical College, Meerut, U.P. India. Gross features were carefully noted, and corrosion casts were meticulously prepared. Prevalence, origin, level, division, course, and variations were exhaustively recorded to provide a thorough understanding of renal vascular anatomy.
Results: Main renal arteries were found to predominantly originate from the abdominal aorta in all specimens. Interestingly, a higher prevalence of origin of right renal arteries was observed, with 47% exhibiting a higher origin than their left counterparts. Further analysis revealed prehilar division in 38.3% and hilar division in 61.6% of specimens. Notably, a segmental pattern of renal arteries was observed. Accessory renal arteries (8%) were identified, including rare occurrences of bilateral and double accessory renal arteries. Of particular significance was the observation of an accessory renal artery passing anterior to the inferior vena cava, highlighting the intricacies of renal vascular variations.
Conclusions: While reaffirming the conventional understanding of renal arterial anatomy, this study emphasizes the complexity and clinical relevance of variations in renal artery morphology. Such detailed insights are invaluable for surgical and radiological practice, underlining the importance of meticulous preoperative assessment to optimize patient outcomes.

Keywords: Kidneys, Corrosion casts, Abdominal aorta, Renal artery, Accessory renal artery, Anterior and posterior

INTRODUCTION

The renal artery arises from the lateral, anterolateral or posterolateral aspect of the abdominal aorta immediately below the origin of superior mesenteric artery at the level of first lumbar vertebra. The right and left renal arteries may arise at the same or at different levels. The right artery is often higher and passes behind inferior vena cava. The left renal artery usually runs horizontally or even slightly upwards. The renal artery divides into anterior and posterior divisions anywhere between the aorta and the renal hilum or even inside the sinus, and further subdivides into segmental arteries supplying renal vascular segments. Most of the abnormalities of the renal arteries are due to changing positions of the kidney as a part of its normal development and ascent.

Accessory renal arteries most commonly arise from abdominal aorta but they may also arise from relatively small suprarenal arteries or gonadal arteries. Accessory renal arteries are important to the clinicians and surgeons. Additional renal arteries play a role in causing hydronephrosis. Dhar state that in the study of renal arteries on the kidneys in forty cadavers, they found that the accessory renal artery when present, invariably crossed the anterior aspect of the ureter.[1] Gulas et al state that inferior polar accessory renal artery running anterior to the ureter at the pyelo-ureteral junction, may obstruct the ureter which can lead to hydronephrosis. Hence, they cannot be ignored.[2]

The presence of renal artery variations may cause complications in surgical procedures such as kidney transplantation. Sungura et al state that knowledge about early branching of the renal artery is vital in renal transplantation as surgeons need at least 1.5-2.0 cm length of main renal artery trunk before branching for effective arterio-arterial anastomosis.[3] Graves made corrosion casts of renal vessels of more than thirty specimens and laid down the concept of the segmental blood supply to the kidneys.[4] Ajmani studied intrarenal arterial segments of human kidney by the corrosion cast method on 100 kidneys and state that presence of accessory renal artery is a rare occurrence (about 2%).[5] Longia et al studied 100 kidneys by corrosion cast method and observed that the abnormal origin of renal artery is rare i.e. only 3 percent.[6]

Corrosion casting is a technique in which injection of plastic material is made into blood vessels or hollow viscera and the tissue is immersed in some caustic substance. This leads to a solid copy of the enclosed space of that tissue. Corrosion casting is a very significant method which allows three-dimensional visualization of blood vessels. Cellulose acetate butyrate used in this study has low viscosity and less shrinkage. It is resistant to corrosion by acid.

The objective of this study was to investigate the morphological variations of renal arteries through cadaveric examination and corrosion casting technique. The study aimed to document the prevalence, origin, course, and distribution of renal arteries, including any accessory renal arteries, and to provide a detailed understanding of these variants. By employing corrosion casting, the study seeks to create three-dimensional visualizations of the renal vasculature to facilitate a comprehensive examination of the renal arterial anatomy. This study aimed to contribute to the existing knowledge of renal artery variations, which is crucial for clinicians and surgeons, particularly in the context of surgical procedures such as kidney transplantation where precise anatomical knowledge is essential for successful outcomes. Additionally, the study aimed to build upon previous research in the field by incorporating both morphological examination and corrosion casting technique, ensuring a thorough and detailed analysis of renal artery variants.

METHODS

This study was an observational anatomical study as it focused solely on observing and recording anatomical features. As per the institutional guidelines, ethical approval was not required as the study was an observational cadaveric study. Sample size: 60 (thirty pairs) cadaveric human kidneys.

Thirty pairs of cadaveric human kidneys were collected from Anatomy department, Subharti Medical College, Meerut, Uttar Pradesh, India, during routine anatomy dissections for undergraduate medical students over a period from September 2019 to October 2023. They were removed with the associated segments of abdominal aorta, inferior vena cava and renal vessels. The details of gross anatomy of renal arteries of all the specimens were observed and relevant data was collected.

Inclusion and exclusion criteria

Kidneys having associated segments of abdominal aorta, inferior vena cava, and renal vessels and specimens suitable for corrosion casting technique were included. Specimens with significant damage or deterioration affecting the integrity of the associated vessels and kidneys presenting with malformations were excluded.

Twenty percent stock solutions of red-colored granules of cellulose acetyl butyrate were prepared by dissolving them in acetone. They were stored in air-tight glass jars for 12 hours for these stock solutions to develop uniform consistency. The kidneys were thoroughly washed in running tap water for about one hour. Then they were flushed with water through a cannula inserted into the upper part of the abdominal aorta whose lower end had been ligated. Then, the blood clots were removed by injecting warm normal saline through the ligated cannula.

Quantities ranging from 25 to 50cc of the red cellulose acetyl butyl butyrate solution were injected slowly with pressure into the upper end of abdominal aorta by a 10cc. syringe fitted with a wide bore cannula. Both the cut ends of the aorta were tightly tagged. These infused specimens were submerged for 72 hours in covered trays containing 10% formalin. The formalin was decanted off and kidneys were decapsulated.

The decapsulated specimens were very carefully immersed into glass jars containing conc. hydrochloric acid and allowed to stay undisturbed for a period of one week. This macerated the renal tissue without least affecting the solidified renal arteries. Each individual cast thus obtained was immersed in 50% glycerin for about half an hour. Relevant observations were made. Patterns and variations of renal arteries were studied, and data was analyzed.

RESULTS

The extra renal course and variations of the renal arteries were studied in 30 pairs of kidneys by both morphological and corrosion casting methods.

Main renal artery

Prevalence of renal arteries (Table 1): In 55 specimens (92%) each kidney had a single large renal artery. In 4 specimens (6.6%) double renal artery and in one specimen (1.6%) triple renal arteries were observed. Origin of renal arteries: In all thirty pairs of kidneys that were studied, main renal arteries arose from lateral aspect of abdominal aorta both on right and left sides. Level of origin of renal arteries (Table 1): the comparative level of origin in right and left renal arteries showed variations.

Table 1: Prevalence and comparative level of origin of renal arteries.

Parameters						
Prevalence of renal arteries						
Number	**Right**		**Left**		**Total**	
	N	**%**	**N**	**%**	**N**	**%**
Single	27	45	28	46.6	55	92
Double	3	5	1	1.6	4	6.6
Triple	-	-	1	1.6	1	1.6
Comparative level of origin of renal arteries						
Level			**Frequency, N=30**	**%**		
Right renal artery at higher level			14 Pairs	47		
Left renal artery at higher level			12 Pairs	40		
Both at the same level			04 Pairs	13		

Table 2: Site of division of renal arteries and prevalence of accessory renal arteries.

Parameters		
Site of division of renal arteries		
Site of division	**N**	**%**
Extrarenal (between hilum and aorta)	23	38.3
Intrarenal (in hilum)	37	61.6
Prevalence of accessory renal arteries		
Type of renal artery	**Frequency, N=60**	**%**
Single main renal artery	55	92
Accessory renal artery	05	8

Right and left renal arteries had the same level of origin from the abdominal aorta in 4 pairs of specimens (13%). Higher level of right renal artery was present in 14 pairs of specimens (47%). Higher level of left renal artery was present in 12 pairs of specimens (40%). So, there was an increased frequency of higher right renal arteries than the left renal arteries. Site of division of renal arteries (Table 2): Pre-hilar division (between hilum and aorta) of renal artery into anterior and posterior divisions was observed in 23 specimens (38.3%), while hilar division was present in 37 specimens (61.6%).

Accessory renal artery

Total and side prevalence of accessory renal artery (Table 2-3): Accessory renal artery was found in 5 specimens (8%), three specimens on right side (5%) and two specimens on left side (3.3%). One pair of kidneys had bilateral accessory renal arteries: one on right side and two on left side.

Table 3: Prevalence of side and types of accessory renal arteries.

Parameters			
Prevalence of side of accessory renal arteries			
Side	**Right**	**Left**	**Total**
N	3	2	5
%	5	3.3	8
Types of accessory renal arteries			
Type	**N**	**%**	
Superior polar	2	3.3	
Inferior polar	3	5	

The right accessory renal artery, going to inferior pole and two accessory renal arteries on left side, one going to hilum and other to inferior pole of left kidney (Figure 1). Origin of accessory renal artery: Three right and two left accessory renal arteries arose from the abdominal aorta. Types of accessory renal artery (Table 3): Two types of accessory renal arteries (superior and inferior polar) were found in the study.

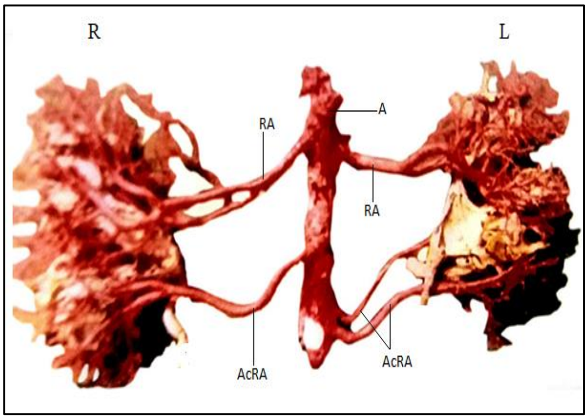

Figure 1: Corrosion cast of renal arteries showing accessory renal arteries on both sides arising from abdominal aorta; Right accessory renal artery going to inferior pole and two accessory renal arteries on left side, one going to hilum and other to inferior pole of left kidney (R-right kidney, L-left kidney, A-abdominal aorta, RA-main renal artery, AcRA-accessory renal artery).

Table 4: Number and course of accessory renal arteries.

Parameters						
Number of accessory renal arteries						
Number	**Right**		**Left**		**Total**	
	N	**%**	**N**	**%**	**N**	**%**
Single	3	5	1	1.6	4	6.6
Double	-	-	1	1.6	1	1.6
Course of accessory renal arteries						
Course			N	%		
Behind inferior vena cava			4	6.6		
In front inferior vena cava			1	1.6		

Superior polar arteries were two in number (3.3%) and inferior polar arteries were three in number (5%). Number of Accessory renal arteries (Table 4): In four specimens (6.6%)), single accessory renal artery was seen, three (5%) on right side and one (1.6%) on left side. Double accessory renal artery was seen in one specimen on left side (1.6%)**.** Course of accessory renal arteries (Table 4): In four specimens (6.6%) accessory renal arteries from abdominal aorta passed posterior to the inferior vena cava to reach the hilum of the kidney. One accessory renal artery on right side (1.6%) was found to be passing in front of inferior vena cava to reach the hilum of the right kidney.

DISCUSSION

The present study delves into the intricate variations of renal artery morphology through the utilization of both conventional dissection techniques and the innovative corrosion casting method.

Table 5: Comparative study of number and site of division of renal arteries.

Parameters				
Comparative study of number of renal arteries (%)				
Number of renal arteries	Khamanarong et al[7]	Natsis et al[8]	Ephraim[9]	Present study
Single	82	83	88	92
Double	17	13	12	6.6
Triple	1	4.3	0	1.6
Comparative study of site of division of renal arteries				
Site of division	Ajmani[5]	Longia et al[6]	Ogeng'o et al[10]	Present study
Prehilar (between hilum and aorta)	68	71	21.6	38.3
Hilar (in hilum)	14	11	76.4	61.6
Intrarenal	18	16	2	Nil

Table 6: Comparative study of prevalence of accessory renal arteries.

Studies	%
Ajmani[5]	2
Satyapal et al[16]	27.7
Bude et al[11]	22
Gupta[17]	24
Dhar[1]	20
Saldarriaga et al[18]	24.90
Ogeng'o et al[10]	14.3
Kapoor et al[12]	12
Palmieri et al[13]	61.5
Ephraim[9]	28
Ramulu[19]	24
Patra et al[14]	33.75
Jamkar et al[20]	24.99
Zainel[21]	26.3
Arasu et al[15]	36
Present study	08

Main renal arteries

Number of Renal arteries (Table 5): Single renal artery was present in 92% specimens in the present study which correlates with studies by Khamanarong et al, Natsis et al and Ephraim.[7-9] Double renal arteries were seen in 6.6% specimens in the present study which correlates with studies done by Natsis et al and Ephraim.[8,9] In the present study,1.6% of specimens had triple renal artery, compared to, 1% by Khamanarong et al and 4.3% by Natsis et al studies.[7,8] Level of origin of renal arteries: Right renal artery had a higher origin from abdominal aorta in 47% of specimens as compared to 40% higher origin of left renal artery in the present study. Ephraim observed high right renal artery in 75%, high left renal artery in 15% and in 10% specimens both renal arteries arose at the same level which does not correlate with present study.[9]

Site of division of renal artery (Table 5): The most prevalent pattern (61.6%) in the present study was the hilar division of the renal artery into anterior and posterior divisions, which corresponds with 76.4% as noted by Ogeng'o et al. In Ogeng'o et al study, 21.6% specimens showed prehilar division corresponding with 38.3% of the present study.[10] According to the study of Ajmani and Longia et al the most prevalent pattern was prehilar division of renal artery into anterior and posterior divisions which does not correlate with present study.[5,6] In the present study no intrarenal division of renal arteries was seen which does not correlate with studies done by Ajmani, Longia et al and Ogeng'o et al.[5,6,10]

Table 7: Comparative study of number and prevalence of side of accessory renal arteries.

Parameters						
Comparative study of number of accessory renal arteries (%)						
Number of accessory renal arteries	Satyapal et al[16]	Jamkar et al[20]	Present study			
Single	23.2	20.75	6.6			
Double	4.5	4.24	1.6			
Prevelance of side of accessory renal arteries (%)						
Side	Satyapal et al[16]	Ozkan et al[23]	Patra et al[14]	Sangura et al[3]	Sangura et al[21]	Present study
Right	23.3	16	30	4.97	20.7	5
Left	32	13	37.5	7.4	32.1	3.3

Table 8: Comparative study of source of origin of accessory renal arteries.

Source of origin	Talovic et al[23]	Ephraim[9]	Patra et al[14]	Present study
Aorta	30.76	15.6	23.75	08
Main renal artery	12.82	7.8	8.75	Nil
Superior mesenteric artery	Nil	Nil	1.25	Nil

Table 9: Comparative study of symmetry and types of accessory renal artery.

Parameters				
Comparative study of Symmetry of Accessory renal artery				
Symmetry of accessory renal artery	Dhar[1]	Ephraim[9]	Zainel[21]	Present study
Unilateral	15	15.6	78.7	5
Bilateral	5	6.2	21.2	3.3
Comparative study of types of accessory renal arteries				
Type of accessory renal artery	Bordei et al[25]	Çicekcibasi et al[24]		Present study
Superior polar artery	9.25	3.33		3.3
Inferior polar artery	29.62	10.5		5

Accessory renal arteries

The presence of accessory renal arteries, though found in a modest percentage holds significant clinical relevance. Prevalence of accessory renal arteries (Table 6): The current study found that the prevalence of accessory renal arteries was 8%, which is consistent with findings from Dhar (20%), Ajmnai (2%), Ogeng'o et al (14.3%), Bude et al (22%) and Kapoor et al (12%).[1,5,10-12] Palmieri et al, Patra et al and Arasu et al reported high prevalence of accessory renal arteries.[13-15] Satyapal et al, Saldarriaga et al and Ramulu observed moderate prevalence of accessory renal arteries.[16-19]. Number of Accessory renal arteries (Table 7): Single Accessory renal artery was observed in 6.6% of specimens in the present study, which does not correlate with studies by Satyapal et al and Jamkar et al. In the present study, 1.6% of specimens had double renal arteries, which correlates with observations done by Satyapal et al and Jamkar et al.[16,20] Prevalence of side of accessory renal arteries (Table 7): The current study found that 5% of specimens had right-sided accessory renal arteries and 3.3% had left-sided accessory renal arteries which is not consistent with the studies by Patra et al Satyapal et al, Zainel and Ozkan et al.[14,16,21,22] The present study is related to the research conducted by Sungura.[3]

Source of origin of accessory renal arteries (Table 8): The current study found that all accessory renal arteries originated from the aorta and that no accessory renal arteries originated from the main renal artery which is inconsistent with previous research by Ephraim, Patra et al and Talovic et al.[9,14,23] Symmetry of accessory renal arteries (Table 9): In the present study, unilateral accessory renal artery was seen in 5% of specimens which is not in accordance with the studies conducted by Dhar et al, Ephraim et al and Zainel et al.[1,9,21] Bilateral accessory renal artery was seen in 3.3% specimens which correlates with studies done by Dhar et al and Ephraim et al.[1,9] Types of accessory renal arteries (Table 9): The superior and inferior polar arteries were the two types of accessory renal arteries that were found in this study. 3.3% specimens had superior polar arteries, while 5% of the specimens had inferior polar arteries which is consistent with research by Cicekcibasi et al, Bordei et al observed high prevalence of inferior polar arteries.[24,25] Hilar accessory renal arteries were not found in the present study. The comprehensive analysis of 30 pairs of cadaveric human kidneys has provided valuable insights into the prevalence, origin, course, and symmetry of main renal arteries and accessory renal arteries. These findings have crucial implications for clinicians, surgeons, and researchers, especially in the context of renal transplantation, urological surgeries, and understanding the developmental dynamics of the renal vasculature.

Clinical implications

The anterior course of accessory renal arteries in relation to the ureter, as reported by Dhar underscores the potential implications for complications such as hydronephrosis.[1] Gulas et al corroborate these findings, emphasizing the obstructive potential of inferior polar renal arteries.[2] Such insights are invaluable for clinicians, enabling them to anticipate and navigate potential challenges in urological procedures. Moreover, the knowledge about early branching of the renal artery, as emphasized by Sungura, is critical in renal transplantation, where effective arterio-arterial anastomosis requires a minimum arterial length.[3] To provide a clearer understanding of the observed variations, a comparative analysis with previous studies, such as those conducted by Ajmani et al and Longia et al is essential.[5,6] The low incidence of abnormal renal artery origins reported in these studies emphasize the uniqueness of the present findings. Corrosion casting, as utilized in this study, has proven to be a valuable technique, enabling detailed three-dimensional visualization of arteries and facilitating a deeper comprehension of renal vascular patterns.

Limitations

While the present study provides valuable insights into renal artery variations through detailed anatomical examination and corrosion casting techniques, several limitations should be acknowledged. Firstly, the study's reliance on cadaveric specimens collected over a specific timeframe from a single institution may limit the generalizability of the findings. Variation in cadaveric specimens, such as differences in age, sex, and underlying health conditions, could also influence the observed patterns of renal artery morphology. Additionally, the study's retrospective design and reliance on observational methods may introduce inherent biases and limit the ability to establish causality or infer temporal relationships. Future studies incorporating prospective data collection and larger sample sizes, along with longitudinal follow-up, could provide a more robust understanding of the clinical significance of renal artery variations and their impact on surgical outcomes.

CONCLUSION

In conclusion, the findings from this study shed light on the intricate variations in renal artery morphology, emphasizing the need for meticulous preoperative assessment and surgical planning. The incorporation of corrosion casting techniques has provided a nuanced perspective, allowing for a comprehensive understanding of renal vascular patterns. The knowledge gleaned from this study not only enhances our anatomical understanding but also serves as a foundational resource for clinicians and surgeons, ensuring optimal outcomes in renal-related surgeries. As we move forward, continuous research in this realm will further refine our knowledge, paving the way for enhanced patient care and improved surgical techniques.

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