Research Article

Prevalence of Anatomical Variant Renal Arterial Diameter, Early Prehilar Branching and Multiplicity on Contrast Enhanced Computed Tomography Scans

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Abstract |

Background: Chronic kidney disease is a widespread condition that significantly contributes to the global disease burden, especially in South Asia and particularly in Pakistan.

Objective: To find out the prevalence of anatomical variations of renal arteries in terms of vessel luminal diameter, early pre-hilar branching, multiple renal arteries, their laterality, and any potential correlation with gender within our population.

Methods: This was an observational, cross-sectional study using non-probability consecutive sampling of contrast-enhanced computed tomography scans of male and female subjects in age range from 18 to 80 years, with no known renal or vascular disease, conducted at the Radiology Department of Combined Military Hospital, Lahore.

Results: The study analyzed 300 contrast-enhanced computed tomography scans, including 167 (55.7%) male and 133 (44.3%) female subjects. The mean value of luminal diameter of renal artery was 6.44±1.41 on right and 6.54±1.54 on left, but not significant association with laterality or gender. Pre-hilar branching was noted in 89 (29.8%) of subjects on the right renal artery and 144 (48%) subjects on the left renal artery. Prehilar branching in males was 58(34%) for right and 92(55%) for left side, while in the females it was 31(23%), for the right and 52(39%), for the left side. A statistically significant correlation between gender and pre-hilar branching on both the right (p = .035) and left (p = .006) sides. Bilateral prehilar branching in 61(20%) of total patients, 37(60.6%) being male and 24(39.3%) females. A supernumerary renal artery was present in 35(11.6%) of total with 17 (5.6%) in right renal and 18 (6%) in the left renal vasculature, and 22(7.3%) in males and 13(4.3%) in females (p=0.788).

Conclusion: The study showed variations in the renal artery caliber, branching pattern and the existence of accessory renal arteries within our local population. The most common variation was Presence of prehilar branching with statistically significant association with left renal artery and male gender in our study population.

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Introduction

Chronic kidney disease is a widespread condition that significantly contributes to the global disease burden, especially in South Asia and particularly in

Pakistan. Globally, Chronic Kidney Disease ranks as the 12th main reason of death, accounting for 1.2 million deaths in 2017.[1]

Presently, chronic kidney disease is impacting 10-16% of the global adult population. The global prevalence of the disease is on the rise, with kidney diseases ranking as the 9th major fatal illnesses in America, resulting in a total expenditure exceeding 47.5 billion dollars in 2010.[2,3] Chronic kidney disease prevalence in Asia ranges from 10-18%, a figure comparable to other regions globally.[4] According to a local study, chronic kidney disease was identified in 25% of the subjects, indicating a significant prevalence in the examined population.[5]

Anatomically, kidneys are paired lentil-shaped reddish-brown organs located retroperitoneally along the abdominal wall. Normally a unit renal artery, nourishing each kidney stems as a lateral visceral branch of the abdominal aorta. Numerical as well as structural variations in renal arteries have been extensively documented. About 30% of individuals exhibit more than one renal artery.[6]

During embryonic development, early formed pelvic kidneys migrate to their adult location in the lumbar region, receiving blood supply from multiple mesonephric arteries. These arteries regress from caudal to cranial regions, with the persistence of only one mesonephric artery being common. Anomalies in renal artery development can occur if regression fails, resulting in variant origins and numbers of renal arteries.[7]

Knowledge of Renal arterial diameter variations is mandatory for any vascular anastomosis or renal graft fixation. Moreover, changes in caliber can occur due to advancing age or with gender or other chronic diseases that affect vascular wall. A prerequisite understanding of renal vascular variations holds clinical significance for transplant surgeons, vascular surgeons, and interventional radiologists.[8]

In instances where a kidney features multiple arteries originating from distinct points in the aorta, the main renal artery is determined by its larger diameter, while the additional arteries are termed supernumerary.[9] Accessory renal artery can be categorized as either hilar, if it enters through the hilum of the kidney, or polar, if entry is through the superior or inferior renal poles.[10] Renal arteries, whether located outside the hilum or entering through the capsule, demonstrate early pre-hilar branching, if they divide into their terminal segmental branches, occurring within 1.5-2 cm from the origin of the primary renal ostium in the case of left renal artery, or within the retrocaval segment in the right renal artery.[11]

Presently, Multidetector-row Computerized Tomographic (MDCT) angiography is a pivotal scanning tool used for study of vascular alterations and variations in morphology.[12,13]

The objective of this study was to determine the prevalence of variations in the morphology of renal arteries in terms of luminal diameter, accessory renal arteries, and pattern of pre-hilar branching of renal arteries. The study also aimed to investigated the laterality, and correlation with gender, of renal artery variants.

Methods

This study was performed in the Departments of Radiology and Anatomy, CMH Medical College, Lahore. The study was conducted from April, 2022 to April, 2023 after the approval of Institutional Ethical Committee (680/ERC/LMC, dated 08-04-22). Consecutive sampling method was used for data collection.

All adult patients aged between 18 to 70 years from both genders, referred for CECT abdomen for various clinical indications who consented to the study were included in the study. The patients with history of renal disease, surgery, transplant or kidney donation, or any vascular pathology or with allergy to contrast agent were excluded from the study.

All those cases with kidney transplant, renal vascular disease or surgery, congenital vascular anomalies, history of allergic reaction to contrast agent, pregnancy, hypertension and diabetes mellitus were not included in the study.

The sample size obtained (300) by applying the statistical formula (N = Z^2 × (P(1-P)) / C^2.)14, with a 95% confidence interval, a margin of error of 5%.

A CT scan was conducted using SIEMENS HEALTHINEERS 128-slice MDCT scanner following a standard CT scan protocol. Prior to the scan, patients were required to be empty stomach for six hours. Contrast material was injected intravenously through an intravenous line placed in the antecubital vein. The contrast dye was

given in a dose of 2ml/kg body weight at a rate of 4 ml/sec.

The imaging included area between costal line of attachment of diaphragm to the level of iliac crest. Image data was acquired 10 to 15 seconds after the start of the contrast dye injection. The image data was then shifted to an imaging workstation from Toshiba Hospital Management Systems. Specialized computer software, Radiant DICOM, was utilized for three-dimensional reconstruction of images in various planes and projections during the arterial phase of the scan. Reconstructed, multiplanar images, were employed to evaluate the renal arteries.

Mean diameter of the renal artery was scaled in the initial segment (1.5 cm from origin) of the vessel from its source artery.[15] In case of more than one renal artery, the vessel with maximum diameter was taken as main renal artery and the other classified as accessory renal arteries. Accessory renal arteries were further grouped as being superior / inferior polar or hilar depending upon their presence along upper or lower poles or hilum of kidney. Early prehilar branching was described to be division of main renal artery 1.5cm away from hilum of kidney.

Demographic data like gender, age and presenting reasons for MDCT angiography were recorded. Variables such as the diameter, accessory renal artery and prehilar branching pattern for both right and left renal arteries were recorded.

Data analysis was performed using SPSS version 26. Quantitative variables were described using frequency, mean, and standard deviation. Comparisons of quantitative variables were made using t-test. Pearson's correlation was utilized to assess the relationships between variables. A p-value of less than 0.05 was considered statistically significant. The evaluation of supernumerary renal arteries by side and gender was carried out using Chi-square analysis.

Results

The study analyzed multiplanar reconstructed, contrast-enhanced computed tomography scans of 300 patients, who presented to the Radiology department of CMH Lahore with various indications. There were 55.7% (167) male patients and 44.3% (133) female patients. Ages of the patients were between 18 and 80 years (51.87 ± 17.01 being mean age), with 120 (40%) falling below 50 years and 180 (60%) above 50 years of age.

The renal arteries were evaluated for the main luminal diameter, evidence of early prehilar branching and presence of accessory renal arteries on the two sides in both genders and then compared amongst the genders and sides for any significant or otherwise correlation. The proximal segment (1.5 cm from origin) of the renal artery was selected to measure the luminal diameter, in the arterial phase in the transverse plan.

Mean lumen diameter for right renal artery was 6.44± 1.41 with a range from 1.9 to 11.4mm and it was 6.54±1.54 with a range of 2.1 to 10.6mm for the left renal artery. Mean right renal artery in female was 6.57±1.47 and in males 6.73±1.58. Mean left renal artery diameter in male was 6.73 while the same in female was 6.30. There was statistically non-significant difference between mean renal artery diameter of the two sides as well as

Table 1: *Renal artery diameter on right and left side.*

	Mean	Std. Error of Mean	Median	Std. Deviation	Minimum	Maximum
-Dm* (mm)	6.441	.0818	6.350	1.4163	1.9	11.4
Lt-Dm* (mm)	6.544	.0894	6.400	1.5486	2.1	10.6

**RT-Dm-right diameter, *Lt-Dm-left diameter*

Table 2: *Variation of renal diameter with gender*

	GENDER					
	Male n=167			Female n=133		
	N	Mean	Std. Deviation	N	Mean	Std. Deviation
Rt-Dm* (mm)	167	6.571	1.4772	133	6.277	1.3232
Lt-Dm* (mm)	167	6.739	1.5852	133	6.300	1.4711

**Rt-Dm-right diameter, *Lt-Dm-left diameter*

between the two genders. Table-1& 2.

Branching of the main renal artery into its segmental branches 1.5 centimeter away from the hilum was considered as Early prehilar branching. Figure-1.

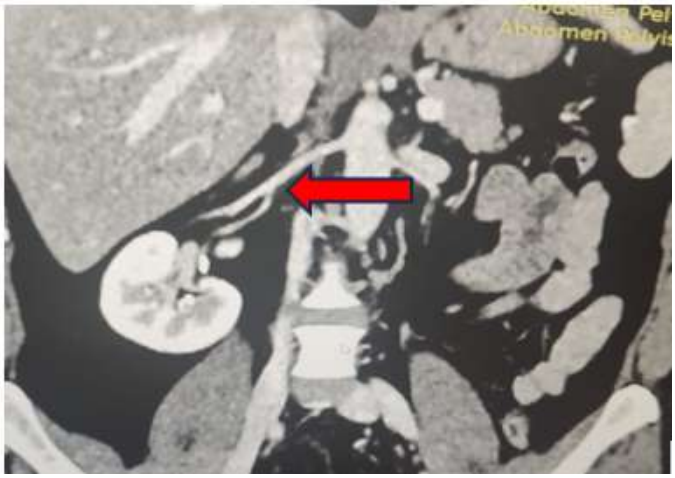

Figure-1. *Contrast-enhanced computed tomography scan revealing early prehilar branching on the right side.*

Overall early prehilar branching was found in 38.83% of study population (n=300). Early pre-hilar branching was observed in the right renal artery in 89 (29.8%) of cases, and in the left renal artery in 144 (48.0%) of cases. There was statistically significant association of prehilar branching with left renal artery (p=0.029). Prehilar branching was observed in males as 58(34%) for right and 92(55%) for left side. While in the female group it was observed to be present in the right and left renal vessel to be 31(23%) and 52(39%) respectively. The research identified a statistically significant correlation between gender and pre-hilar branching on both the right (p = .035) and left (p=.006) sides. Bilateral prehilar branching was observed in 61(20%) of total patients, out of which 37((60.6%) being male and 24(39.3%) in female cases, however not statistically significant. Table-3.

Table 3: *Showing prehilar branching variation frequency and association with sides and gender.*

Variations	laterality		P-value	Gender Distribution		P-value
Prehilar branching N=300	Right	89 (29.8%)	0.029	Male 167(n)	58(34%)	0.035
	Left	144 (48%)		Female 133(n)	31(23%)	
				Male 167(n)	92(55%)	0.006
				Female 133(n)	52(39%)	

Normally each kidney is supplied by a single renal artery branching from abdominal aorta. If there are two or more arteries, the arteries with smaller diameter than main artery, and arising separately from the aorta are taken as accessory renal arteries. Accessory renal arteries reach the kidney parenchyma along upper or lower poles or through hilum; so they are accordingly grouped into polar or hilar arteries. Figure-2

Figure- 2. *Contrast-enhanced computed tomography scan illustrating dual renal arteries on the right side.*

Among males, 157 participants (94.0%) did not have a Right-accessory, while among females, 126 participants (94.7%) did not have a Right-accessory. Overall, 283 participants (94.3%) did not have an accessory right renal artery.

The right accessory artery was reported in 10(6.0%) male and 7(5.3%) female patients, making a total of 17 participants (5.7%) with an accessory renal vessel, and showed a negligible correlation, with approximate significance levels of 0.788.

Out of total 300 patients 155 males (92.8%) and 127 females (95.5%) did not have a Left-accessory renal artery. In total, 282 participants (94.0%) did not have a Left-accessory, and 12 males (7.2%) and 6 females (4.5%) had a Left-accessory, resulting in a total of 18 participants (6.0%) with a Left-accessory renal artery.

The Pearson chi-square value was 0.939 with 1 degree of freedom. The analysis reveals no significant association between gender and an accessory renal artery on left.

The presence of accessory renal artery was not observed to have any significant association with gender for both sided renal arteries (p > .05)

Table 4: *Frequency of accessory renal arteries and Association with laterality and gender.*

	Total N (300)	Male N (167)	Female N (133)	Types of accessory renal artery	TOTAL N (35)	Male N (22)	Female N (13)	P-value
Accessory renal artery	35(11.66%)	22(13.17%)	13(9.77%)	Superior polar	13(37%)	9(40%)	4(30%)	0.496
				Hilar	12(34%)	9(40%)	3(23%)	
				Inferior polar	11(31%)	4(18%)	7(53%)	
Right accessory renal artery	17(5.66%)	10(6%)	7(5.3%)	Superior polar		2(1.2%)	2(1.5%)	0.788
				Hilar		7(4.2%)	3(2.3%)	
				Inferior polar		1(0.6%)	2(1.5%)	
Left accessory renal artery	18(6%)	12(7.2%)	6(4.2%)	Superior polar		7(4.2%)	2(1.5%)	0.205
				Hilar		2(1.2%)	0(00)	
				Inferior polar		3(1.8%)	5(3.8%	

Discussion

This study was conducted on 300 contrast enhanced computed tomography scans of abdomen of subjects of ages ranging from 18 to 80 years, obtained consecutively in the radiology department of Combined Military Hospital. In this way in 300 patients, we studied 600 renal arteries in both sides.

These scans were reconstructed in multiplanar view and studied for renal arterial pattern. Renal Arterial diameter was measured 1.5cm away from their respective origin and compared on the two sides and for the two genders. The renal arterial variants observed in our study were the early prehilar branching pattern and presence or absence of accessory renal arteries, and the comparison of these observations on both sides as well as between both genders was made.

The average age of patients in our study was 51.87 years. This is lower compared to the study by Cinar et al., which had a mean patient age of 56.4 years. Most participants in this study were between 30 to 60 years old with approximately 20% of the patients under 30 years of age, while we observed that 40% of cases were below 50 years and 60% were above 50 years.[16]

The gender distribution of our patients was 167 (55.7%) male and 133 (44.3%) female. A similar study conducted by Agarwal et al, in India observed male participants 134 (60.54%) and female participants were 39.46%. It may be due to consecutive sampling, the male patients approaching tertiary health care facility is more than female in our part of world due to cultural priorities.[17]

Mean luminal diameter was measured to be 6.44±1.41 mm for the right and 6.54±1.54mm for the left renal artery. Although there was a very slight variation in right and left diameters with diameter slightly large for left renal artery but that was insignificant statistically. Probably retrocaval course of right renal artery is the reason behind this minor variation.

In the male patients, the renal arterial diameter was observed to be 6.57±1.58mm for the right and 6.73± 1.58mm for the left side. Mean right renal artery in female was 6.27±1.32mm and on the right and 6.30±1.47mm on the left. So, the mean diameters were slightly larger in male than female patients but that finding was not statistically significant. Similar findings were reported by Agarwal et al, who has observed more than 66% of both male and female patients with bilateral renal artery diameter between 3-6mm, however another study conducted by Mohiuddin have reported a very thin decline in renal artery diameter probably owing to age related arteriosclerosis.[18]

Early prehilar branching is subdivision of main renal artery stem 1.5cm away from the hilum. This is very important for transplant surgeons, interventional vascular surgeons as a 1.5-2cm stem is required for vascular anastomosis during kidney transplants.

Early pre-hilar branching in this study, was observed to be present in 89(29.8%) of cases in the right renal artery and 144 (48.0%) in the left renal artery and the gender distribution for the right prehilar branching was 34% in male cases and 23% in female cases, whereas left prehilar branching was found in 55% male and 39% female cases. We observed that prehilar branching pattern was more in the male gender and more so in the left renal arteries for both the genders.

Prehilar branching showed statistically significant association with male gender for the right (p=.035) as well

as for the left renal artery (p=.006). So male gender is associated with occurrence of prehilar branching pattern more than female as per our finding.

A recent study from Nepal has reported Prehilar branching to be the main variation that they reported to be 49% in their study population. It was also reported to be more for the right side than left side. This study reported prehilar branching in the female more than male population but the difference was not found statistically significant.[19]

A similar study from India reported early branching to be 21% in left and 15% in right renal artery.[20] These findings are much lower than ours, while in contrast, some other studies found prevalence of early arterial branching to be even lower to only 4% and it was significantly more common on the right than left side.[2] A similar study from neighboring country has reported early division of renal artery in 21.7% of patients, being more in the right renal artery. [22]

The existence of an accessory renal artery, poses major risk during surgical procedures in the area as accessory vessel may be hidden in fascia or fat and can be severed inadvertently and cause hemorrhage.

In our study, we identified, an accessory renal artery in 11.66% of cases, with 5.6 and 6.0 % on the right and left side respectively. We did not observe any significant association between accessory renal artery and sidedness (p=>0.05). In contrast, a comparable study conducted in our own country reported an extra renal artery in 26.4% of cases with 13.8% and 12.6% on right and left sides respectively.[23]

As per gender distribution of accessory renal arteries, it was 13% in male patients and 9.77% in female patients, though the association was not statistically significant.

Accessory renal arteries were subclassified into superior, inferior polar and hilar arteries according to their location, and our study observed mainly the superior polar and hilar types (40% of accessory renal arteries). A similar finding was reported from India, where the superior polar and hilar accessory were found to be 36% and 32% respectively.[24]

Literature has demonstrated, the incidence of accessory renal arteries to fluctuate between 4 to 61% in the Malaysian and Brazilian populations, on the basis of ethnicity. The lowest prevalence was documented in Eastern and South Asian nations (from 4 to 18.4%).[25] Our findings are in concordance with this observation for south Asian population.

The occurrence of a supernumerary renal artery in our studied population contrasts with some findings in other regions across the globe. One such study reportedly detected a supernumerary renal vessel 13.8% on the right and 12.6% on the left side of the subjects. It was also concluded that the prevalence was higher in males at 14.4% compared to females at 12.2%, though this difference was not statistically significant.[19] This finding aligned with a Malaysian study, where the reported incidence was far higher in males (28%) than females (5.1%).[26]

A recent study found out occurrence of accessory renal artery in 41.2% of the subjects (n=231), with statistically non-significant laterality ratio and gender distribution on computed tomography scans. In the literature, the prevalence given between 9 -76% for extra numerary renal arteries, while with the postmortem observations, it is reported to fall between 28 – 30%.[27] This, however, is contrastingly higher than our finding.

So, our finding of renal arterial variations, its laterality and relationship with gender in comparison to rest of the world signifies considerable difference in prevalence due to variable genetic, racial and environmental factors.

This was a single center study, so limited population size was explored. In future the study can be extended to multiple centers, for a larger data base.

Cost of CT scan is another limitation to be conducted on larger population for our financially restrained set up.

Conclusion

We found renal artery variations, early hilar branching (38.83%) and accessory renal arteries (11.66%) in our study population(n=300). The incidence of early hilar division of renal artery was found to be more common than other variations and it was significantly associated with male gender as compared to female and to the left renal artery in comparison to right renal artery. Bilateral prehilar branching (20 % of total) was observed with higher incidence in males.

Prevalence of accessory renal artery (11.6% of total) was higher in the males than females, and higher on the left than right, though not statistically significant. Renal artery diameter was slightly greater in males than females but not significant statistically.

Ethical Approval: The Ethical Review Committee of CMH Lahore Medical College & Institute of Dentistry approved the study vide letter Case #.680/ERC/CMH/LMC.

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Authors' Contribution:

SAJ: Conception & design, analysis & interpretation of data, drafting of article, critical revision for important intellectual content, final approval

TF: critical revision for important intellectual content, final approval

TMM: Analysis & interpretation of data,

UF: Acquisition of data

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