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Original Article

MORPHOMETRIC STUDY OF RENAL VASCULATURE WITH MULTIDETECTOR COMPUTED TOMOGRAPHY

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ABSTRACT

Background

The end-stage renal disease is a public health problem with an increasing incidence rate and preoperative evaluation of renal vessels is important for transplant. The arteries and veins differ in terms of their level of origin, size, obliquity, level of confluence, tributaries, and relationships. The purpose of the study was to examine how common different anatomical variations in the renal vessels are, using Triple phase Contrast Enhanced Computed Tomography (CECT).

Methods

A cross-sectional observational study was conducted. A total of 89 patients undergoing Triple Phase CECT of the abdomen and pelvis who met inclusion criteria were evaluated following ethical clearance from the Institutional Review Board (IRB), NAMS. The number of renal arteries and veins, the diameter of the renal artery, the distance from the renal artery's origin to its first bifurcation, the distance from the inferior vena cava to the confluence of the right renal vein, and the distance between the confluence of the left renal vein and aorta were measured, and descriptive analysis was done.

Results

The prevalence of multiple renal arteries was 39 (43.82%-right kidney: 18 cases, left kidney: 21 cases). Hilar arteries were found in 16 right kidneys and 18 left kidneys, and polar arteries were found in 3 right kidneys and 4 left kidneys. Early renal artery bifurcation was identified in 11 right kidneys and 18 left kidneys. Sixteen kidneys had a double right renal vein, one had a double left renal vein, and one had a triple right renal vein. One kidney had retroaortic left RV whereas 35 right kidneys and 10 left kidneys had late venous confluence.

Conclusion

MDCT is a non-invasive, effective imaging method to evaluate renal vascular anatomy and their variations for preoperative evaluation. It provides exact information regarding renal vasculature and is crucial for preoperative planning in renal surgeries and transplantation. Therefore, this study might contribute information regarding kidneys, renal vasculature and variations and help surgeons to reduce the chance of any surgical complications.

Keywords: *Angiography,* MDCT, Renal Artery

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INTRODUCTION

The end-stage renal disease is a significant public health problem. Renal transplantation from living donor is associated with better survival and quality of life in end-stage renal disease patients.[1] However, adequate preoperative living kidney donor evaluation regarding the renal vasculature is mandatory to reduce surgical complications [3,4] Multidetector computed tomography (MDCT) for preoperative evaluation is a non-invasive technique and has an accuracy of 95%-100%. [5]MDCT that has replaced catheter angiography and excretory urography4. A CT angiography for both kidney donor and recipient is now a standard and indispensable part of the pre-transplant workup, allowing clinicians a more comprehensive assessment of the vascular anatomy and the opportunity to safely approach and successfully perform a renal transplantation.[4,6,7] During embryologic developmental process, when primary renal arteries don't regress, accessory renal arteries typically develop from the aorta above or below them. [6] Main renal arteries are the one with greatest diameter and others as accessory arteries. Accessory arteries are categorized as either hilar or polar.[8] A possible contraindication for renal transplant can be considered if there are more than two accessory renal arteries because of the high risk of thrombosis and lengthened recovery time.[9] Similarly the venous drainage of the kidney occurs through paired renal veins which drain into inferior vena cava. Right renal vein has no major venous tributaries.[10] While left renal vein has several major tributaries such as left inferior phrenic, capsular and left gonadal vein.[10] Left renal vein is longer than right renal vein so left kidney is preferred for donation.

By using MDCT angiography, it is simple to see the renal arteries and veins' number, size, branching pattern, course, and relationship. It may be made easier by a noticeable lumbar or gonadal vein the cutting open of these veins to prevent hemorrhage during surgery.[11,12] Limited data available regarding morphometric study of renal vasculature in Nepalese population. This study, thus had been partaken to know the length and diameter of renal arteries and veins and their variations in Nepalese population.

METHODS

A cross-sectional observational study was carried out in the Department of Radiodiagnosis at the National Academy of Medical Sciences (NAMS), Bir Hospital, Kathmandu, over a 12-month period from May 2021 to June 2022. Both male and female patients above 18 years undergoing Triple phase CECT Abdomen and pelvis for any clinical indication at Bir Hospital after obtaining informed consent were included. Participants with previous history of abdominal surgery, history of medico renal disease, large renal mass, gross hydronephrosis were excluded from the study. Ethical clearance for the study was obtained from Hospital's Institutional Review Board (IRB). (Ref no:-333/2079/80). The examination was carried out on a 128-slice CT scanner (Philips) in accordance with the CT protocol as shown in figure 1. A plain scan was undertaken first, and then a contrast scan. The dose of 1-2 ml/kg of water-soluble non-ionic iodinated contrast was administered in a volume of 80–100 ml, with a flow rate of 3–4 ml/s. The arterial phase was obtained at around 18–20 seconds, the portal phase at 44-45sec and the venous phase at 75–80 seconds after contrast administration respectively. The renal arteries and veins were assessed using multiplanar reconstruction and maximum intensity projection (MIP) images with thin (0.5mm) and thick (5mm) slice thickness. We evaluated and measured total number and diameter of renal arteries; Total number and course of renal vein . Distance between origin and first bifurcation of renal artery; Distance between inferior vena cava to right renal vein and distance between left renal vein confluence and lateral margin of aorta were taken… The renal artery was measured in the proximal region of the renal artery, 1-1.5mm from the ostium, where the renal artery had uniform width. The largest caliber was measured perpendicular to its long axis. The caliber was determined prior to the level of branching if the renal artery showed early branching, which is defined as any branching of main renal artery that occurs less than 2 cm from the ostium in the abdominal aorta[17]. All measurements were taken three times and a mean value was taken in consideration. Data were entered in MS Excel 2016 and statistical analysis were carried out using SPSS version 25. The general characteristics, such as age and sex, were represented as percentages and numbers using descriptive analysis.

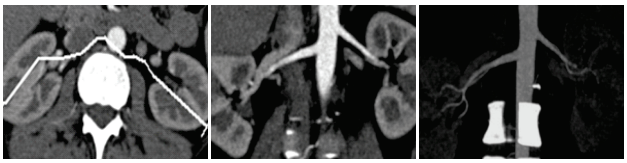
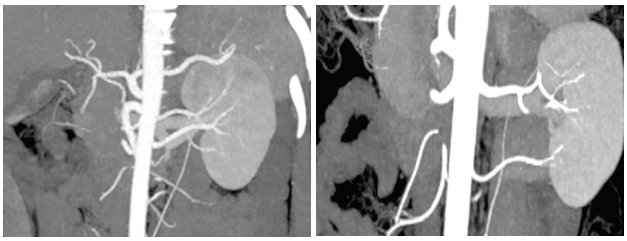


Figure 1: Reconstruction protocol. (a) Axial CT image shows a curved line drawn at the level of the renal arteries. This line is used to create the curved plane. (b) Curved coronal reformatted image shows the renal arteries. (c) Curved thin-section (15 mm) MIP image better depicts the renal artery branches.[10]



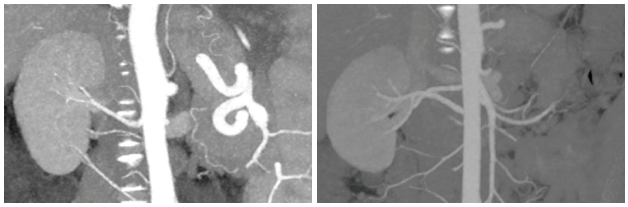


Figure 4: Curved coronal reformatted CT images showing (a) Left hilar accessory artery (b) Left polar artery (c) Right polar artery and (d) Right hilar artery

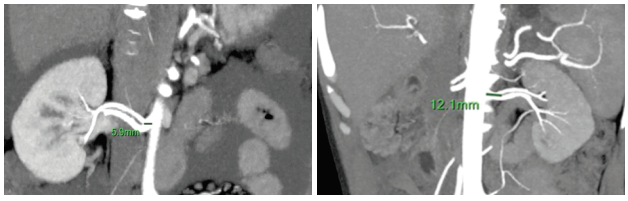


Figure 6: Curved coronal reformatted CT images showing early bifurcation of right (a) and left (b) renal artery.

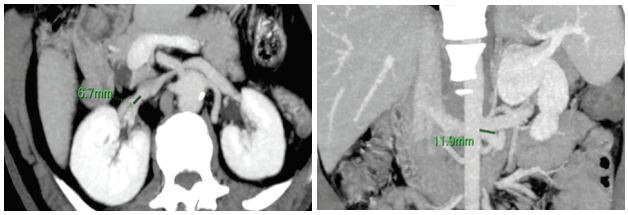


Figure 7: Curved axial and coronal reformatted CT images showing late venous confluences on right (a) and left (b) kidney.

RESULTS

A total of 89 adult patients who met the inclusion criteria were enrolled in the study. 56 (62.9%) were male and 33 (37.1%) were female. Male to female ratio was 1.69:1. The age of the participants in this study ranged from 18 - 86 years (R = 68) and the mean age was 50.51±16.46 years. Among the studied population ,36% were in the group of 30-44 (n = 29) and the least (6.7%) were in age group 75+ years (n = 6)

In our study number of cases with accessory renal artery were 39(43.82%) with 18 in right kidney and 21 in left kidney. Cases without accessory renal artery were 50 (56.18%). Similarly ,16 right kidney (17.8%) and 20 left kidney (22.4%) had single accessory renal artery and 2 right kidney (0.22%) and 1 left kidney (0.11%) had double accessory renal artery (Figure 2)

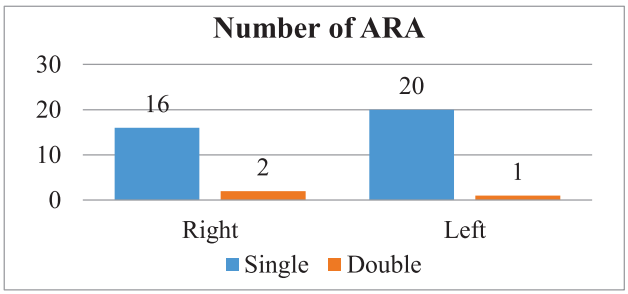


Figure 2: Bar diagram showing number of accessory renal artery (ARA)

Similarly, out of 89 individuals (178 kidneys), 16 right kidneys (17.9%) and 18 left kidneys (22.22%) had hilar artery out of which 16 individuals had unilateral hilar artery (64%) and 9 individuals had bilateral hilar artery. Similarly, Poar artery was seen in 3 right kidneys (3.37%) and 4 left kidneys (4.5%) out of which 7 individuals had unilateral polar artery and we did not find the individual having bilateral polar artery (Figure 3 and 4).

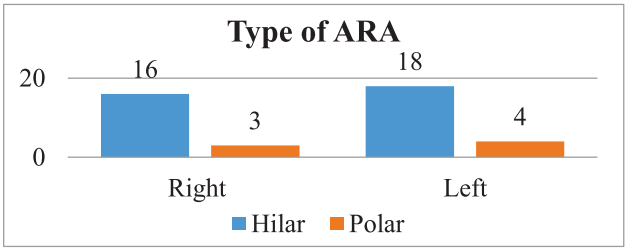


Figure 3: Bar diagram showing type of accessory renal artery (ARA)

Among the 89 studied population, the right renal artery's mean diameter was found to be 4.9mm with standard deviation of 0.9681mm. The minimum right renal diameter was found to be 2.3mm and maximum diameter was 7.3mm. The mean diameter of left renal arteries was found to be 4.98mm with standard deviation of 0.882mm. The minimum left renal diameter was found to be 3.5mm and maximum diameter was 7.6mm. (Figure 5).

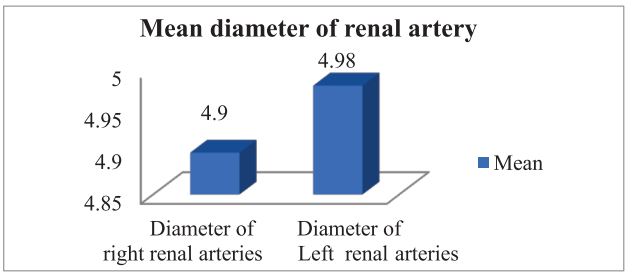


Figure 5: Mean Diameter of renal arteries

Similarly, Out of 89 individuals (178 kidneys), the mean distance of origin of right renal artery from abdominal aorta to its first bifurcation was 30.039±13.7036mm with minimum distance of 4.7mm and maximum distance of 79.7mm. The mean distance of origin of left renal artery from abdominal aorta to its first bifurcation was 27.411±10.1352 mm with minimum and maximum distance of 4.3mm and 54.7mm respectively. (Table 1). Early bifurcation of right renal artery was noted in 11 right kidney and of left renal artery in 18 left kidney. Also figure 6 shows early bifurcation of right and left renal artery.

Regarding renal vein, double renal vein was detected in 16 right kidney and 1 left kidney. Triple renal vein was detected in 1 right kidney. There was no triple renal vein in the left kidney. Only one left kidney (1.13%) had retro-aortic course of left renal vein. All

other (98.87%) had preaortic course of left renal vein. Among 89 studied individuals, mean distance between right renal vein confluence and inferior venacava was found to be 18.142mm±6.1136. The minimum distance was 7.9mm and maximum distance was 36.4mm as demonstrated in table 3. Late venous confluence was found in 35 (39.32%) right kidneys. Among 89 studied individuals, mean distance between left renal vein confluence and lateral wall of aorta was found to be 29.697±11.787. The minimum distance was 1.5mm and maximum distance was 54.3mm. Late venous confluence was found in 10 (11.23%) left kidneys, Figure 7

Table 1: Mean distance of renal arteries from first bifurcation and renal Vein from IVC and aorta (n=89)

Variables	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard deviation
Distance between origin of right renal artery and first Bifurcation	4.7	79.7	34.039	13.7036
Distance between origin of left renal artery and first Bifurcation	4.3	54.7	27.411	10.1352
Distance between RRV confluence and IVC	7.9	36.4	18.142	6.1136
Distance between LRV and Aorta:	1.5	54.3	29.697	11.787

DISCUSSION

The first successful kidney transplant was performed on identical twin brothers on December 23, 1954, in Boston. In August 2008, the Tribhuvan University Teaching Hospital in Nepal began a successful renal transplantation service.[13]. One of the most crucial preoperative tests when selecting a donor is computed tomography. It can provide details regarding anatomical variations including renal vasculature to assist clinical decision-making. We studied the prevalence of anatomical variations of renal vasculature in MDCT with the identification of numbers of main and accessory renal arteries, measurement of length and diameter of main renal artery, measurement of length of renal vein and identification of numbers of renal vein.

In our study, a total of 89 individuals from 18 years to 86 years were included with mean age of the participants was 50.51 years ±14.46 years which is almost similar to the other studies.[13,14] However we did not include pediatric population in our study. In our study, proportion of male participants were slightly higher than the female participants. Similar, high male proportion was also seen in another study.[15]

In this study, 50 (56.18%) had a normal renal arterial supply i.e. one main renal artery on each kidney. Higher prevalence of normal variants were reported by other studies. [16,17,18] This could be because their study's sample frame only consisted of kidney donors, and those with substantially aberrant vasculature were inevitably excluded.

In their study, out of a total of 129 people 72.09% had unilateral variations 27.91% had bilateral variations. [16] Single polar arteries were the most prevalent unilateral variation in 66 (70.97%) cases, followed by accessory hilar arteries in 7 (7.53%) cases and double polar arteries in 2 (2.15%). In those who had bilateral arterial variations, accessory hilar and polar arteries were revealed in 25 (69%) and 30 (83%) of the cases respectively.[9,16] Compared to this, our study showed more accessory renal arteries, this is due to small number of cases in our study or case variations. Whereas there are similar findings of arterial variation, as both studies showed that unilateral arterial variations are more common than bilateral arterial variations and hilar arterial variations are more common than polar arteries. Similar findings on accessory renal arteries were shown by another study.[14] In one other study, out of 300 individuals, a total of 22% of individuals and 12.12% of kidneys had multiple renal arteries.[15] The identification of one variant renal artery (93.1%) was the most frequent pattern found, followed by the identification of two (5.6%) and three (1.4%) arteries. [15] Compared to this, our study found more accessory arteries.

Regarding right renal artery's mean diameter, our study shows similarity with other studies.[14,19] However, the mean diameter of left renal artery was slightly more than that of the right renal artery in our study compared to others. This might be due to the small sample size and geographical variations. In another study, the mean renal artery ostial diameters for the right and left kidneys in one other study were M/F 5.06/4.59 mm and M/F 5.14/4.66 mm respectively.[20] In comparison to our study, there were few differences in the bilateral renal artery diameters, which were measured at the ostia and ranged from 4-5 mm.

In another study, renal artery was seen bifurcate at an average of distance 36.72 mm from origin on right side and of 28.94 mm on left (The minimum and maximum distance from origin of both sides is seen to be 5 mm to 62.8 mm). [14] This is also similar to our study. The early bifurcation of renal artery was more common in our study as compared to the studies,[14,17] which might be due to the small sample size.

The shape and size of the renal veins are crucial factors in kidney donation.[21] Major left renal venous malformations include supernumerary veins such as the circumaortic left renal vein, the retroaortic left renal vein, and duplicated IVC. These are referred to as IVC-related major left renal venous anomalies. [22]

The renal vein variation findings in our study are similar to another study.[14] This could be due to the similar geographical region and ethnic origin.

Variations in context to multiple renal veins and retroaortic vein while comparing the studies.[17,21] However

the circumaortic left renal vein prevalence was higher in these studies as compared to our study, this could be because of small sample size and ethnic variation. But Similar findings were also noted in another study.[23]

In our study, the mean distance between the right renal vein confluence and inferior vena cava was 18.142 mm, and the average distance between the left renal vein confluence and lateral wall of the aorta was 29.697 mm. In 10 (11.23%) left kidneys and 35 (39.32%) right kidneys, late venous confluence was observed. Compared to other study,[14] our study shows a slightly greater mean distance on both sides. Similarly compared to other study,[17] our study prevalence of late venous confluence was more in right kidney. This could be due to variation in sample size, geographical variation and different ethnic origin.

Regarding late RV confluence, the majority of research on variations in renal vascular anatomy found no confirmation of late RV confluence. However, compared to study done by Steven et al there was higher prevalence of late renal vein confluence on right side in our study whereas similar prevalence on the left side.[22]

CONCLUSION

Prior to laparoscopic donor nephrectomy, surgeons must have a complete understanding of the renal vasculature of the patient. MDCT is an excellent imaging technique for assessing both normal and accessory renal vascular anatomy. With MDCT, the number and course of the RA and RV may be precisely and quickly identified. Anomalies in the renal vasculature are frequently seen during the work-up of live kidney donors. The result of this study will help in better understanding variations in renal vasculature in Nepalese adult population. This further helps transplant surgeons for pre-evaluation of patient to reduce the chance of any surgical complications.

LIMITATIONS OF THE STUDY

First and foremost, the study was a small-scale that may not have been a representative of the general population. Data were not exclusively collected from the donor's kidneys so surgical confirmation for the cases was not included. The prevalence of renal vascular abnormalities in our community could be determined with the continued pooling of data from various institutions over a long period of time. The variations in renal artery diameters and racial differences in kidney size were not taken into account. The kidney's size, laterality, and accessory renal artery existence all affect the renal artery's diameter which was not shown in our study.

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