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Defining Vascular Anatomy of Kidney and Variation among Potential Live Kidney Donors Using Spiral Computed Tomographic Angiography

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ABSTRACT

Introduction
This study measured the accuracy of spiral computed tomographic angiography (SCTA) in defining renal vascular anatomy and estimating the prevalence of renal vascular anomalies in live kidney donors.

Methods
This prospective clinical study included 400 live-related-donor nephrectomies from June 2017 to December 2023. Renal vascular anatomy was described after SCTA. Reporting included the number of renal arteries and veins. Analysis was done by considering intraoperative findings as "actual" findings and compared to preoperative SCTA images for their prediction. For donated side kidneys, the prevalence of vascular variations was calculated using surgical and SCTA findings. The non-donated side was evaluated using SCTA alone.

Results
Four-hundred live-donor nephrectomies were performed including 326 left and 74 right-sided cases. Of the 400 kidneys harvested, 429 renal arteries were detected out of which 414 arteries (96.5 %) were predicted by SCTA. Fifteen accessory renal arteries (1-2 mm) were identified at nephrectomy, which was not predicted. In two cases, SCTA was reported to have renal arterial stenosis (multiple in one and in mid-part in the other) which turned out to be normal intraoperatively. Similarly, 417 renal veins were detected in 400 harvested kidneys. Out of these, 408 renal veins (97.8 %) were predicted by SCTA. Two renal arteries were found in 161 Kidneys and three renal arteries were found in seven kidneys. In addition, two renal veins were found in 35 kidneys.

Conclusion
Spiral computed tomographic angiography provided a reliable and accurate assessment of renal vascular anatomy and its variations in live donor nephrectomy. Small accessory arteries were missed occasionally.

Keywords
CT angiography; donor nephrectomy; renal vascular anatomy; renal transplantation

INTRODUCTION

The history of organ transplantation dates back to the sixth century BC. The first skin autograft was performed in India.[1] It took centuries before the successful renal transplantation (RT) by Joshep Murray and team on December 23, 1954, in Boston. The transplant was between identical twin brothers.[2] First successful RT in Nepal was done at Tribhuvan University Teaching Hospital (TUTH), Kathmandu, on 8th August 2008.[3]

To address the shortage of organs for transplantation, the Kidneys from live donors are increasingly used.[4] In our country, the law permits the transplantation from live-related donors,[5] and cadaveric transplantation has also been permitted. One of the prerequisites of RT includes pre-operative imaging of live donors. It provides information on the function of bilateral kidneys, anatomical information including position and vascular anatomy, and the presence of any pathology if any.

The ideal renal imaging should provide accurate anatomical information and rule out pathologies precluding donation with minimal invasiveness and should be acceptable to patients.[6] Traditional kidney imaging combined angiography and intravenous urography (IVU).[7] These invasive investigations come with inherent risks of invasiveness, prolonged observation after the procedure, inconvenience, increased cost, and limited venous imaging.[8] To mitigate these disadvantages spiral computed tomographic angiography (SCTA) for the anatomical assessment of living kidney donors (LKD) was introduced. Aulakh et al,[9] had shown that SCTA is superior to conventional angiography in terms of demonstration of arterial, venous and collecting system anatomy, ruling out intra-abdominal pathology and no need of a separate IVU study. Planning and execution of safe laparoscopic donor nephrectomy (LDN) depend a lot on proper knowledge of arterial, venous, and collecting system anatomy. So the present study was designed to assess the accuracy of SCTA for defining renal vascular anatomy and to identify the prevalence of renal vascular anomalies in Nepalese LKD.

METHODS

This clinical study of 6 years and 5 months duration was carried out in the Renal Transplant Unit from June 2017 to December 2023. The 400 consecutive living donors who underwent live-related-donor nephrectomy (LRDN) at Tribhuvan University Teaching Hospital were included in this study. The ethical approval for this study was taken from Institutional Review Committee of Institute of Medicine.

Evaluation of donors included detail clinical history and examination along with urine routine and culture, complete blood count, hemoglobin levels, platelets count, coagulation studies, renal function and liver function tests, electrocardiogram, chest x-ray, echocardiography, ultrasonogram of the abdomen, SCTA and DTPA scan. Females patients under went additional tests with PAP smear and mammography. Males above the age of 35 years were subjected to prostate-specific antigen tests. Renal vascular anatomy was described by a consultant radiologist after SCTA and included the number of renal arteries and veins and the presence of tributaries. Follow-through abdominal film taken 20 min after injecting an intravenous contrast medium was used to assess anomalies of the collecting system and ureter.

The consultant urologist carried out LRDN (open or laparoscopic) using a standard technique. In the absence of any anomalous vascular anatomy, the left kidney was chosen. Right nephrectomy was performed only in special situations. Analysis was done by considering intraoperative findings as "actual" findings and compared to preoperative SCTA images for their prediction. Clinically insignificant tributaries, defined as <1 mm, were excluded.

For donated side kidneys, calculation of the prevalence of vascular variations was carried out using surgical and SCTA findings. The non-donated side was evaluated using SCTA alone. Recording of the presence of accessory renal arteries and veins, early branching of renal artery, late confluence of renal vein, and retroaortic or circumaortic renal vein was made.

Working definitions:

- Accessory renal artery: The second renal artery (other than the main renal artery) arising from the aorta with separate ostia, irrespective of the size.
- Accessory renal vein: Another renal vein that drained into the vena cava with a separate ostium, irrespective of the size.
- Early branching of the renal artery: Distance between ostium and the first branch of renal artery<= 1.5 cm.
- Late confluence of the renal vein: A final confluence point within 1.5 cm from the left lateral border of the aorta for the left kidney.

RESULTS

Four hundred (male, 122; female, 278) LRDNs were performed during the study period. Right-sided nephrectomy was performed in 74 (18.5%) cases. Indications for right nephrectomy included multiple renal arteries on the left side (forty-one), early branching of the left renal artery (twenty-seven), poor right functioning kidney on DTPA nephrogram (three), prior transplantation on the right side in

Table 1. Incidence of major vascular variation in renal donors

Blood vessel	Donated Kidney* (n=400)	Both Kidney** (n=800)
Artery		
Accessory renal artery	29 (7.3)	161 (20.1)
Early branching of renal artery	29 (7.3)	75 (9.4)
Vein		
Accessory renal vein	17 (4.3)	35 (4.4)
Late confluence of renal vein	11 (2.8)	16 (2)
Retroaortic renal vein	4 (1)	5 (0.6)
Circumaortic renal vein	1 (0.25)	1 (0.13)

*n=Number of patients, *data from surgical findings, **data from CTA reports*

the recipient(one), complete duplex collecting system(one), and proximal right renal artery stenosis(one). At nephrectomy, all 400 kidneys elected for retrieval were found to be suitable for transplantation.

Of the 400 kidneys harvested, 429 renal arteries were detected out of which 414 arteries (96.5 %) were predicted by SCTA. Fifteen accessory renal arteries (1-2 mm) were identified at nephrectomy, ten supplying the variable area of the upper pole and five to the lower pole, which were not predicted. In one case SCTA reported to have bilateral accessory renal artery, which actually found to have two accessory renal arteries. In two cases, SCTA was reported to have renal arterial stenosis (multiple in one and in midpart in the other) which turned out to be normal intraoperatively. Similarly, 417 renal veins were detected in 400 harvested kidneys. Out of these, 408 renal veins (97.8 %) were predicted by SCTA. There was one case of infrarenal double IVC.

A single renal artery was detected in 673 kidneys (79%, 632 kidneys out of 800 kidneys), whereas single renal vein was detected in 768 kidneys (96%, 768 kidneys out of 800 kidneys). Two renal arteries were found in 161 kidneys (20.1%, 161 out of 800 kidneys) and three renal arteries were found in seven kidneys (0.9%, 7 out of 800 kidneys). In addition, two renal veins were found in 35 kidneys (4.4%, 35 out of 800 kidneys). Retroaortic renal vein was present in 5 kidneys (0.63%, 5 out of 800 kidneys) and circumaortic renal vein (0.13%, 1 out of 800 kidneys) was found in one kidney. The summarized results of the renal vascular variations are shown in Table 1.

A total of 319 gonadal veins (79.8%, 319 gonadal veins in 400 renal donors) and 312 adrenal veins (78%, 312 adrenal veins in 400 renal donors) were found draining to the renal veins. Similarly, 301 lumbar veins (75.3%, 301 lumbar veins in 400 renal donors) were also found as tributaries. Renal veins of 74 kidneys were found to have no tributaries (68 right-sided, six left-sided). The remaining six right-sided donor kidneys had a single gonadal vein as a tributary. The prevalence of the renal veins tributaries is summarized in Table 2.

Table 2. Prevalence of renal vein tributaries

Tributaries	Donated Kidney* (n=400)	Left kidney (n=326)	Right kidney (n=74)
No tributary	74 (18.5)	6 (18.4)	68 (92)
Gonadal vein	319 (79.8)	313 (96)	6 (8.1)
Adrenal vein	312 (78)	312 (95.7)	0 (0)
Lumbar vein	301 (75.3)	301 (92.3)	0 (0)

DISCUSSION

The information about morphology of renal parenchyma, outflow tract, and exact vessel anatomy is crucial before the commencement of live donor nephrectomy.[4] Traditionally, it has been obtained by IVU followed by conventional angiography. In those years, finding at surgery occasionally surprised the surgeon which was not predicted by preoperative imaging. Wlaker et al[10] evaluated 81 potential LKD with conventional single-plane aortography and intraarterial digital subtraction and/or selective renal arteriography in selected cases. Discovery of oncocytoma at surgery led to resection of mass and kidney was not procured for transplantation. Even on the retrospective review of the aortogram, no renal mass or abnormal vascularity was visible to suggest the presence of that tumor. Therefore, the advantages of performing SCTA include a better assessment of renal parenchyma morphology, accurate vascular anatomy and lower costs, discomfort, morbidity and radiation exposure. Rubin et al evaluated twelve potential live kidney donation

(LKD) with both SCTA and conventional angiography and correlated with intraoperative findings and concluded that SCTA had the potential to replace conventional imaging.[11] Various studies have shown the usefulness of SCTA in the preoperative evaluation of kidneys obtained from living donors. Current evidences suggest that conventional angiography can be replaced by SCTA.[12-15] Faster scanning with thinner section imaging and improved longitudinal spatial resolution with multi-detector CT (MDCT) can provide greater coverage during a single breath hold and reduce motion and partial volume artifacts. The quality of three-dimensional images generated by multi-detector row CT are expected to be superior.[16]

Right-side donor nephrectomy was performed in 74 cases, which were technically challenging because of the right renal vein being short and often multiple. In our series, out of 74 right kidneys harvested, nine cases of accessory renal vein were identified (12%), whereas eight was noted on left side (8 out of 326 cases, 2.45%). Satyapal[17] studied drainage pattern of 306 renal veins and found additional renal vein in 44 (14.4%) cases. There incidence of accessory renal vein of right side was ten folds greater (40; 13.1% Vs 4; 1.3). The indications of right nephrectomy were mostly dictated by SCTA which demonstrated multiple or early branching of renal artery on left side. Early renal arterial branching was technically considered to be equivalent of having multiple renal arteries.[10] Yang et al[18] performed 112 right donor nephrectomy among a total of 771 donors (14.5%) and the most common causes to choose right side was multiple left renal arteries in 90 (89.3%) cases. Similarly, in a study done by Walker et al[10], right donor nephrectomy was performed in 26 of 78 patients in which 19 cases had multiple renal artery on left side. Therefore, SCTA for comprehensive evaluation of renal vasculature of LKD is utmost important which even became paramount while choosing the side for kidney retrieval.

In our study, 429 renal arteries and 417 renal veins were found, out of which 414 renal arteries (96.5%) and 408 renal veins (97.8%) were predicted by SCTA. Fifteen accessory arteries were not predicted by SCTA, which were considerably small ranging from 1mm to 2 mm in diameter supplying the upper pole in eight cases, hilum in two cases and lower pole in three cases, of which two were anastomosed to the inferior epigastric artery of the recipient and all others were sacrificed. Ayuso et al[19] reported that the arteries most frequently overlooked on SCTA were small in size and even if they were sacrificed at surgery, they did not interfere with graft outcome because the loss of renal volume was negligible. In one case SCTA predicted to have bilateral accessory renal artery and the left side was elected for nephrectomy, which actually had two accessory renal arteries and the middle smaller branch was sacrificed. This patient later developed ureteric leak and needed re-exploration and antegrade double J stent placement. The causes to underestimate the number of renal arteries by SCTA are size (usually less than 2 mm), close proximity of two arteries and a suboptimal imaging due to breathing artifacts. The last two causes can be rectified by careful analysis of the images at the workstation or by repeat examinations.[19] Lewis et al4 studied 40 harvested kidneys with 48 renal arteries and 41 renal veins. Of these, 47arteries (98%) and 40 veins (98%) were predicted by SCTA. Chai et al reported that the SCTS predicted the number of renal arteries and veins with accuracy of 96% and 99%, respectively.[20] Thus, results of this study corroborate well with earlier studies confirming SCTA had high accuracy for evaluation of renal vasculature.[4,8,12,13,20]

In our study, 79 % of 800 kidneys had single renal artery, 20.1% and 0.9% of cases had two and three renal arteries respectively. In a recent study, the prevalence of single renal artery was reported to be 69.3% (106 kidneys out of 153 kidneys). Fourty-seven (30.7%) kidneys had multiple arteries; 42 had two renal arteries, three had three renal arteries and two had four renal arteries.[19] The prevalence of accessory renal arteries reported in larger series of living renal transplant donors ranges from 27% to 44%.11 Early branching of renal artery (branching within 1.5 cm from ostium) was found in 75 (9.4%) kidneys which was as equivalent as to have multiple arteries. Kornafel et al[21] noted early branching in 6.7 % of kidneys in their series of 201 patients.

The accessory renal vein was present in 35 kidneys (4.4%, 35 out of 800 kidneys) and its incidence was high on right side. All the accessory veins were sacrificed at bench dissection without being clinical compromised. Other variations include late confluence of renal veins in 16 kidneys, retroaortic course in five kidneys and circumaortic course in one kidney. Rubin et al[11] also mentioned about existence of renal venous variants in their study viz. accessory polar vein, retroaortic course and circumaortic renal veins. The prevalence of accessory renal veins in another series was 4.6% (7 kidneys out of 153 kidneys).[22] Kim et al[12] reported higher incidence of accessory renal veins in their series, where they found 19 accessory veins in 154 kidneys (12%). The prevalence was detected high on right (12%, 16 kidneys out of 77 kidneys) as compared to left (4%, 3 kidneys out of 77 kidneys).

Theoretically a right renal vein does not have tributaries; we found six (8.1%) gonadal veins being drained into right renal veins. Mostly right gonadal veins drained into the inferior vena cava (83%) and sometimes into right renal vein (16.1%) or into both of them (0.9%).[19] Although rare, we found six left renal veins without a single tributary. The anatomical variations viz. precaval renal artery, supradiaphragmatic origin of renal artery and double vena cava were not noted so far, although many reports had mentioned about its existence in general population.[22] Limited number of live donors in this study may not be the representative sample for Nepalese population which further remands large multicentric clinical study.

CONCLUSION

Spiral computed tomographic angiography provided a highly reliable and accurate method of evaluating renal vascular anatomy and its variations prior to live donor nephrectomy. Small accessory arteries were occasionally missed.

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CONFLICT OF INTEREST

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REFERENCES

1. Thomas DJ. Renal Transplantation [Online]. June 8, 2007 [cited 2009 April 1]; [1 screens]. Available from: URL: http://emedicine.medscape.com/article/430128-overview.
2. Murray J. Interview with Dr Joseph Murray (by Francis L Delmonico). Am J Transplant 2002; 2: 803-6. https://doi.org/10.1034/j.1600-6143.2002.20901.x
3. Chalise PR, Shah DS, Sharma UK, et al. Renal Transplantation in Nepal: The First Year's Experience. Saudi J Kidney Dis Transpl 2010; 21
4. Lewis GR, Mulcahy K, Brook NR, et al. A prospective study of the predictive power of spiral computed tomographic angiography for defining renal vascular anatomy before live-donor nephrectomy. BJU International 2004; 94: 1077-81. https://doi.org/10.1111/j.1464-410X.2004.05107.x
5. Kidney Transplantation Act 2058 (B.S.) in Compilation of Health Act and Regulations, Makalu publication, Dillibazar, Kathmandu, Nepal, 5th Ed., Reprint in Falgun 2064:277-93.
6. Riehle RA Jr, Steckler R, Naslund EB, et al. Selection criteria for the evaluation of living related renal donors. J Urol 1990; 144: 845-8. https://doi.org/10.1016/S0022-5347(17)39606-4
7. Derauf B, Goldberg ME. Angiographic assessment of potential renal transplant donors. Rad Clin N Am 1987; 25: 261.
8. Kaynan AM, Rozenblit AM, Figuera KI et al. Use of spiral computerized tomography in lieu of angiography for pre-operative assessment of living renal donors. J Urol 1999: 161: 1769-75. https://doi.org/10.1016/S0022-5347(05)68796-4
9. Aulakh BS, Singh J, Sandhu JS, et al. Benefits of spiral CT angiography in preoperative assessment of living renal donors. Tranplantation Proceedings 2000; 32: 1582. https://doi.org/10.1016/S0041-1345(00)01321-X
10. Walker TG, Geller SC, Delmonico FL, et al. Donor renal angiography: Its influence on the decision to use the right or left kidney. AJR 1988; 151: 1149-51. https://doi.org/10.2214/ajr.151.6.1149
11. Rubin GD, Alfrey EJ, Dake MD, et al. Assessment of living renal donors with spiral CT. Radiology 1995; 195: 457-62. https://doi.org/10.1148/radiology.195.2.7724766
12. Kim JK, Park SY, Kim HJ, et al. Living donor kidneys: Usefulness of multi-detector row CT for comprehensive evaluation. Radiology 2003; 229: 869-76. https://doi.org/10.1148/radiol.2293021098
13. Alfrey EJ, Rubin GD, Kuo PC, et al. The use of spiral computed tomography in the evaluation of living donors for kidney transplantation. Transplantation 1995; 59: 643-5. https://doi.org/10.1097/00007890-199502270-00037
14. Platt JF, Ellis JH. Korobkin M, et al. Helical CT evaluation of potential kidney donors: findings in 154 subjects. AJR AM J Roentgenol 1997; 169: 1325-30. https://doi.org/10.2214/ajr.169.5.9353451
15. Cochran ST, Krasny RM, Danovitch GM, et al. Helical CT angiography for examination of living renal donors. AJR AM J Roentgenol 1997; 168: 1569-73. https://doi.org/10.2214/ajr.168.6.9168727
16. Rubin GD, Shiau MC, Leung AN, et al. CT angiography of the aorta and iliac arteries: single versus multiple detector-row CT. Radiology 2000; 215:670-6. https://doi.org/10.1148/radiology.215.3.r00jn18670
17. Satyapal KS. Classification of the drainage patterns of the renal veins. J Anat 1995; 186: 329-33.
18. Yang SC, Seong DH, Kim YS, et al. Living donor nephrectomies-right side: Intraoperative assessment of the right renal vascular pedicle in 112 cases. Yonsei Medical Journal. 1993; 34: 175-8.
19. Ayuso JR, Openheimer F, Ayuso C, et al. Living donor kidney transplantation: Helical CT evaluation of candidates. Acta Urol Esp 2006; 30: 145-51. https://doi.org/10.3349/ymj.1993.34.2.175
20. Chai JW, Lee W, Yin YH, et al. CT angiography for living kidney donors: Accuracy, cause of misinterpretation and prevalence of variation. Korean J Radiol 2008; 9: 333-9. https://doi.org/10.3348/kjr.2008.9.4.333
21. Kornafel O, Baran B, Pawlikowska I, et al. Analysis of anatomical variations of the main arteries branching from the abdominal aorta, with 64-detector computed tomography. Pol J Radiol. 2010; 75(2): 38–45
22. Habuchi T, Narita S, Tsuchiya N, et al. Laparoscopic nephrectomy in patients with renal vein and/or inferior vena cava anomalies: Video presentation. Int J Urol 2009; 16: 854. https://doi.org/10.1111/j.1442-2042.2009.02398.x