DEPICTION OF VENOUS ANOMALIES BY MDCT RENAL ANGIOGRAPHY IN PREOPERATIVE EVALUATION OF LIVING RENAL TRANSPLANT DONOR: CAN THE UROLOGISTS RELY ON IT?

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ABSTRACT

Background and Objective: *Renal transplantation grew rapidly over the past three decades, subsequently lead to shortage of available organs to meet the increasing demand. This has led to an increase in the number of living donors. Recent advances in imaging technology now allow safe, rapid, and non invasive evaluation of potential donors. Multidetector computed tomography angiography (MDCTA) is a fast, minimally invasive procedure that is quickly becoming the imaging modality of choice for preoperative evaluation of potential renal transplant donors as it depicts arterial and venous anatomy accurately*

Aim of the work: *To determine the accuracy of MDCTA as the primary imaging technique in the evaluation of the renal venous system and its anomalies in living kidney donors*

Patients and Methods: *30 living kidney donors (20 male, 10 female; mean age was 37 years) who performed MDCTA were evaluated. Surgical correlation was made for the late confluence of renal vein, detection of venous anomalies and prominence of renal vein tributaries.*

Results: *25 subjects underwent left nephrectomy, and 5 subjects underwent right nephrectomy. Single retro-aortic left renal vein (LRV) was detected in 5 cases, circumaortic LRV and late confluence of LRV was noted in one case each. A combined circum-aortic and retro-aortic LRVs were depicted for the first time in Literature. The sensitivity, specificity and accuracy for detection of main renal veins were 100% while in detection of left renal veins tributaries was 100%. 92.1% and 92.15 respectively.*

Conclusion: *MDCTA provides accurate information about the main renal venous system, however, it offers suboptimal information about renal veins tributaries.*

Keywords: *MDCTA, venous anomalies, renal vascular anatomy.*

INTRODUCTION

Renal transplantation is considered the best treatment for chronic renal failure. It ensures a better life quality for patients and provides them a longer life expectancy when compared to those on haemodialysis [1].

For many decades, cadaveric kidneys were the only option for renal transplantation, but nowadays living kidney transplantation is the mainstay for organ transplantation as it decreases the waiting time and can be easily arranged even before dialysis program [2].

Conventional open laparotomy is now replaced by laparoscopic living donor nephrectomy. For almost 20 years, this technique became an essential treatment method decreasing the postoperative complications and thus the need for further medications and management [3].

Adopting laparoscopic nephrectomy, surgeons face some difficulties where the operative bed is narrow and the preoperative assessment of donor's anatomy is crucial [4].

This emphasizes the need for radiologists to assess the renal anatomy and to report the relevant anatomic variations before nephrectomy [2].

It is well established that renal vessels demonstrate a wide spectrum of variations and identifying them had its positive impact on the developing technique of renal transplantation [2].

To assess the possible renal donors, renal angiography and intravenous pyelography (IVP) have been always used [5].

However, many reports have proved that helical CT angiography can be the alternative of IVP and renal angiography in the assessment of possible renal donors before they perform laparoscopic nephrectomy [6].

Multidetector CT (MDCT) is a short time procedure which helps in decreasing the tube heating, and has a better spatial resolution when compared to single-detector helical CT. MDCT has been used also to assess the renal vessels and very good results were obtained [7].

Variations in renal veins are far more than those of renal arteries and right sided supernumerary renal veins are more common than left ones [2]. Literature reported different venous variations due to developmental errors [8].

Accurate depiction of the site and caliber of the renal vein tributaries is of paramount importance because of the deficient field of view of laparoscopic nephrectomy and for limitation of haemorrhagic complications intraoperatively [9].

AIM OF THE WORK

The purpose of this study is to highlight the role of MDCT angiography as a primary imaging technique in the evaluation of the renal venous system variations in living kidney donors.

PATIENTS AND METHODS

Patients:

Over a period of 48 months, a prospective study included 30 potential live kidney donors (20 males and 10 females) were evaluated by MDCT renal angiography in preparation for kidney donation.

According to the hospital regulations, renal transplantation is only performed after passing through meticulous steps.

Strict regulations were provided including patient consent and other legal requirements for approval of kidney donation.

The approval of local ethical committee was obtained as well as medico-legal procedures for kidney donation for both related and non-related donors.

Inclusion and exclusion criteria

As the MDCT renal angiography was the last step in pre-operative evaluation of transplant donor, there were no exclusion criteria as the donors were screened clinically and with laboratory investigations in transplantation clinic to rule out any medical contraindications for kidney donation such as mental illness, history of tuberculosis, urological diseases or cancer.

Donors who didn't proceed to transplantation were only excluded (only one excluded case because of left hydronephrosis secondary to ureteric stone which was missed in pre-CTA ultrasound).

All donors were subjected to

I. Clinical examination

II. Laboratory investigations including Hepatitis markers, liver functions, coagulation profile, renal functions (serum creatinine and blood urea).

III. Ultrasonography (US) and Doppler US to rule out major anomalies which could exclude the donor from the program

IV. MDCT renal Angiography was the final step and only performed to healthy donors.

Donors were referred to CT unit from the urology outpatient clinic; they were scheduled to perform the examination.

Serum creatinine and blood urea levels were mandatory before the scan, all donors were below the accepted limit for IV contrast injection (serum creatinine limit was 1.4 mg/dl and blood urea limit was 40 mg/dl)

Each candidate was instructed to fast at least 8 hours before scan and ingest 1 litre of water 60 minutes before examination. No oral contrast material was administered.

MDCT renal angiography Protocol:

The study was performed using (Aquilion 16, Toshiba Medical Systems) CT machine.

CT scan was performed in cranio-caudal direction. Unenhanced CT of abdomen and pelvis was performed from the vertebral body of T12 to the sacro-iliac joint by 5-mm sections thickness and table speed of 5 mm per-rotation, collimation = 4x1 & rotation time = 0.5 second.

Subsequently, all donors received 70-80 ml intravenous non-ionic iodinated contrast material containing 300 mg/ml iodine (Optiray™ 300 [Ioversol Injection 64%])

Contrast enhanced CT was initiated, the arterial phase was adjusted according to bolus tracking method, then cortico-medullary and excretory phases were adjusted at 55 seconds and 10 minutes after injection respectively.

Post MDCT renal angiography procedure workup:

One- and 5-mm axial images and 5-mm coronal images routinely were thoroughly reviewed for all phases. Images were then transferred to a workstation (VITREA, Toshiba medical systems) and the following reconstructions were obtained for all cases:

- Sagittal reformation of each kidney to measure kidney length.
- Axial thin-section maximum intensity projection (MIP) images of the renal arteries and veins.
- Curved coronal reformation across the renal arteries and veins (drawn through axial images)
- Thin-section coronal MIP: volume-rendered (VR) images obtained on the basis of previous curved coronal reformations.
- Three-dimensional (3D) VR images for evaluation of arteries and veins.

After surgery and in case of discrepancy between intra-operative data and CT findings, a second review of images was done by both the surgical team and the radiologist.

Donor nephrectomy was performed in all subjects through an open approach. Surgery was performed after two or three months (median two months) after CT examination. The findings on MDCT renal angiography were used to guide the selection of the donor kidney.

Intra-operatively, the urology surgeon recorded the surgical findings, including number of arteries, the branching distance, the number of renal veins, the presence of late venous confluence and presence venous anomalies.

Statistical analysis was done using SPSS (statistical package for social sciences, version 21 IBM software).

The following criteria were examined in each case and then compared to the intraoperative findings, then the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of each criterion were calculated.

a) Assessment of main renal veins

b) Assessment of presence of late confluence of veins

c) Assessment of LRV tributaries

RESULTS

The Mean donor age at time of evaluation was 37 years (range 24 to 55 years).

Table (1): Shows age distribution of donors

	Range	Mean	Standard deviation
Male	24 – 48 years	35.15 years	6.69
Female	34 – 55 years	41.8 years	7.19

Only one case was excluded from the donation program according to MDCT renal angiography findings (not included in the study) due to the presence of a ureteric stone and hydronephrosis.

In this study, only four donors were classified as (normal donors) who had neither anatomical variants nor pathological findings.

The work focused on renal venous system variations, but we encountered arterial system variations and pathological findings were encountered as well (Table 2)

Table (2): Overall distribution of anatomical variations and pathological findings in donors. LRA=left renal artery, RRA=right renal artery, RRV=right renal vein, LRV=left renal vein.

Findings	Number of donors (%)
Normal donors	4 (13.3 %)
Renal stones	3 (10 %)
Renal cysts (Bosniak type I)	1 (3.3 %)
Single accessory LRA	6 (20 %)
Two accessory RRA	1 (3.3 %)
Bilateral accessory renal arteries	2 (6.6 %)
Early branching of RRA	1 (3.3 %)
Early branching of LRA	3 (10 %)
Early branching of bilateral RAs	2 (6.6 %)
Double RRVs	3 (10 %)
Double LRVs	3 (10 %)
Single retro-aortic LRV	5 (16.6 %)
Triple RRVs	1 (3.3 %)
Double retro-aortic LRV	1 (3.3 %)
Circum-aortic LRV	1 (3.3 %)
Late confluence of LRV	1 (3.3 %)

<u>Assessment of main renal veins:</u>

In this study, most of main renal veins were single, their number and distribution are shown in Table 3.

Table (3): Types of main renal veins according to number

	Right renal vein	Left renal vein
Single	26	27
Double	3	3
Triple	1	0

Most of renal veins depicted in this study were antro (pre) aortic in position (83.4%). Retro, combined antro and retro aortic and cicumaortic were variants which were also present in the current study.

<u>Assessment of the presence of late confluence of veins:</u>

Late confluence of renal veins (in which confluence is located less than 1 cm from IVC in right side and less than 1 cm from aorta in left side) is noted in one case in our study. This finding changed the surgical decision to right nephrectomy. **(Figure 1)** In our study, most donors showed normal confluence of renal veins (96.7%).

<u>Assessment of LRV tributaries:</u>

Right renal vein has no tributaries whereas left renal vein has multiple tributaries. If diameter of tributaries exceeds 5 mm, it is termed prominent and must be mentioned in CT report as this may change sectioning technique. Two cases with prominent gonadal vein were found and one case with prominent ascending lumbar vein was depicted. **(Figure 2)**

<u>Intraoperative findings</u>:

a) Regarding the surgical data related to venous systems, the MDCT renal angiography depicted 7 donors with supernumerary renal veins which matched with the intra-operative findings.

True positive cases for supernumerary renal veins were 7 and true negative were 23. There were no false positive or false negative cases.

b) Regarding surgical findings related to venous tributaries, the MDCT renal angiography failed to detect, left adrenal vein in one donor, left gonadal vein in two donors and ascending left lumbar vein in four donors.

Left adrenal vein

The true positive cases were 27 whereas the true negative cases were 2 cases.

There were no false positive cases. There was one case of false negative left adrenal vein.

The sensitivity of MDCTA for detection of left adrenal vein was 96.4 %, sensitivity was 100 % and accuracy was 96.6 %.

Left gonadal vein

The true positive cases were 25 whereas the true negative cases were 3 cases.

There were no false positive cases, however the false negative cases were 2.

The sensitivity of MDCT renal angiography for detection of left gonadal vein was 92.6 %, sensitivity was 100 % and accuracy was 93.3 %.

Left ascending lumbar vein

The true positive cases were 21, whereas the true negative cases were 5.

There were no false positive cases, and the false negative cases were 4.

The sensitivity of MDCTA for detection of left ascending lumbar vein was 84 %, sensitivity was 100 % and accuracy was 86.6 %.

Table (4): Statistical indices of MDCT renal angiography in venous system variants in donors

	Venous anomalies	Tributaries of LRV (Lumbar/gonadal/adrenal veins)
Sensitivity	100 %	100 %
Specificity	100 %	92.1 %
PPV	100 %	100 %
NPV	100 %	60.7 %
Accuracy	100 %	92.1 %

MDCT renal angiography changed surgical decision from left nephrectomy to right nephrectomy in five donors (16.6 %) (two donors had right renal stones, one donor had double retro-aortic left renal vein, one had late confluence of left renal vein and the last one had combined circum-aortic and retro-aortic left renal veins) (Figure 3).

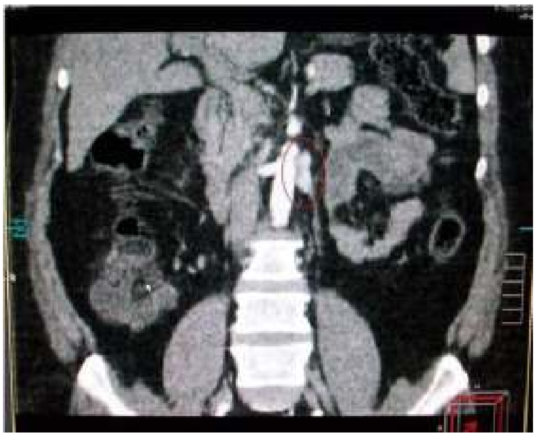

Fig. (1): Coronal MPR show late confluence of LRV (red circle)

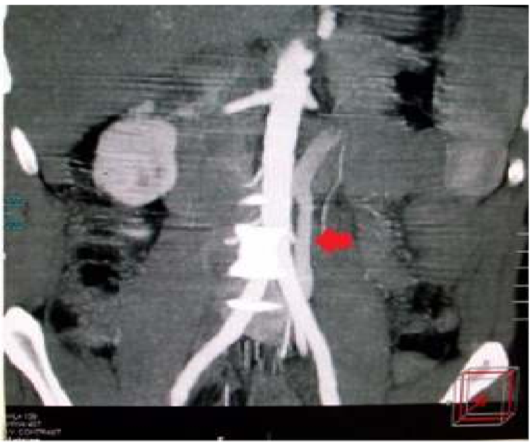

Fig. (2): Coronal MPR cortico-medullary phase (thick slice) show prominent left gonadal vein (red arrow) (diameter = 9 mm).

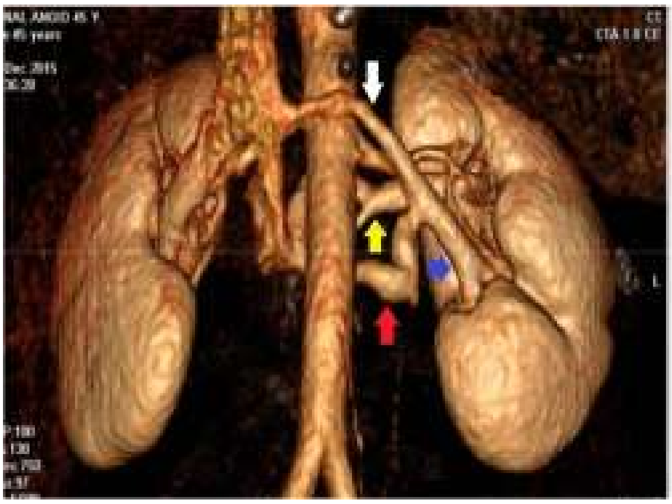

Fig. (3): VR image (anterior view): main stem of retro-aortic LRV **(blue arrow)** and retro-aortic arm of circumaortic LRV **(red arrow)** and pre-aortic arm of circumaortic LRV **(white arrow)** and reto-aortic LRV (yellow arrow).

DISCUSSION

The preoperative imaging of living renal donors is crucial to depict renal anomalies to choose the potential donors for living kidney transplantation, to decide the best surgical method for donor nephrectomy and to minimize the hazards of post operative complications that can endanger graft survival and sometimes the life of donors [10].

Depicting the renal vascular anatomy is the corner stone of the preoperative evaluation of the live renal donors as it helps in selection of the appropriate donors and the choice of the donated kidney [11].

Classically, most of the worthy data are obtained from the transverse images. The presence of accessory arteries, early arterial branching, venous variants, and ureteral duplication are the essential information required by the urologists [12].

In this study, we thoroughly assessed the renal venous system, however there were incidental variants in the renal arterial system that we will mention briefly.

In the current study, a single renal vein was depicted in 86.6 % on right side and 90 % on left side. Multiple renal veins were noted in 7 donors (23.3 %).

These results are in line with **Chu et al.,** reported single renal vein in 94 % and 90 % of donors in right and left sides respectively [13].

The most common renal venous anomaly is multiple renal veins which are present in approximately 15 – 30 % of cases, more at right side. [13] In the study by **Chai et al,** accessory renal vein was depicted in 15.7 % of donors [14].

In this study, seven donors (23%) had multiple renal veins; four of them were on right side which is in line with literature.

Double renal veins were noted in three donors (10 %) on the right side and three donors (10 %) on the left side. On the other hand, **Chu et al,** reported double right renal veins in 4.9 % and 0.3 % of donors on right and left sides respectively [15].

Moreover, triple right renal veins were depicted in one case (3 %) whereas they were reported in 1.1 % by **Chu et al** [15].

In a study performed by **Staśkiewicz et al,** supernumerary right renal veins were more frequent than the left ones. [16] This is similar to the results obtained by **Zhu et al,** who noted left supernumerary veins in 2.7% and right supernumerary veins in 18.7% of their population [17].

Several studies described the prevalence of variations in the left renal vein. **Zhu et al,** noted RRV variations in 19.2%, and LRV in 7.1% in their population [17]. **Janschek et al,** depicted more frequent variations on the right side (23%) than on the left (6.7%) [18].

The available literature reported the presence of retro-aortic LRV in approximately 0.3% to 6.6% of their population [19-26, 18].

However, the results in this study confirm the presence of retro-aortic LRV in 5 cases (16.6%) which is a higher percentage than that recorded in literature.

As to the circum-aortic LRV, literature confirmed its presence in 0.3% to 8.7% of their population [19-26,14].

In the current study, circum-aortic left renal vein was depicted in one case (3 %) which is in line with the available literature.

Regarding the double retro-aortic LRV, only one case (3%) was depicted, whereas, **Chu et al,** reported one case (0.2%) in their study [15].

In the current study, a note was made of one case of combined circum and retro-aortic left renal veins which wasn't previously reported elsewhere in literature. **(Figure 3)**

Regarding the late confluence of left renal vein, one case was depicted (3.3 %). **(Figure 1)** However, **Chai et al** stated that its incidence was 10.8 % [14].

As to the encountered renal arterial system variations, double (two main arteries) right renal arteries were depicted in only one case (3.3%). This wasn't in line with **Bordei et al.** who found 54 double renal arteries in 272 kidneys (20%) six of which were bilateral [27].

Satyapal et al. as well, described double renal arteries in 31.3% of the African population in their study, 30.9% of the white population, 18.5% of the half-caste population and 13.5% of the Indian population [28].

In the current study, triple renal arteries were noted in one case only on the right kidney (3.3%) where it had been reported in 0.6% in the study done by **Balachandran** [29] and 2.4 % in the study performed by **Chu et al** [15].

The most common renal arterial variant is the accessory renal artery [30]. In this study, accessory renal arteries were seen in 30 % of cases.

This was in line with a study done by **Chai et al.** where the accessory renal arteries were seen in 28.1 % of donors [14].

Moreover, two renal arteries were depicted (main renal artery and an accessory renal artery) in 10 % of the cases on the right side and 26.6 % on the left side whereas it was reported in 19 % and 21 % in right and left sides respectively in the study done by **Chu et al** [15] .

As to the right accessory renal artery, it was depicted in three donors (10%) whereas it was reported in 22 % to 39% of cases of the previously reported studies as stated by **Zhao et al** [31].

The left renal accessory artery was depicted in 8 donors (26.6 %) and whereas it was reported in 16 % to 32% of cases of the previously reported studies as mentioned by **Satyapal et al** [15].

In this study, bilateral accessory renal arteries were seen in 2 cases (6.6 %) whereas it had been reported in 5% in previously reported studies as stated by **Dhar and Lal** [32].

Although the origin of accessory renal artery from common iliac artery is very rare [33], it was depicted in one case in this study (3.3 %).

In the current study, early branching was depicted in 8 donors (26.2%), two donors bilaterally (6.6 %), one donor on the right side (3%) and five donors on the left side (16.6 %). This is in line with the results of **Gumus et al**. who found early division in 27% of cases [34].

However, results of this study were not in line with **Holden et al**, **Parmar et al and Chai et al,** who reported early branching in about 10-12% of their studies of cases in a study by [35, 36, 14].

The urologists prefer the left kidney for laparoscopic living donor nephrectomy because its renal vein is longer and it is easily surgically resected [37].

In this study, right nephrectomy was performed in 5 cases (16.6 %). Two cases had right renal stones (40%) and three cases had complex left vascular anatomy (60%).

On the other hand, in the study done by **Chu et al**, 29 out of 654 donors (4 %) underwent right nephrectomy. Three of them (10 %) had right renal stones and 5 of them (17 %) had complex left vascular anatomy [15].

Regarding renal simple cortical cysts, only one donor was reported (3 %) with left simple renal cyst **(Bosniak type I)**. On the other hand, Chu et al, reported renal cysts in 34 % of their cases [15].

In this study, partial duplication of renal collecting system was depicted in one donor (3 %) whereas it was reported in 0.3 % of donors in the study done by **Chu et al** [15].

In this study, only one donor was reported (3%) with mal-rotation, but it was excluded from the study as the donor did not undergo nephrectomy for other reasons (left ureteric stone with secondary hydronephrosis). In the study by **Chu et al**, 0.3 % of donors had mal-rotation [15].

In this study, it was found that the MDCT anatomy matched the surgical findings in 29 out of 30 donors (96.6%) and the accuracy of the prediction of the renal vein number was 100%.

It was also observed that the discrepancy between MDCT renal angiography findings and surgical data were more common on the left side than the right side and in the venous system more than the arterial system.

The ongoing advancement in CT technology makes the angiographic information acquired by MDCT similar to intraoperative findings [38].

When comparing results of this study to similar studies, in the study by **Chai et al,** it was found that the MDCT anatomy exactly matched the surgical findings in (95.4%). The accuracy of the prediction of the renal artery number in the initial CT interpretation was 96% and the accuracy of the prediction of the renal vein number was 99% [14].

As regards venous anomalies, **Laugharne et al,** reported that sensitivity of MDCT renal angiography was 92 %, specificity was 98 % PPV was 80 %, NPV was 99 % and accuracy was 97 %. [39] These results are in line with those of this study where the sensitivity specificity, PPV, NPV and accuracy were all 100 %. (Table 4)

Results of this study were comparable to those in the published literature about studies of 16 multi-detector row CT in evaluating potential renal donors. **Fishman et al,** reported similarity between CT and operative findings regarding renal arteries in 69 of 74 donors [3].

The evolution of MDCT and the advances in the CT technology in increasing the number of detectors minimized the drawbacks of the single detector CT. the number of the detectors is inversely proportional to the scan time [40].

Shortening of the scan time markedly decreases the motion artefacts and enables imaging in the desired arterial and venous stages separately. In addition, the detection of variations in renal vasculature is optimized using the MIP and VR reconstruction techniques [40].

Initially, MIP images were obtained for all cases. However, through the course of the study it was obvious that essential anatomical information were not often finely depicted on MIP rendering. As MIP images have no depth orientation, VR images were better for clearly demonstrating different anatomical variants especially when overlapping vessels were present.

Moreover, the current experience suggests that all of the original sections should be thoroughly investigated for small accessory arteries and branches. This helps increasing the accuracy of the pre operative MDCT images.

Currently, laparoscopic donor nephrectomy is becoming more popular than open nephrectomy. It is well known that laparoscopic nephrectomy has a limited visual field than open nephrectomy because the posterior aspect of the renal vein often cannot be directly visualized during surgery. Moreover, full description of lumbar-gonadal venous pattern is very important for laparoscopic surgeons so as not to be missed during surgery. That's why, the presence of venous anomalies constitutes a potential surgical nightmare if they are not documented in advance [41].

In this study, CT missed 23 % of left renal vein tributaries (gonadal / adrenal and / or lumbar veins). This dictates that surgeons should not completely rely on preoperative CT findings for detection of renal vein tributaries.

However, the fact that MDCT was not 100 % accurate in showing the renal vascular anatomy did not affect the outcome of transplantation in any of our cases.

CONCLUSION

MDCT renal angiography provides suboptimal information about renal venous anatomy, particularly renal veins tributaries. The surgeons shouldn't rely fully on preoperative CTA while performing donor nephrectomy.

However, it provides the most accurate preoperative assessment of renal arterial system and uretero-vesical anatomy for potential kidney donors, without the risks of more invasive conventional angiography.

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