MDCT evaluation of potential living renal donor, prior to laparoscopic donor nephrectomy: What the transplant surgeon wants to know?

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Abstract

As Laparoscopic Donor Nephrectomy (LDN) offers several advantages for the donor such as lesser post-operative pain, fewer cosmetic concerns and faster recovery time, there is growing global trend towards LDN as compared to open nephrectomy. Comprehensive pre-LDN donor evaluation includes assessment of renal morphology including pelvi-calyceal and vascular system. Apart from donor selection, evaluation of the regional anatomy allows precise surgical planning. Due to limited visualization during laparoscopic renal harvesting, detailed pre-transplant evaluation of regional anatomy, including the renal venous anatomy is of utmost importance. MDCT is the modality of choice for pre-LDN evaluation of potential renal donors. Apart from appropriate scan protocol and post-processing methods, detailed understanding of surgical techniques is essential for the Radiologist for accurate image interpretation during pre-LDN MDCT evaluation of potential renal donors. This review article describes MDCT evaluation of potential living renal donor, prior to LDN with emphasis on scan protocol, post-processing methods and image interpretation. The article laid special emphasis on surgical perspectives of pre-LDN MDCT evaluation and addresses important points which transplant surgeons want to know.

Key words: Laparoscopic donor nephrectomy; living renal donor; MDCT evaluation

Introduction

Renal transplantation continues to remain the most effective treatment option in patients with end-stage renal disease (ESRD).[1-3] Long waiting period for these patients on dialysis adversely affects the patient survival and significantly increases the cost of treatment.[4] After renal transplantation, the 5-year survival is 70%, as compared to 30% survival for a similar group of patients who receive dialysis.[5] The cadaveric kidneys have failed to meet the growing need for organs for patients with ESRD. It is well accepted that related or unrelated living donor renal allografts have a higher graft survival than cadaveric donor transplants.[6-8] This resulted in growing trend toward living donor nephrectomy as compared to cadaveric source. The first successful kidney transplant from a live donor to his identical twin was performed 50 years ago. Since then, living renal transplantation has come a long way to become the preferred treatment option for ESRD. Though the organ donation rates for living renal transplantation are variable, it has recently increased to be the predominant form of kidney transplantation in the western world.[9,10]

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Laparoscopic donor nephrectomy

Initially LDN was performed through open approach with a surgical incision over the loin. With advancements

in laparoscopic techniques, the laparoscopic donor nephrectomy (LDN) was introduced in 1995.[11] As compared to open nephrectomy, LDN offers several advantages for the donor, such as lesser post-operative pain, fewer cosmetic concerns, and faster recovery time, which have been credited for the recent increase in living renal donation rates. LDN leads to shorter hospital stays (2-4 days as compared to 3-7 days) and an early return to work (12-21 days as compared to 30-60 days) as compared to open procedure.[12-15] LDN is reported to have faster recovery, less fatigue, and better quality of life for the donor, even when compared with mini-incision open donor nephrectomy.[16]

The standard LDN approach involves four small (1-1.5 cm) laparoscopic ports - first just supero-lateral to the umbilicus, second along the mid-clavicular line (midway between the xiphoid and the umbilicus), third lateral to the rectus muscle (midway between the umbilicus and the iliac crest), and fourth along the mid-axillary line (superior to the iliac crest). The visualization camera is positioned at the peri-umbilical port and operating instruments are operated through the other three ports. A supra-pubic incision measuring 4-5 cm is used for retrieval of kidney [Figure 1].

While performing a LDN, the left kidney is often preferred by the surgeon due to its longer pedicle, as compared to the right side. The important clamping sites for renal dissection include proximal renal artery (close to aorta), renal vein (anterior to aorta), gonadal artery (close to aorta), gonadal vein, and ureter (inferior to "golden triangle"). It is important for the radiologists to know and understand these locations, so as to evaluate the corresponding regions on pre-transplant imaging studies [Figure 2].

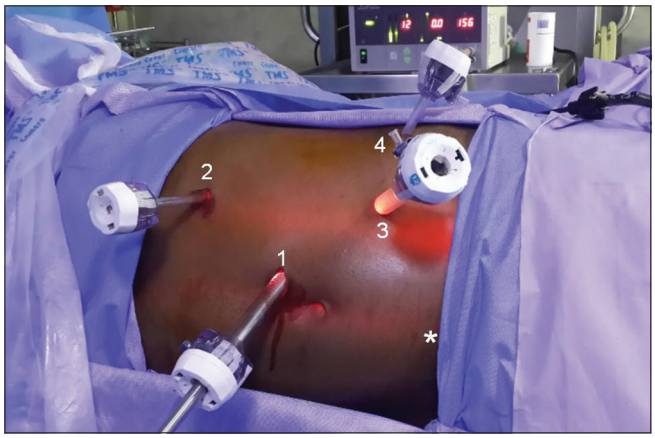

Figure 1: Pre-operative photograph, prior to laparoscopic donor nephrectomy (LDN) showing the laparoscopic port locations over the anterior abdominal wall. There are a total of four ports - first in peri-umbilical location for the visualization camera (marked as 1), and other three ports for the operating instruments (marked 2, 3 and 4). Apart from these, a small transverse incision is placed in supra-umbilical region to retrieve the kidney (*)

Pre-transplant donor evaluation in LDN

According to the consensus statement of Amsterdam Forum on the care of live kidney donors, all potential donors should have certain standard tests performed prior to renal harvest surgery.[17,18] Donor safety is the primary objective of living donor organ transplant programs. The prospective donor must be educated about the procedure and future risks of organ donation. Apart from detailed clinical history and examination, these include blood and urine tests including renal function tests, electrocardiogram, serum prostate specific antigen or mammography and chest radiograph (if indicated, high-resolution CT). Subsequently, anatomical assessment of kidneys and renal vessels is performed with imaging studies.

In contrast to the open approach, LDN is associated with limited intra-operative visibility. There is lack of visualization of posterior and supero-medial aspects of the kidneys. These patients, therefore, require comprehensive pre-operative evaluation which initially includes evaluation of the renal status in terms of morphology and functions, which will decide the fitness to donate. Subsequently, the regional anatomy is evaluated in detail to decide the precise surgical approach. Unlike open surgery, laparoscopic surgeons need detailed information about the venous anatomy because venous bleeding is a potentially serious complication that may require the conversion of LDN to open nephrectomy. Optimal pre-transplant imaging work-up is crucial to avoid donor complications and to ensure good recipient graft function. Apart from optimal scan acquisition, post-processing and image interpretation, knowledge and understanding of the surgical techniques including the critical steps during LDN is essential for the radiologists to perform an accurate pre-transplant evaluation".[19,20]

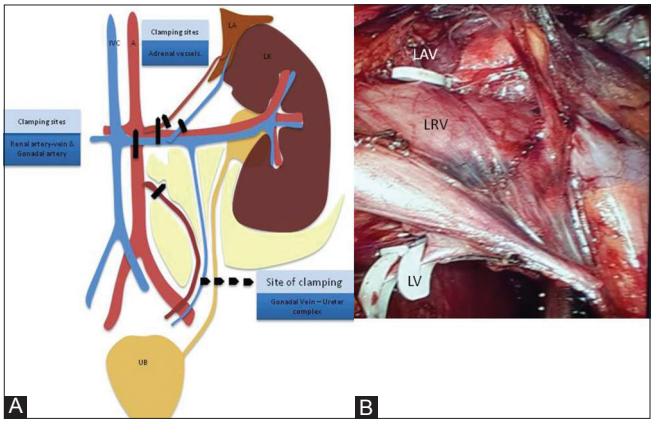

Figure 2 (A and B): Line diagram (A) and corresponding intra-operative photograph (B) showing the left renal vascular pedicle; during the LDN procedure. The clamping sites for renal, gonadal and adrenal vessels and left ureter are illustrated in A. [LRV: Left renal vein, LAV: Ligated left adrenal vein, LV: Ligated lumbar vein]. Laparoscopy images are rotated in accordance with CT images for comparison

Imaging options, diagnostic accuracy, and work-flow

Though structural evaluation of kidneys and renal vascular system is feasible with multi-detector CT angiography (MDCTA), contrast-enhanced MR angiography (CE-MRA), and digital subtraction angiography (DSA), MDCTA is the modality of choice for preoperative evaluation of living renal donors.[21-24] MDCT shows diagnostic accuracy of 95-100% with use of 4-64 row scanners and is preferred over MRI because of its higher spatial resolution and faster acquisition. MDCT can detect accessory arteries, early branching of renal arteries, and renal vein anomalies, with an accuracy of 89-97%, 93-97%, and 96-100%, respectively.[24] MDCTA, including arterial and venous phase images and delayed urographic images, offers minimally invasive and accurate evaluation of renal donors in a single study.

MR angiography is another important modality for the preoperative evaluation of living kidney donors, which has the additional advantage of avoiding ionizing radiation and potentially nephrotoxic iodinated contrast agents. MR angiography of kidneys has shown a sensitivity of 89%, specificity of 94%, and accuracy of 91% in the evaluation of arterial anomalies and a sensitivity of 98.3%, specificity of 100%, and accuracy of 98.4% for venous anomalies.[25] These results were, however, not consistent and several studies have reported poor performance of MRI as compared to CT, mainly in the evaluation of renal venous system.[26,27]

Due to the high volume of renal transplant at our hospital, MDCT is widely considered to be the "imaging workhorse" and "one-stop shop" for all pre-transplant work-ups and is included as a package for renal transplantation. Doppler, CE-MRA, and DSA are only done in select cases for specific reasons. If the donor kidneys show unilateral or bilateral parenchymal alteration, renal scintigraphy is performed for differential renal functions. The relative function of donated kidney should be less than 55%.

Renal MDCT angiography protocol

The present article is based on pre-transplant MDCT work-up studies performed between May 2010 and May 2014, involving a total of 3200 patients. Out of these, 520 patients subsequently had LDN and formed the basis for the correlation.

The cases were scanned on either Siemens Sensation-64 scanner or Toshiba Aquillion 64-slice MDCT scanner. Our MDCT protocol includes an unenhanced scan, which mainly helps to detect nephrolithiasis and serves as the baseline to diagnose foci of abnormal enhancement. Arterial or cortico-medullary phase scan is acquired using the bolus-tracking method with a scan delay of approximately 24-48 s from the time of commencement of contrast injection. The cranio-caudal coverage extends from the level of dome of the diaphragm to the pubic symphysis. Subsequently, venous or nephrographic phase acquisition is done after a scan delay of approximately 70 s. The arterial and venous phase scans are useful for delineation of regional anatomy including the vascular system. Delayed or pyelographic phase scan is done after an interval of 5-15 min with the patient in prone position to ensure optimal ureteric filling [Table 1]. This is useful for the morphological evaluation of pelvi-calyceal system and the ureter.

Several modifications of the scan protocol exist, and therefore, the protocols often vary from center to center. Studies have reported on the utility of split-bolus technique, which generates simultaneous nephrographic and pyelographic phases in reducing the radiation dosage.[28,29] In an effort to further reduce the radiation dose, Sahani, *et al.* have used low kilovolt peak (100 kVp) setting for MDCT angiography and reported acceptable diagnostic quality, despite more image noise.[30] Though the images do not look very pretty and the 3D post-processing is sub-optimal, the low radiation protocols consistently provide the desired diagnostic information and should be encouraged in clinical practice. Our protocol for evaluation of potential renal donor remains standardized, if the donor is asymptomatic and does not have any significant clinical history. We have not used low-dose protocols in the arterial and venous phases, mainly due to the sub-optimal evaluation of veins. Our four-phase protocol provides approximate radiation dose of 15-25 mSv, which is acceptable.

Post-processing in MDCT renal angiography

After the scan acquisition, post-processing is performed on dedicated workstations using 1-mm-thick images with an overlap of 0.5 mm. Images were processed on either Leonardo, Siemens Medical Solutions workstation, or Osirix 64-bit platform using the images from GE-Centricity system. The post-processing options included multiplanar reformation (MPR) technique to generate axial, coronal,

Table 1: Scan parameters for data acquisition and post-processing in renal angiography study for pre-transplant living renal donor evaluation; using 64-slice MDCT scanners

Scanner	Siemens - Sensation 64 / Toshiba Acq
Tube Voltage	120 kVp
Effective current (ATCM)	150 mAS.
Rotation time	0.5 seconds.
Detector collimation	64x0.6 mm.
Scan time	10-12 sec.
Kernel	B 30f - medium smooth
Intravenous contrast	100 ml & 40ml saline; 4ml/sec.
Scan acquisition (phases)	NC, Art (BT), Ven (70s) & Del (5-15 min).
Image viewing (PACS)	Axial , Coronal & Sagittal (3mm).
3-D image reconstruction	ST : 1mm; Increment: 0.5
Radiation dose (mSv).	15-25.

ATCM: Automated Tube Current Modulation; PACS: Picture Archiving and Communications System; NC: Non-contrast; BT: Bolus Tracking; ST: Slice Thickness

and sagittal images with 3 mm thickness for overall image interpretation including the renal morphology and evaluation of regional anatomy. Dedicated imaging planes are used for generating MPR images for each kidney and its vessels. Curved planar reformation (CPR) image allows a curved reconstruction plane and shows bilateral renal vessels in a single image [Figure 3].

Maximum intensity projection (MIP) is a volume rendering method in which the brightest vowels are projected into the 3D image. Volume rendering technique (VRT) is another processing method which displays data without categorizing the attenuation values into strict "all or none" categories. MIP images are preferred in delineation of finer intra-renal vessels due to their inherent sensitivity to contrast density, while VRT images are preferred for delineation of complex venous anatomy due to their excellent three-dimensional depth perception [Figure 4]. Vessel wall calcification interferes with visualization to a greater extent in MIP as compared to VRT and, therefore, leads to tendency for stenosis over-estimation.[31] As VRT involves greater user interaction, it is vulnerable to inter-observer variability. The image quality and processing time depends on user's experience and expertise. MIP is, however, simple to use and involves less variability in terms of the final image.[32]

All the cases were evaluated prospectively, and due reports with measurement tables were conveyed to the operating surgeon before the LDN. Periodic reviews and discussions were performed for imaging intra-operative correlation. The patients included in this article were evaluated by a single radiologist, who had more than 10 years of experience with abdominal CT and CT angiography studies.

Imaging findings and implications on decision for renal harvesting

General rules

As donor safety is of prime importance in living donor transplant program, the donor must retain one normal kidney. If one kidney shows mildly altered morphology, the altered kidney should be harvested. Presence of renal calculi is not a contraindication, if the calculus is less than 4 mm and there is no clinical history of obstruction. If the calculus is more than 5 mm or there are multiple calculi, the kidney can be used after the calculi are removed and metabolic analysis is performed. Small (less than 5 mm), simple parenchymal cysts and angiomyolipomas do not constitute a contraindication, while larger and simple cysts require excision.[20,33]

If both kidneys show normal morphology, the surgeon usually prefers the kidney with less complicated vascular anatomy. The left kidney is often preferred for LDN because of its longer vascular pedicle and the technical ease in harvest surgery. Presence of accessory arteries increases the operative time and complexity in both donor and recipient surgeries with resultant risk of arterial thrombosis. Small-caliber accessory upper polar renal artery can be safely sacrificed without any ischemia to the renal parenchyma. Intra-operatively, the surgeon may temporarily clamp a polar renal artery to assess its parenchymal supply, before cutting the artery. According to a rough estimate, when a small-caliber polar renal artery (<2 mm diameter) is cut or thrombosed, it produces a graft infarct with volume of less than 10%.[34] The same rule, however, does not apply to the lower polar accessory arteries as they may supply branches to the ureter and should always be preserved.

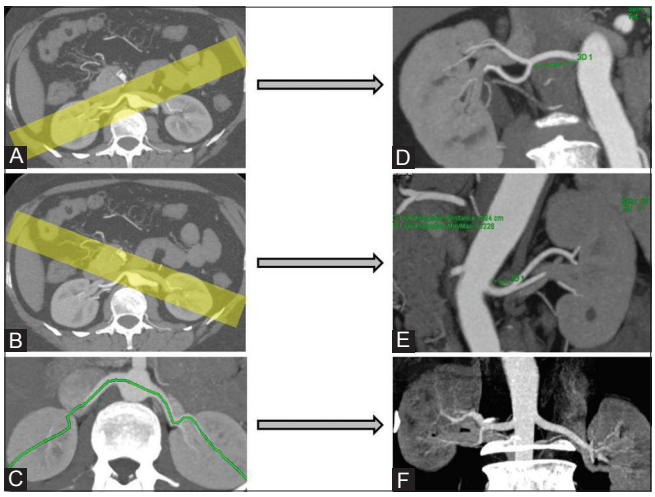

Figure 3 (A-F): CT angiography - transverse Maximum Intensity Projection (MIP) images showing the dedicated reconstruction planes for right kidney (A) and the left kidney (B) and the resultant corresponding multi-planer reformatted (MPR) coronal images (D and E). Panel C shows a transverse CTA - MIP image with curved reconstruction plane and the resultant coronal image (F) showing bilateral renal arteries in a single image

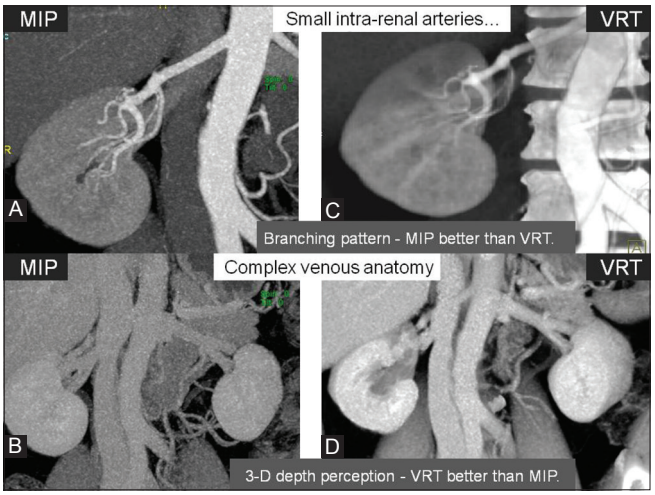

Figure 4 (A-D): MDCT renal angiography - coronal Maximum Intensity Projection (MIP) and Volume Rendering Technique (VRT) images for comparison. MIP images (A and B) better delineates the small arterial branches and is therefore preferred over VRT images (C and D) to show renal hilar branching pattern. VRT images provides superior three dimensional depth perception and is therefore preferred over MIP images to delineate complex venous anatomy

According to a study performed at Mayo clinic, Rochester, USA[35] involving 1956 potential renal donors, 75% had no radiographic abnormalities on CT angiography. The abnormalities that constitute absolute contraindications to renal harvesting were found in 0.5% (n = 10) of potential donors and included polycystic kidney disease, solitary or horseshoe kidney, and pelvic kidney. The rest were relative contraindications and were reported in 24% (n = 478) of potential donors. In a total of 27% (n = 132), the radiographic abnormality was the main reason for donor rejection. In these patients, renal stones (39%) were the most common radiographic abnormality, followed by parenchymal abnormalities (29%) and renal artery abnormalities (27%).

Renal arterial anatomy and variants

The nomenclature for reporting the CT angiography studies should be standardized. When one renal artery is dominant in terms of dimension, then it is appropriate to label it as the main renal artery and others as accessory renal arteries. If the arteries are similar-sized, it is better to use the terms upper and lower renal arteries [Figure 5]. The accessory renal arteries could be categorized into hilar, polar, or capsular in terms of their course after their origin from the aorta [Figure 6]. Accessory renal polar arteries may also arise from the iliac, superior and inferior mesenteric, celiac, middle colic, lumbar, gonadal, middle sacral arteries, and even contralateral renal artery.[36] These small polar arteries may not be seen on thick-MIP or VRT images and would require review of thin-section axial images on the workstation.[20]

In case of multiple renal arteries, it is important to mention the inter-arterial distances, as the closely located renal arteries still allow single anastomotic site with the recipient iliac artery. If the renal artery origins are wide apart, the surgeon needs to create two separate anastomotic sites in the recipient iliac artery, thereby increasing the risk of potential complications [Figure 7].

Precise evaluation of proximal renal artery in terms of luminal diameter and presence of intimal plaques is an important component of pre-transplant work-up. "True transverse" plane is necessary for accurate measurement. The luminal calibers of donor and recipient arteries at the anastomotic sites should not be discordant. Luminal diameter of atleast 3 mm is necessary to create a safe anastomotic site during the transplant surgery, which should be free of any atherosclerotic disease. Presence of calcified plaque prevents complete luminal obliteration during clamping and may cause intimal injury in the renal artery or aorta and consequent bleeding. It is, therefore, important to differentiate calcified plaque from soft plaque and to alert the surgeon before surgery of its presence to decide the exact site of clamp placement. Presence of bilateral renal artery atherosclerosis or fibro-muscular dysplasia is an absolute contraindication to renal donation. In patients with unilateral renal artery atherosclerotic plaque, the affected side may be harvested, followed by the endarterectomy or resection of the affected segment. In patients with unilateral segment of fibro-muscular dysplasia, the affected kidney may be harvested and the affected segment should be replaced with a biologic or synthetic graft.[20]

Evaluation of renal arterial system-vascular pedicle

Precise delineation of the arterial vascular pedicle is one of the most important aspects of pre-transplantation imaging

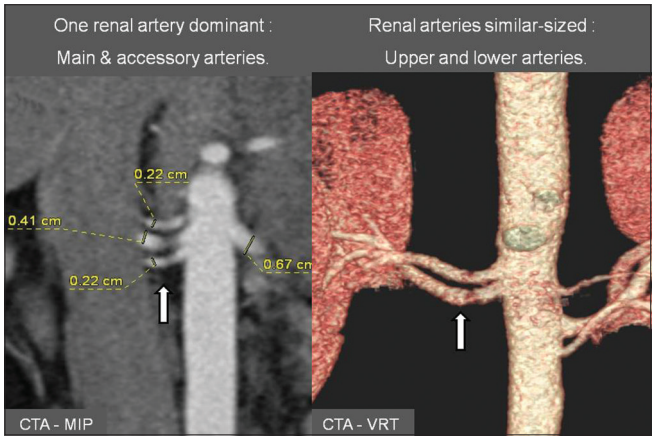

Figure 5: MDCT renal angiography showing three renal arteries in panel A (coronal MIP image) and two renal arteries in panel B (coronal VRT image, different patient) in the right kidney. When one of the arteries is dominant in terms of caliber, it is labeled as main renal artery and rest as accessory renal arteries, as illustrated in panel A (arrow). When the renal arteries are similar-sized, they are labeled as upper and lower renal arteries as in panel B (arrow)

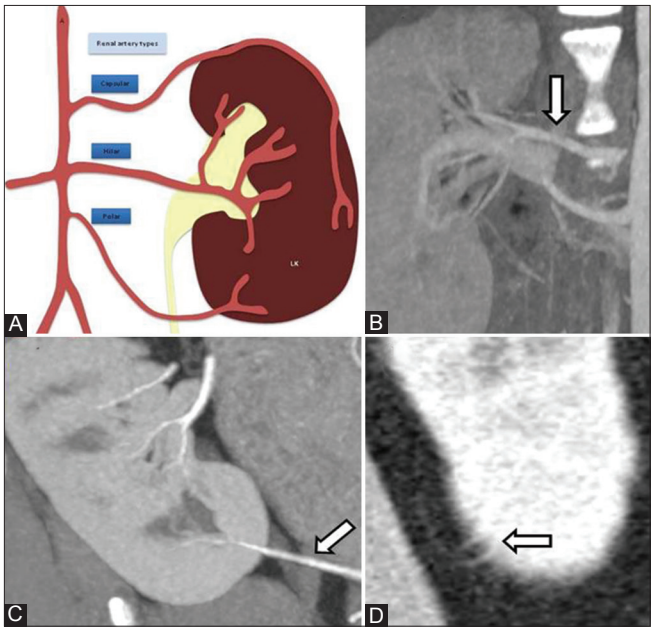

Figure 6 (A-D): (A) Line diagram and (B) corresponding CTA - coronal images to show types of renal artery (arrows) in terms of vessel course - hilar (C) polar and (D) capsular

work-up. During LDN, the available operative window needs a minimum arterial pedicle length of 10 mm. It is important to localize the renal artery ostium along the aorta and follow the arterial course along till the first segmental branch. The length of renal artery from the ostium up to the first segmental branch constitutes the arterial pedicle length on each side [Figure 8]. Another important consideration is the relationship of site of bifurcation of right renal artery and the IVC. As right renal artery is the only arterial structure posterior to IVC, IVC needs to be retracted during LDN to clamp the right renal artery [Figure 9]. Retrocaval area is a difficult area to work at during LDN; therefore, the exact location of the first segmental branch of right renal artery with respect to the IVC should be clearly identified in the pre-transplant imaging work-up.

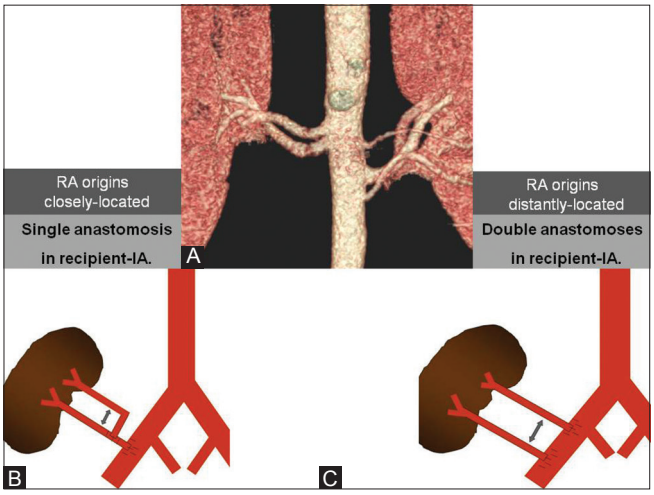

Figure 7 (A-C): (A) MDCT renal angiography - VRT coronal image (B)showing two renal arteries on right side and three renal arteries on the left side with variable inter-arterial distances. If donor arteries are closely separated, end-to-side vascular anastomosis is possible (C) If donor arteries are wide apart, end-to-side vascular anastomosis between the donor arteries is not possible and double arterial anastomosis is performed with the recipient iliac artery

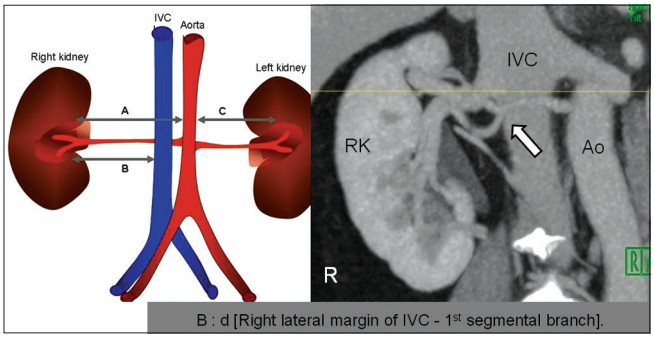

Figure 9: Line diagram and corresponding MDCTA - coronal MIP images for right kidney (R) showing the anatomical relation of arterial pedicle of right kidney and the IVC [(A) distance from the right renal artery origin to site of first branch of right renal artery (B) distance from the right lateral margin of IVC to the site of first branch of right renal artery (arrow) (C) distance from the left renal artery origin to site of first branch of left renal artery, IVC: Inferior Vena Cava, Ao: Aorta, RK: Right kidney]

Renal venous anatomy and variants

The right renal vein is often short and shows slightly oblique course before draining into the IVC. The right renal vein usually does not show significant variations in the course. On the other hand, the left renal vein is longer and usually shows horizontal pre-aortic course [Figure 10]. Not uncommonly, the left renal vein shows a retro-aortic course when it follows an oblique course and forms a caudal loop [Figure 11]. This caudal loop usually spans one or two vertebral segments before drainage into IVC.

Evaluation of renal venous system-vascular pedicle

Similar to arterial pedicle, delineation of venous vascular pedicle is also an integral component of pre-transplantation

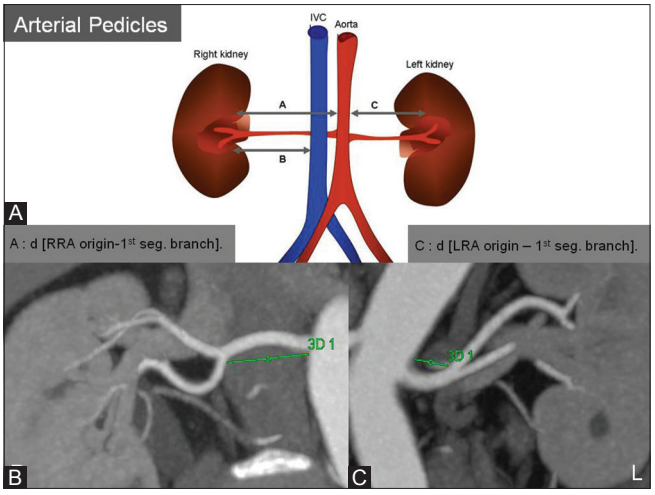

Figure 8 (A-C): Line diagram and corresponding MDCTA - coronal MIP images for right kidney (R) and the left kidney (L) showing the measurement techniques to evaluate the arterial vascular pedicles [(A) distance from the right renal artery origin to site of first branch of right renal artery (B) distance from the right lateral margin of IVC to the site of first branch of right renal artery (C) distance from the left renal artery origin to site of first branch of left renal artery]

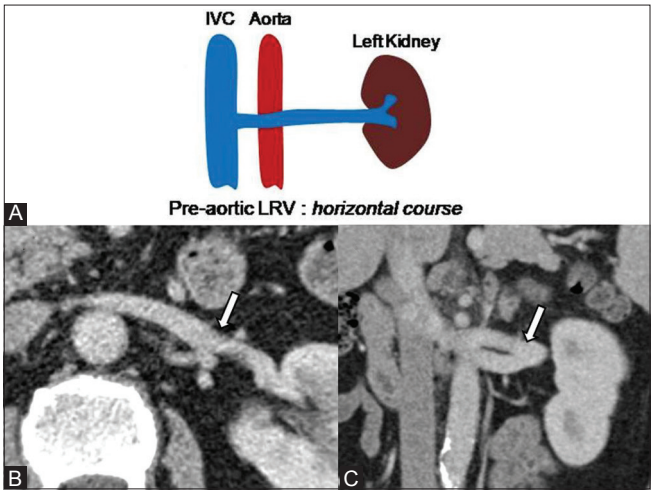

Figure 10 (A-C): (A) Line diagram and (B) corresponding MDCTA transverse and (C) coronal images showing the common pre-aortic course of left renal vein. The pre-aortic left renal vein usually has a horizontal course (arrows)

imaging work-up. During LDN, the available operative window needs a minimum venous pedicle length of 10 mm. It is important to localize the insertion site of renal vein into IVC and then follow the renal vein up to the site of first venous confluence (toward the IVC). The length of renal vein from the insertion site into IVC to the site of venous confluence constitutes the venous vascular pedicle length on each side [Figure 12].

Duplication of renal vein is more common on the right side and is reported in as much as 15% of potential renal donors.[37] Pre-operative diagnosis and localization of the insertion sites into IVC is important. The separation of the insertion sites of the two venous trunks may show circumferential as well as cranio-caudal separation [Figure 13]. This information should be communicated to the operating surgeon, as circumferential separation without cranio-caudal separation is likely to create difficulty during IVC repair.

Duplication of left renal vein is also seen, when one of the venous trunks is pre-aortic while another one is retro-aortic and the configuration is called as circum-aortic. In patients with duplication of renal veins, it is important to measure the exact luminal caliber of the veins in the proximal segments. If there is significant discrepancy between the calibers of these veins or if one of the veins is significantly small, then the surgeon may even decide to completely ligate the smaller vein without any major risk to the transplanted kidney.

Venous tributaries and communications

Accurate pre-operative assessment of the renal vein tributaries is important to avoid hemorrhagic complications during LDN. All the draining veins more than 5 mm should be reported, as the surgeon may need to use surgical staples or plastic clips rather than cautery for these larger tributaries. Pre-operative information about these venous communications of renal vein is of vital importance to laparoscopic surgeon for the surgical planning and to minimize the intra-operative venous bleeding.

The adrenal vein, gonadal vein, and retroperitoneal veins may drain into the right renal vein in 30%, 7%, and 3% of cases, respectively.[20] Apart from these, the right renal vein often does not have any major tributaries and therefore does not constitute any problem during the renal harvesting of right kidney. Even in patients with pelvic varices, dilated gonadal vein may be seen draining into IVC [Figure 14].

On the contrary, the left renal vein shows major tributaries all along its circumference [Figure 15]. The adrenal vein drains into the left proximal renal vein along the superior aspect, while the gonadal vein drains along the inferior aspect just lateral to adrenal vein [Figure 16]. Retroperitoneal veins including lumbar veins communicate with proximal part of left renal vein along its posterior aspect [Figure 17]. Unusually, prominent venous collateral may communicate with left renal vein and need to be ligated during surgery [Figure 18]. These communicating veins may show significant variations and complex anatomy, which at times can only be delineated on a CT workstation using the post-processing tool and may not be optimally illustrated on the films.[19,36]

Surgical concerns about ureteric arterial supply

Initial studies on LDN reported high rates of postoperative ureteral complications (9.1%), which was most likely

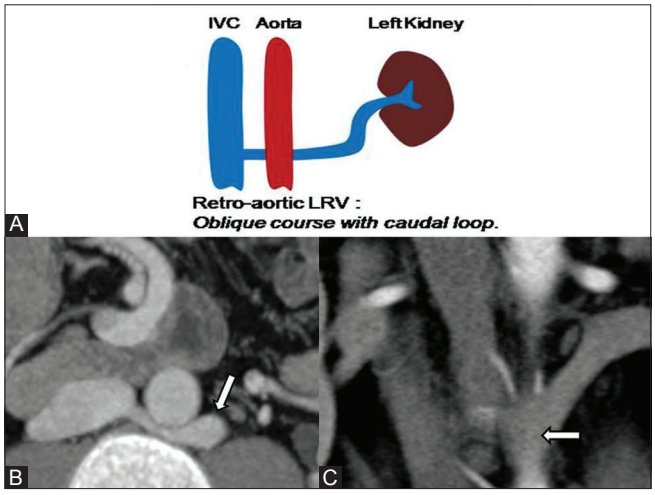

Figure 11 (A-C): (A) Line diagram and (B) corresponding MDCTA transverse and (C) coronal images showing the retro-aortic course of left renal vein. The retro-aortic left renal vein usually has an oblique course with a prominent caudal loop (arrows)

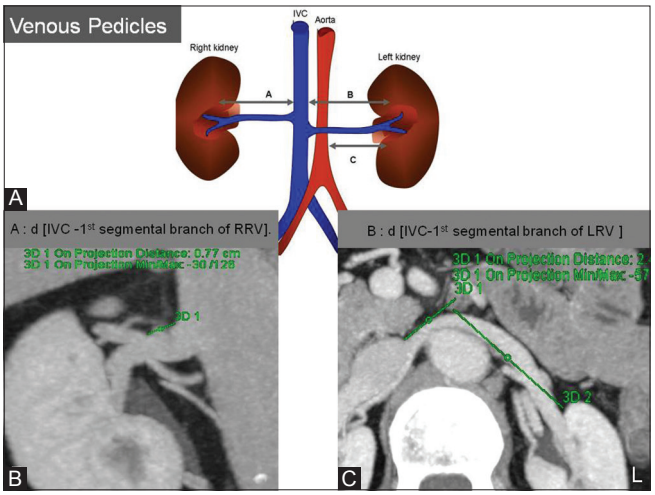

Figure 12 (A-C): Line diagram and corresponding MDCTA - coronal and transverse MIP images for right kidney (R) and the left kidney (L) showing the measurement techniques to evaluate the venous vascular pedicles [(A) distance from the last confluence of right renal vein to insertion site into the IVC (B) distance from the last confluence of left renal vein to insertion site into the IVC (C) distance from the last confluence of left renal vein to the left lateral margin of aorta]

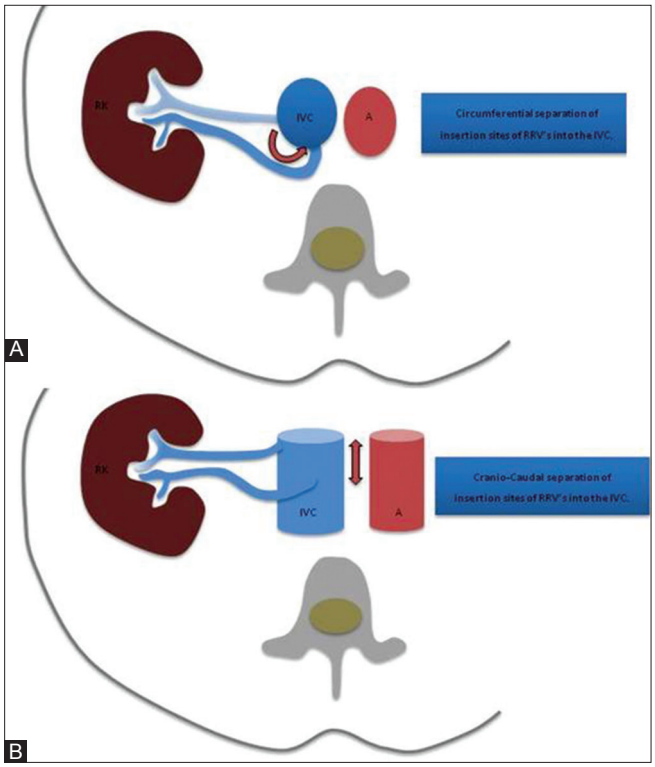

Figure 13 (A and B): Line diagram showing evaluation of potential renal donors with duplication of right renal vein. (A) shows the insertion of right renal vein trunks into IVC at the same level with only circumferential separation. (B) shows the insertion of right venal vein trunks into IVC at different levels with cranio-caudal separation [IVC: Inferior Vena Cava, Ao: Aorta]. The former situation creates greater difficulty in separating the venous pedicle from IVC

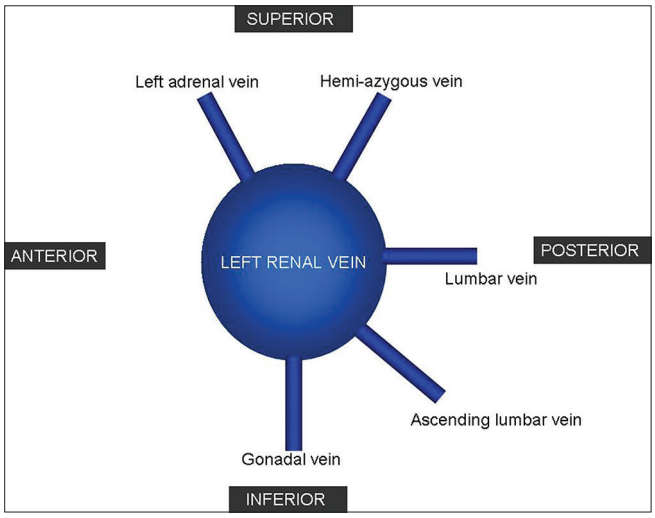

Figure 15: Line diagram with positional coordinates (anterior, posterior, superior and inferior) showing the circumference of left renal vein and its communications. Left renal vein shows several communications all along its circumference with wide range of variant anatomical patterns. Most commonly left adrenal vein join the left renal vein along the antero-superior aspect, while gonadal vein joins the left renal vein along the inferior aspect. Lumbar vein (posterior), ascending lumbar vein (postero-inferior) and hemi-azygous veins (postero-superior) are frequently seen

due to extensive ureteral dissection and resultant distal ureteral ischemia.[12,38] Subsequently, with modifications

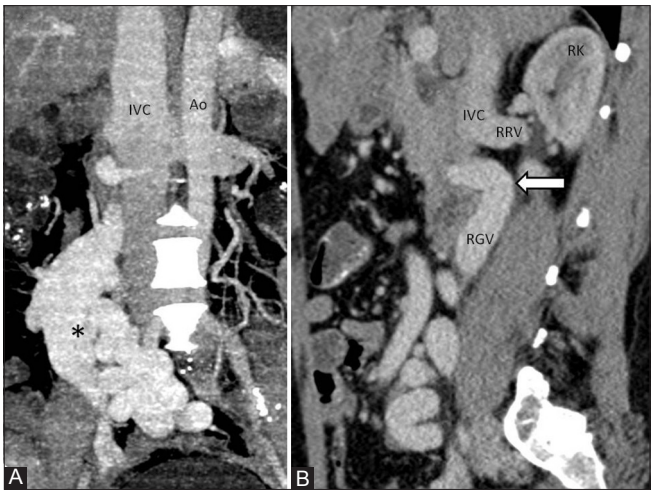

Figure 14 (A and B): (A) MDCT renal angiography - coronal and (B) sagittal MPR images showing a large right-sided pelvic varix (*) with dilated right gonadal vein, which is draining into IVC (arrow). [RGV: Right gonadal vein, RRV: Right renal vein, RK: Right kidney, IVC: Inferior Vena Cava, Ao: Aorta]

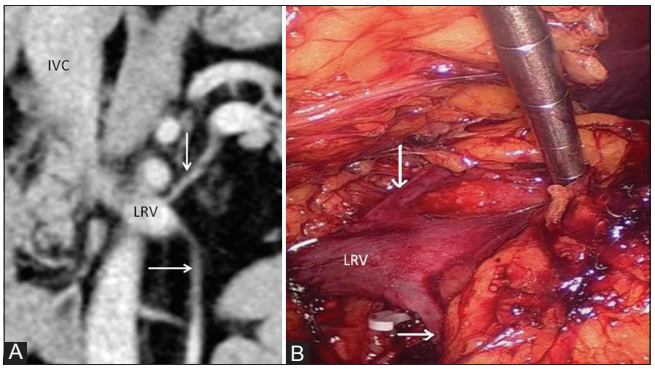

Figure 16 (A and B): (A) MDCT renal angiography coronal image and (B) the corresponding laparoscopy image showing left adrenal vein joining the left renal vein along the antero-superior aspect, while gonadal vein joins the left renal vein along the inferior aspect (arrows) [LRV: Left renal vein, IVC: Inferior Vena Cava]

in the surgical technique, there was significant reduction in the rate of ureteric complications with LDN (3%). Fine ureteric branches that mainly arise from the renal and gonadal arteries traverse the adipose tissue surrounding the gonadal vessels and ureter before piercing the ureteric adventitia. Presence of a prominent gonadal artery arising from the aorta may be nicely demonstrated on CT study and should always be reported. Similarly, CT may show prominent pyelo-ureteric branch arising from the main or accessory renal artery, which provides arterial supply to the pelvis and ureter [Figure 19]. Surgical dissection along this adipose tissue and ureteric adventitia is likely to injure these finer arterial branches and increase the risk of ischemic ureteric complications. Preservation of ureteric vascular supply allows uretero-neocystostomy during recipient surgery. Otherwise, pyelo-ureteral anastomosis needs to be performed, which is a difficult surgical option. The close anatomical proximity of ureter and gonadal vein needs to

be respected and both the structures should be managed as combined "ureter-gonadal vein complex" to preserve the ureteric vascular supply. According to the modified technique, the fat in the region of "golden triangle" (defined by the lower pole of kidney, gonadal vessels, and renal vascular pedicle) should be preserved during surgery.[39,40] Surgical dissection is, therefore, avoided in this region, and the left gonadal vein and ureter are clamped inferior to the triangle [Figure 20].

Evaluation of non-vascular structures in the operative field

Pre-LDN donor evaluation with MDCT includes assessment of non-vascular structures at the renal hilum. Presence of renal calculus, cysts, tumors, and anomalies should be reported. The amount of hilar and peri-renal fat should be mentioned in the report and communicated, as presence of excessive hilar and peri-renal fat is associated with increase in operative time and surgical complexity.[41] Presence of prominent lymphatics in the renal hilum or any space-occupying lesion like lymphangioma also has important surgical implications. With dilated renal pelvis, it is important to differentiate a prominent extra-renal pelvis from a pelvi-ureteric junction obstruction [Figure 21]. Delayed pyelographic images should be reviewed to look for the pelvi-calyceal and ureteric anatomy, including the presence and extent of duplicated system. Image interpretation should essentially include details about the regional anatomy and neighboring structures like spleen and large bowel [Figure 22]. Presence of splenomegaly and retro-renal positioning of colon should be reported. Pre-operative MDCT detection of entero-parietal and entero-enteric peritoneal adhesions is feasible and should be communicated to the operating surgeon.[42] Presence of adhesions in the operative field may create difficulty during LDN and may require conversion to an open approach. The report should also mention any other focal/diffuse abnormality in the abdominal wall and the abdominal cavity, which may have direct or indirect medical or surgical implications on the LDN procedure.

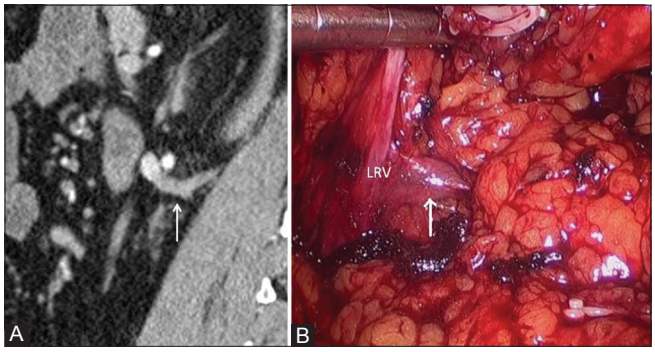

Figure 17 (A and B): (A) MDCT renal angiography sagittal image and (B) the corresponding laparoscopy image showing a prominent lumbar vein joining the left renal vein along the posterior aspect (arrows) [LRV: Left renal vein]

Use of reporting checklist and measurement table

Comprehensive pre-transplant donor evaluation with MDCT is an integral component of LDN. Apart from

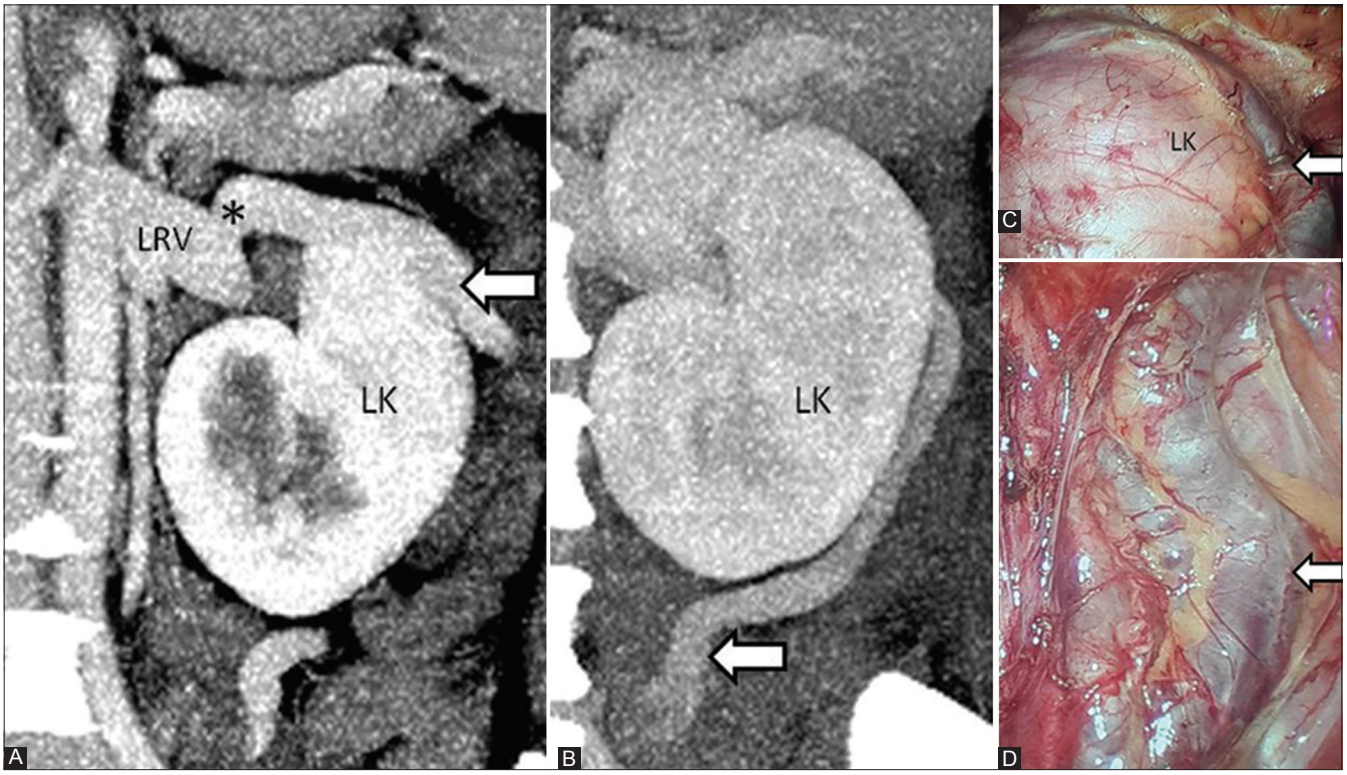

Figure 18 (A-D): (A and B) MDCT renal angiography coronal images and (C and D) corresponding laparoscopy image showing a prominent tortuous collateral vein (arrows). This is draining into the left renal vein along the superior aspect (*) and inferiorly communicates with the left-side iliac veins (not shown). The venous collateral is intimately related to left kidney and needs to be surgically dissected. [LRV: Left renal vein, LK: Left kidney]

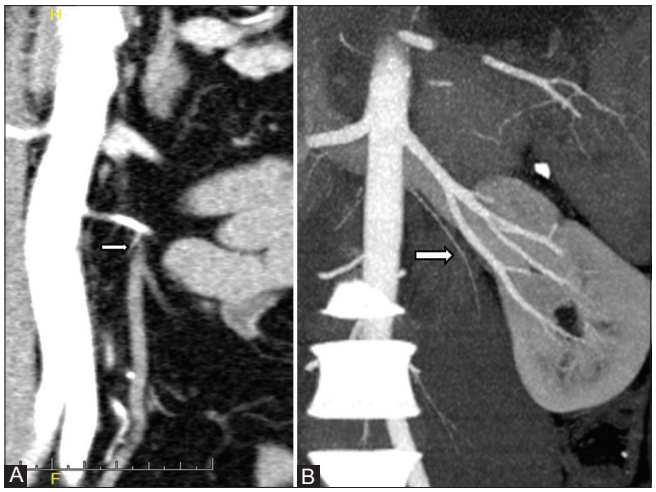

Figure 19 (A and B): MDCT renal angiography - coronal MIP images showing a prominent pyelo-ureteric branch from left lower polar accessory renal artery [small arrow in (A) and prominent left gonadal artery large arrow in (B)] these thin arterial branches are often seen on CTA and should be reported, as they are likely to provide major vascular supply to renal pelvis and the ureter

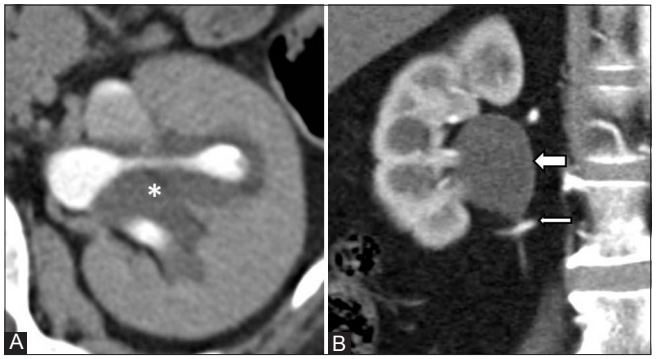

Figure 21 (A and B): (A) MDCT renal angiography - axial and (B) coronal images showing hilar lymphangioma (*) in panel A and pelvi-ureteric junction obstruction (arrow) in panel B. Presence of a crossing vessel is also noted (thin arrow). These non-vascular findings constitute an important component of MDCT donor evaluation

appropriate scan protocol and use of optimal post-processing methods, precise image interpretation is important to extract the desired pre-operative information. In a busy clinical practice, the performance of the reporting radiologist is expected to improve with the use of a standardized reporting checklist. This should correspond with prevalent surgical techniques in the hospital and may be developed in the department based on the surgical feedback and inputs. The "reporting checklist" we use in our hospital is presented in Table 2. MDCT report for pre-LDN evaluation of the living renal donor includes a detailed description of the renal morphology, including the vascular and pelvi-calyceal system. Comprehensive evaluation also includes a detailed description of renal vascular measurements as mentioned in Table 3. Apart from this, description of the regional anatomy including the relevant details about the neighboring structures is also given in the report.

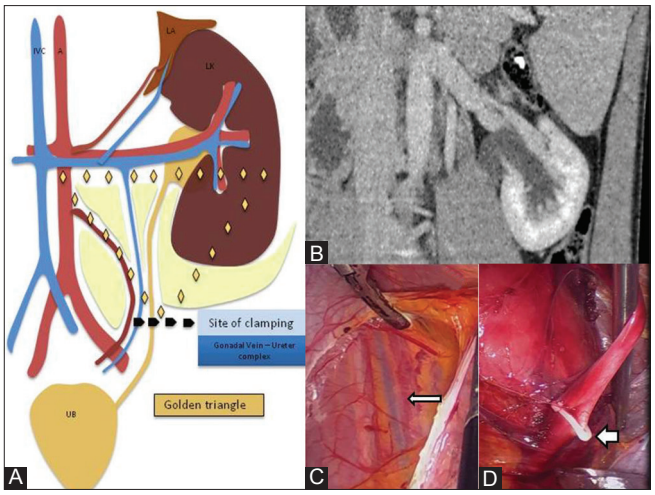

Figure 20 (A-D): (A) Line diagram and (B) corresponding CTA-coronal image intra-operative (C and D) images showing 'Golden triangle' confined by the lower pole of kidney, gonadal vessels and renal vascular pedicle (golden dots). The peri-ureteric fat in the triangle is preserved (arrow in C) and left ureter-gonadal vein complex is clamped inferior to the triangle (black dots in A; arrow in D). [LA: Left adrenal, LK: Left Kidney, IVC: Inferior Vena Cava, A: Aorta, UB: Urinary bladder]. [Laparoscopy images are rotated in accordance with CT images for comparison]

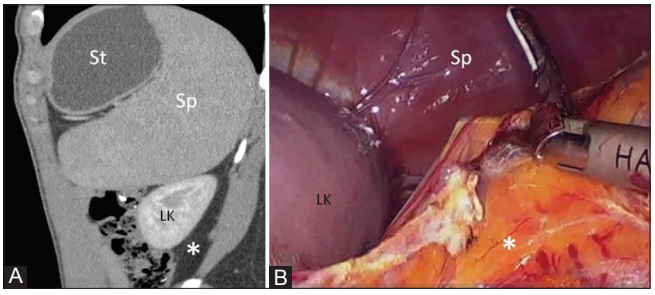

Figure 22 (A and B): (A) MDCT renal angiography - sagittal image and (B) corresponding laparoscopy image showing the important neighboring structures in the operative field during LDN. Presence of excessive fat in hilar and peri-nephric space (*) may interfere with surgical dissection and should be conveyed to laparoscopic surgeon [LK: Left Kidney, Sp: Spleen, St: Stomach]. [Laparoscopy images are rotated in accordance with CT images for comparison]

Conclusions

In recent times, LDN is rapidly evolving as the method of choice for renal harvesting in renal transplant programs. MDCT is the modality of choice for pre-transplant evaluation of potential living renal donors. Use of appropriate scan protocol and post-processing methods is necessary for accurate image interpretation and workflow efficiency. Apart from radiologist's expertise, detailed knowledge and understanding of surgical techniques is essential to attain these objectives in a renal transplant program. Case-based interactive discussions between surgeon and radiologist with continuous quality surveillance are the key to ensure accuracy and efficiency in pre-LDN MDCT evaluation of living renal donors.

Table 2: Proposed 'reporting check-list' for image interpretation and reporting of MDCT renal angiography study for pre-LDN evaluation of potential renal donors. Such a reporting checklist is based on inputs from the laparoscopic surgeons and may vary from center to center, depending upon the surgeon's preferences

Pre-LDN MDCT work-up : *Reporting Check-list …*
- Renal morphology - Location, length & axis.
- Renal lesions - Calculus / cysts / tumor / anomalies.
- Renal vessels - Number, types & caliber of main / accessory vessel.
- Accessory artery / veins - Inter-vessel distances / separation.
- Renal vein tributaries : Number, types & caliber.
- Arterial and venous vascular pedicle - measurements.
- Renal Pelvis and Ureter – Pelvi-ureteric junction.
- Status and amount of peri-renal / hilar fat.
- Presence and extent of atherosclerotic / other vascular diseases
- Upper/lower urinary infection / Tuberculosis.

Table 3: Comprehensive reporting (sample report) for vessel measurement in MDCT renal angiography study for pre-LDN evaluation of potential living renal donors

Pre-LDN MDCT work-up : *Vessel measurements …*

		Right Kidney	Left Kidney
1.	Proximal MRA lumen diameter	3mm	4mm
2.	Proximal MRA plaques	None	None
3.	Accessory arteries (calibre & type)	2mm, hilar	None
4.	Inter-arterial distance	3mm	-
5.	Proximal MRV lumen diameter.	7-8mm	10-12mm
6.	Ureteric arterial branch	-	-
	Renal vein tributaries	**Two RRV trunks with lateral insertion**	
7.	Gonadal vein	-	4-5mm
8.	Adrenal vein	-	2-3mm
9.	Lumbar / Ascending Lumbar veins	-	2mm
	Vascular Pedicle – Arterial		
10.	d [RRA origin – 1st segmental branch].	28mm	-
11.	d [LRA origin – 1st segmental branch]	-	18mm
12.	d[IVC – 1st segmental br' of RRA]	Retrocaval.	-
	Vascular Pedicle – Venous		
13.	d[RRV confluence – IVC]	-	-
14.	d[LRV confluence- IVC]	-	30mm
15.	d[LRV confluence – Aorta]	-	6-7mm

[All measurements in mm; MRA: Main Renal Artery; MRV: Main Renal Vein]

This approach will ensure that the amount of relevant information from pre-LDN MDCT scans is maximized, in this era of minimally invasive surgeries.

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