Research Article

Role of multidetector CT (64 Slice) in the evaluation of living potential donors for renal transplantation

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ABSTRACT

Background: Renal transplantation is the definitive therapy for the end stage renal disease. This study was undertaken to assess the role of MDCT (64-slice) in the preoperative evaluation of living potential renal transplantation donors for transplantation.

Methods: This prospective one year study included 31 potential living renal donors aged between 22-69 years, sent to the department of radio diagnosis for MDCT using 64-slice CT scanner. Nonionic IV contrast material (130-150mL) was given at a rate of 4-5 mL/sec. Arterial images were acquired by smart prep technique followed by venous phase after 20-25 second delay. Finally, excretory phase was taken after 8 minutes from the start of injection. KV of 120, mAs of 250-790 and collimations of 0.625 mm were used. CT data included determination of renal size, assessment of renal parenchyma (cyst, calculus, mass etc); depiction of renal arterial, venous, and urographic anatomy and identification of important vascular variants. Image processing included three-dimensional volume renderings, maximum intensity projections and multiplanar reformations.

Results: We identified surgically important vascular variants and renal parenchymal abnormalities. Of the 31 subjects evaluated, 4(12.9%) subjects were excluded on the basis of CT findings, due to vascular variants in 3 cases (9.7%) subjects and bilateral microliths in 1(3.2%). The surgical decision of right nephrectomy was taken in 2 (6.4%) cases due to complex vascular anatomy on left side depicted on CT.

Conclusions: Triple phase MDCT provided comprehensive parenchymal and vascular preoperative evaluation of potential living donors for renal transplantation, thus had an impact in deciding the suitability of donor and side of kidney to be harvested for nephrectomy. It provided a road map to the surgeons which helped them in surgical planning to reduce surgical complications.

Keywords: Multidetector CT, Living donors, Renal transplantation, Vascular variants, Surgical road map

INTRODUCTION

Renal transplantation is the definitive therapy for the end stage renal disease.[1-4] Insufficient supply of deceased donors, higher and longer graft and patient survival rates in living graft recipients in comparison to cadaveric graft recipients lead to preference of living donors. The suitability of the potential renal donors is determined after comprehensive imaging evaluation of renal vessels anatomy, renal parenchyma and upper urinary excretory system.[3,5,6] Imaging also helps to select which side of kidney to be harvested depending on vascular anatomy and variants. After the advent of laparoscopic approach of nephrectomy in 1995, it has become even more important to delineate the complex vascular anatomy and to identify the arterial and venous variants to avoid complications like excessive hemorrhage. Traditionally, anatomic screening of potential living renal donors has

been performed with intravenous urography and renal catheter angiography. The purpose of intravenous urography was to give idea about renal size and delineation of pelvicalyceal system, also renal or ureteric calculi. It was not giving any idea about vascular anatomy. The subjects with normal IVU findings and without any clinical contraindication will underwent conventional angiography. It is an invasive procedure with a large dose of radiation exposure and contrast administration. Furthermore, it tells only about arterial anatomy and does not give any information about venous anatomy. Volume CT angiography is a fast, safe, minimally invasive and quite accurate modality and presently has almost replaced excretory urography and conventional angiography in most places and has become an accepted method for pre-operative evaluation of living donors.[3,5,7.] With several advantages, like thinner section imaging, faster acquisition, improved longitudinal spatial resolution and isotopic viewing, Multidetector CT (MDCT) is now providing better details of vascular anatomy with greater confidence than single slice CT.

METHODS

This prospective study was approved by the review board of Narayana Multispeciality Hospital, Bangalore and informed consent was taken. We studied 31 subjects from Feb 2008 to May 2009, referred to our department for renal donor CT angiography after laboratory work-up and HLA cross-matching. Patients with absolute contraindications to intravenous contrast medium were excluded from the study.

CT protocol

All donors were scanned on 64-slice GE -Helical CT (GE High speed Advantage) scanner. The following technical parameters were used: KV of 120, mAs of 250-790, Rotation time of 0.50sec, table speed of 55 mm/rotation, detector Collimation: 0.625 mm, rows: 64×0.625, detector coverage: 40mm, slice Thickness: 0.625 mm, pitch: 1.375:1, standard algorithm, matrix size: 512× 512, Window setting: Abdomen and pelvis. No oral contrast was given. An 18 G venocath in a peripheral vein preferably in either of the antecubital fossa was used for intravenous access. The study was started with a scanogram of the abdomen, followed by a non-contrast study of the abdomen covering from domes of diaphragm upto the pubic symphisis. This was followed by 2 phase (arterial and venous) CT renal angiography covering from the right dome of diaphragm upto iliac crest and excretory urography covering from the dome of diaphragm to pubic symphysis. Non-ionic contrast medium namely, Iohexol 350 available as Omnipaque was routinely used. 120-150 ml of contrast medium was injected at the rate of 4-5 ml /second using a power injector. Arterial phase was done using smart prep technique, 20-25 sec delay (from arterial phase) for venous phase and 8 min delay (from start of injection) for excretory phase.

Image Processing

Axial images were reconstructed with a standard algorithm, and postprocessing was performed on a commercially available workstation (Advantage windows 4.2; GE medical systems). For the arteries, volume rendering (VR) and maximum intensity projection (MIP) were performed with the arterial phase data. The venous anatomy was mainly delineated on MIP images. The axial images were carefully scrutinized before volume rendering. Care should have been taken while choosing threshold. For the CT urography thick slab coronal maximum intensity projection were used with different degree of obliquity and arbitrary slab thickness.

Image Interpretation

The study was considered technically adequate if there was visualization of the vascular structures in all phases sufficient to permit image reconstruction. The documentation of renal size and parenchymal abnormality had been done. The cysts were optimally visualized in the venous phase images as well defined fluid attenuation hypodensity in the well enhanced parenchyma. The vessels length and caliber were measured on thin slab MIP images with different degree of obliquity. The arterial length was measured from its aortic origin to its first branch. It had been termed as prehilar branching when it branched within 2 cm from the aorta.[1] Number, course and the supply of the accessory arteries were noted on either side. The length of the vein was measured from its IVC confluence to pelvis. A late venous confluence was diagnosed on the left side when venous branches converge within 1.5 cm from the left lateral wall of abdominal aorta and on the right side when venous branches converge within 1.5 cm of the confluence with the IVC.[20] Number and caliber of the tributaries to the renal vein were noted on either side, mainly left side. Each study was evaluated for possible anatomic exclusion criteria.

RESULTS

There were 15(48.3%) males and 16(51.6%) females. The mean age of the subjects was 36 yrs and most of the patients (45%) belonged to 31-40 age group.The study was technically adequate with optimum opacification of renal arterial and veins. Of the 31 patients evaluated, 4 patients (12.9%) were considered unfit for renal donation. 3 patients (9.6%) were excluded from surgery based on vascular variants- 2 due to complex arterial anatomy another due to complex venous anatomy. One (3.2%) donor was excluded due to bilateral calculus disease. The decision of right nephrectomy was taken in two cases on the basis of complex vascular anatomy on left side. The first excluded case was having bilateral accessory arteries, which were arising very close to main renal arteries. Over that the main left renal arteries showed very early prehilar branching with ultrashort proximal segment of 3mm and right accessory artery also had

prehilar branching with ultrashort main segment of 2 mm. The second case of complex arterial anatomy also showed multiple arteries, 2 on right and 2 on left. Both the accessory arteries were arising very near (< 5 mm) to main renal arteries origin. The left accessory artery was arising proximal to main renal artery, having a downward course in front of renal pelvis to supply the lower pole. Among the 62 examined kidneys, 15 (24%) were shown to have more than one artery, all arising from abdominal aorta; none of the examined kidneys demonstrate more than 2 arteries. Eight of the accessory arteries were on right side and seven on left as shown in Table 1.

Table 1: Side distribution of accessory arteries.

Side	Number	%
Right	8	53.33
Left	7	46.66
Total accessory arteries	15(out of 62 kidneys) Incidence-24.19%	100

Five of the cases demonstrated bilateral accessory arteries. There was significant predominance of accessory artery supply to lower pole (14 out of 15). No accessory artery was originating from iliac arteries. The average lengths of right and left main renal arteries was found to be very variable ranging from 3.7 mm to 51 mm (mean length 21.04 ± 13.72) and 1.1 mm to 82 mm (mean length 12.85 ± 16.61). Out of 62 arteries, 11 demonstrated prehilar branching. Prehilar branching was defined as a branch within 2 cm from the aorta. The early origin of adrenal artery from renal artery was not considered as prehilar branching. One of the right accessory artery also demonstrated prehilar branching with the length of 7.2 mm as given in Figure 1.
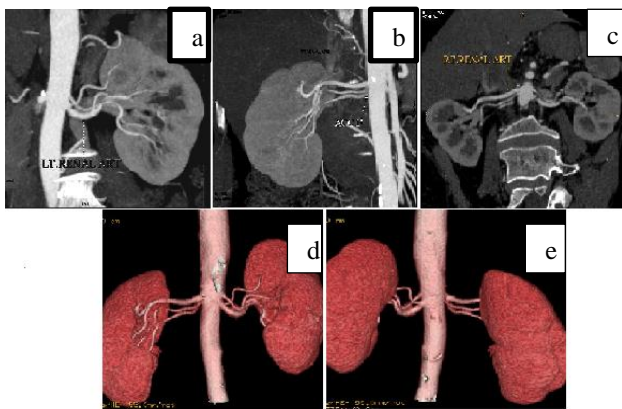

Figure 1: Bilateral complex renal artery anatomy. Renal angiography in 56 year old female - 1(a) and 1(b) are thin coronal MIP of right and left kidneys respectively, 1(c) oblique axial MIP and 1 (d and e) volume rendered images (anterior and posterior aspect) of both kidneys demonstrating bilateral accessory arteries with origins very close to main renal arteries, also prehilar branching of left main and right accessory artery with ultrashort segments.

Major venous variants were present in five of the cases, accessory renal vein being the most common venous variant found in four. Circum-aortic renal vein was noted in one case as seen in Figure 2.

Figure 2: Axial MIP (a) and VR (b) images of venous phase in a 24-year-old female show circumaortic left renal vein.

Retro-aortic renal vein variant was not present in any of the examined cases. Late confluence of renal veins was noted in five cases, three on left side, and two on right side. Minor variants were noted 15 of the cases and were related to the tributaries. Most common was multiple tribuatries found in 19% of the cases as given in Table 2.

Table 2: Prevalence of minor venous anomalies.

Minor venous variants	No.	%
Multiple left venous tributaries	6	19.35
Prominent left lumbar vein	4	12.9
Prominent left gonadal vein	2	6.45
Tributaries draining in distal left gonadal vein near its renal vein confluence	3	9.67
Left lumbar vein draining to IVC	1	3.22
LLV and LGV forming a common confluence before draining	1	3.22
Total	17	

The tributaries were mentioned as prominent if it measures more than 5mm in caliber. Any tributaries draining to gonadal vein very close to its renal vein confluence was also mentioned. Small cortical cysts were present in six cases (19.4%), the largest cyst being 12 mm. Three of the donors (9.7%) demonstrated small renal calculi, largest one being 4 mm. The nephrectomy had been done in 23 of the donors by open approach. Surgical correlation from the surgical notes and feedback from the surgeons was obtained. No discrepancy was noted on surgery in terms of number and length of renal arteries and the main renal veins. Some surgical discrepancy was noted regarding the number of left renal vein tributaries. The maximum of 6 tributaries (duplication of all three standard left renal vein tributaries) were present in one case, but CT could identify only 4. The two non-documented tributaries could not be visualized on retrospective examination. In another case there were 5

tributaries but only 4 could be identified on CT. Isolated duplication of left lumbar and left gonadal veins was noted in 1 and 2 cases respectively. Incidental extrarenal abnormalities were demonstrated in 32% of our cases including liver hemangioma (6%), calcified granuloma in liver (3%), bulky uterus and ovarian cysts (6% each), prostatomegaly and splenomegaly in 1 case each (3%). Median arcuate syndrome with arcade of Buhler was noted in one of the case as given in Table 3.

Table 3: Incidental extra-renal pathology.

Extra-renal pathology	Number	%
Liver hemangioma	2	6.45
Calcified granuloma liver	1	3.22
GB calculus and polyp	2	6.45
Ovarian cysts	2	6.45
Bulky uterus	2	6.45
Prostatomegaly	1	3.22
Median arcuate ligament syndrome	1	3.22
Splenomegaly	1	3.22
Total	12	

DISCUSSION

A renal donor must have two kidneys of normal size and position. The exclusion criteria for donor nephrectomy include presence of a renal anomaly such as unilateral agenesis, renal ectopia, horseshoe kidney, multiple renal arteries, renal arterial disease, complex venous anatomy (circumaortic or retroaortic left renal vein), renal neoplasm, hydronephrosis, cortical atrophy, medullary sponge kidney disease, renal papillary necrosis, retroperitoneal varices, polycystic disease, the presence of a single calculus larger than 5 mm or of multiple calculi. In our study 4 patients had been excluded for nephrectomy, two due to complex arterial anatomy, one due to complex venous anatomy and another due to bilateral multiple calculi. Routinely left kidney is chosen for nephrectomy as it has a long pedicle. Selection of the kidney to be harvested also depends on the vascular anatomy, surgical technique, surgeon's preference and associated pathology if found incidentally. It should be kept in mind that the healthy kidney to be left in the donor and the other harvested for the recipient. First normal size, location, and function of donor kidneys is confirmed, than a precise delineation of the donor kidney's vascular and collecting system anatomy should be made as a prerequisite for presurgical planning. In our study, decision of right nephrectomy was taken on the basis of complex arterial anatomy on left side. We used smart prep technique for the initiation of arterial phase after starting of contrast. By this technique, optimum contrast opacification was obtained in abdominal aorta and renal arteries. In the prior studies, with fixed time delay, contrast might not reach in renal aorta at the same time due to different hemodynamic, rate of contrast administration and volume of contrast used, hence resulting in suboptimal opacification. With 64 slice MDCT, the complete scan area (25-30 cm) could be covered in 5-8 seconds, resulting in lesser period of breath-holding required and thus decreased motion artifact and better contrast-bolus use. The thin collimation of 0.625 mm made visualization of even very small caliber vessels (even <1 mm) possible. The isotopic viewing resulted in 3D reconstructions in sagittal, coronal or any other desired plane with the same resolution as in axial sections. This property was utilized in defining the complex anatomy, to demonstrate the vessel origin and to resolve the controversy of accessory artery versus prehilar branching with ultrashort segment. The vascular variants are quit common. In our series we identified multiple renal arteries in 24% of 62 kidneys, comparable with the results by Kim et al [2] and Kawamoto et al.[5] Bilateral accessory arteries were demonstrated in 16% of the donors quite comparable with the study done by Kawamoto et al.[5] CT angiographic findings agreed with surgical findings in all the 23 cases undergoing nephrectomy. These results are higher in comparison to most of the standard studies done with single and multidetector (4 or 16 slice) spiral CT. All the accessory arteries were delineated on axial images as well as 3D reconstructions achieving 100% accuracy, similar to that of conventional angiograph. The earlier studies showed difficulty in demonstrating small caliber (<3 mm) accessory arteries. In our study three of the detected accessory arteries were less than 3 mm in caliber and were easily visualized throughout their course. The identification of renal arterial branches arising from within 2 cm of origin of the renal artery is also very important. The main renal artery must be long enough to allow sufficient cuff on either side of a 3-5 mm clamp when the vessel is cut. In our study, we found prehilar branching in 17.7% of the 62 studied kidneys, comparable with the prior studies by Kawamoto et al, Rubin et al, Ratner et al , Platt et al which showed the prehilar branching in 7-21% of the cases.[1,7-9] 3D reconstructions were more useful than axial sections for the identification of prehilar branching. Detection of venous variants is an advantage of multiphase MDCT over conventional angiography and is very important for laparoscopic nephrectomy. Major and minor venous variants were noted in 16% and 48% of the cases respectively. Accessory renal vein was most common major was found in 13% cases, comparable with study by Kawamoto et al.[1] Late confluence of renal vein was noted in 16% of cases, 10% on left side and 6% on right side; slightly lesser than the study done by Raman et al which demonstrated it with the incidence of 17% and 10% on left and right side respectively.[12] There was 100% surgical correlation for the number of the renal vein on CT.

The minor variants had been noted in 48% of the cases, all were on left side. Multiple left renal tributaries being most common among all, was present in 19% of cases. Some surgical discrepancy was noted regarding the number of left renal vein tributaries. The other common

minor variant was prominent renal vein tributaries. It was denoted as prominent when they were more than 5mm and related to increase incidence of per-operative bleeding. Prominent lumbar and gonadal veins were noted in 13% and 6% subjects respectively. Few less common minor variants were common confluence of gondal and lumbar vein in left renal vein (3%), draining of left renal vein in IVC (1%), some nonspecific tributaries draining into distal left gonadal vein (10%).

In our study we observed that although the overall frequency of venous variants was higher on the left side than on the right side kidneys, the frequency of major venous anomalies, such as supernumerary veins, was higher for right-sided kidneys (10% versus 3%), like the study by Raman et al [12], which had shown the ratio of 24% versus 8%.

Limitations Surgical confirmation for the cases with complex arterial anatomy and major venous variants could not be obtained as these cases were either not operated or the contra-lateral kidney was chosen for nephrectomy. In case of minor venous variants, inadequate surgical notes and feedbacks were available, as nephrectomy was done with open approach and minor variants did not much affect the surgeons. The other main adverse point about our study was high doses of radiation with 64-slice CT. The mean weighted CT dose index was 19.5 mGy for all the phases

CONCLUSION

The MDCT correctly identified the necessary exclusions for the renal donation and helped to decide the side of the kidney to be harvested on the basis parenchymal and vascular findings. The accuracy of detection of renal arterial variants with 64-slice MDCT was 100%, which is either comparable or more than conventional angiography or other lesser slice CT. The major renal vein variants could be identified with 100% accuracy, which is not possible with conventional angiography. Minor venous variants also could be detected with acceptable accuracy. The knowledge of vascular anatomy and high quality 3D display obtained with thin collimation provided a vascular map to surgeons for avoiding complications.

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