Original Article

Comparison between helical computed tomography angiography and intraoperative findings

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Abstract

Background: Live donor nephrectomy has gained popularity on account of the laparoscopic technique, to overcome a small donor pool. Laparoscopic donor nephrectomy requires a precise study of the vascular and morphological renal anatomy, as laparoscopy is technically challenging due to the limited field of vision. In-depth knowledge of the renal anatomy before a laparoscopic procedure is essential for a successful transplant. The left kidney is preferred over the right even in cases of multiple vessels because of the long renal vein, which requires precise preoperative vascular mapping. Helical computerized tomography (CT) angiography, with its axial, coronal, and 3D reconstruction, gives a better understanding of renal anatomy. There are instances where the helical CT findings are misleading and less informative in a small number of cases. This study highlights a case study of the helical CT findings compared with the intraoperative findings of 200 live donors, who underwent laparoscopic donor nephrectomy, and the renal anatomy has been understood at the same time.

Aims: 1. To compare the helical CT findings on the operated side with the intraoperative findings. 2. To analyze the CT findings

Materials and Methods: Two hundred cases of laparoscopic transperitoneal donor nephrectomy were included in this study.

Statistical Method Used: Chi square test was the statistical test used to compare the findings between CT and the intraoperative data.

Results: The axial, coronal, and 3D images of the CT findings were on par with the intraoperative findings in most of the cases. Incidental findings help in the better planning of surgery. Multiple vessels on the left side are preferred over the right sided normal anatomy; with not much technical difficulty with the aid of a helical CT. Male donors had more incidences of multiple vessels, gonadal vein, Retroaortic Renal Vein (RARV), lumbar vein, and duplication of ureter, compared to females. Furthermore, these variations are more in the left side donors. Ninety-two percent of the cases in this study are left-sided donors. The helical CT finding shows that renal vein variations are more on the right side.

Conclusions: Helical CT is important in delineating the arterial, venous, and ureteral anatomy and can show the important incidental findings. Left renal donors and males have more variations in their renal anatomy. Technically challenging laparoscopic nephrectomy on the multiple-vessel-side donor is possible with the aid of helical CT. The importance of the CT in evaluating donor renal anatomy for a technically challenging laparoscopic donor nephrectomy is commendable.

Key Words: Computerized tomography, laparoscopic left donor nephrectomy, laparoscopic right donor nephrectomy, laparoscopic donor nephrectomy, retroaortic renal vein

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INTRODUCTION

On account of limited operative visibility and surgical exposure, laparoscopic donor nephrectomy requires precise preoperative vascular mapping. In addition to evaluating the renal artery, the status of the donor kidney and collecting system and the anatomic definition of the renal venous system are important for living laparoscopic donor nephrectomy. With the recent advances in helical CT, it has replaced traditional angiography and the intravenous pyelogram (IVP) for the evaluation of live kidney donors.[1] The less invasive, cost-effective helical CT, axial coronal, and 3D reconstruction findings are similar to the traditional invasive angiography findings.[2]

The capability of a helical CT, including its fast data acquisition and narrow collimation, is valuable for angiographic applications because of greater anatomic coverage, increased contrast opacification of the arteries, and higher longitudinal spatial resolution. The reported accuracy of a helical CT in the evaluation of the renal vein anatomy ranges from 93 to 100%.[3-5]

Although the evaluation protocols vary between transplant centers, general guidelines have been developed.[6] In addition to the standard history and examination, a laboratory evaluation is performed. Patients with significant risk factors for chronic kidney disease are excluded from kidney donation.[7] Protocol renal imaging has also become a component of potential kidney donor evaluation. Imaging of the kidneys and renal vessels not only defines the surgical anatomy, but also detects the occult pathology that might preclude donation.[8]

The renal vein is the most important venous structure that needs to be evaluated before laparoscopic surgery. It is important to detect the retroaortic and circumaortic renal veins because of the potential for inadvertent venous injury. Left adrenal and gonadal vein visualization on preoperative imaging may facilitate the dissection of these veins and help avoid vascular injury.

In general, the left side was preferred because of the anatomical long renal vein, even in cases of multiple vessels on the left side and a normal anatomy on the right side. The right side was preferred in women of childbearing age, because the left may be spared from hydronephrosis during pregnancy.[2]

The findings of a CT were used as a guide selection of the donor kidney. However, if the anatomy was normal, the left kidney was preferred.[1,2,9] The surgeon noted the number of renal arteries and the presence of early branching (defined as originating <1 cm from the aorta). The discoloration was noted, which suggested the possibility of a transected small accessory vessel not detected before nephrectomy.

MATERIALS AND METHODS

Donors with a history of diabetes mellitus, hypertension, morbid obesity, active drug use, psychiatric disorders, positive virology, significant cardiovascular disease or a history of nephrolithiasis were excluded. All patients underwent laboratory investigation, documented histocompatibility, and helical CT, as part of their kidney donor evaluation protocol between 2010 and 2012. All patients underwent an enhanced and non-enhanced helical CT with coronal and 3D reconstruction made up from the overlapping reconstructions. All CT scans were interpreted independently and compared with the intraoperative findings. After ethical committee clearance, 200 consecutive donors underwent laparoscopic transperitoneal laparoscopic donor nephrectomy with no open conversion. The findings on CT were compared with the intraoperative findings on the operated site. The CT finding results from both sides were interpreted in the same population. Details about the vascular anatomy and morphology variations were abstracted.

A helical scan was taken on inspiration [GE 120 kv, smart mA (100-450)/0.7 second, 1.375: 1 pitch, 55.00 mm speed, 40 mm beam collimation, 55-second scan delay]. Thirty milliliters of Iohexol (Omnipaque 350) followed by 40 mL of saline prior to scouts, then a five-minute delay followed by 100 mL Iohexol (Omnipaque 350), 3 mL/second, 55-second scan delay. After a scout scan was obtained, an unenhanced scan was obtained through the kidneys, either helical or axial. On the basis of the unenhanced images, a scanning range from the level of the celiac axis to the mid pelvis was selected. The patients were hyperventilated before scanning was performed and instructed to suspend inspiration when the scan was obtained. If they could not hold their breath for the duration of scanning, they were instructed to exhale as slowly as possible. Helical CT scans were obtained through the kidneys to better evaluate the parenchymal abnormalities. A further delayed scan was obtained for visualization of the ureters and bladder. Opacification of the renal veins with the use of late arterial and venous phase images was done. The helical CT dataset was reconstructed; 2D and 3D images were evaluated for the number of renal vessels, the presence or absence of early branching, and morphological anomalies.

RESULTS

Out of the 200 cases, 184 cases underwent left laparoscopic donor nephrectomy and 16 underwent right laparoscopic donor nephrectomy [Table 1]. In 184 cases 151 had single vessel, 31 had a double vessel and two had a triple vessel. Only four cases in LLDN had early branching. Only one case of triple vessel was interpreted as a double vessel in Helical CT. Similarly 183 cases had single vein and one case had double

vein. Helical CT interpreted a case of double vein as single. The rest of the arterial and venous anatomical findings were similar to the operative findings. There were seven cases of retroaortic renal vein, two cases of gonadal vein, and two cases of double ureters in the left-sided donor nephrectomy, which were on par with the helical CT. Sixteen cases, who underwent laparoscopic right donor nephrectomy, had a single artery and vein matching the helical CT findings. There was no evidence of retroaortic renal vein, gonadal vein or double ureter. Incidence of single, double, and triple vessels on LLDN in our study was 82, 17, and 1% [Table 2].

Findings on the lumbar vein anatomy were on par with the helical CT findings, except in two cases, where a case of quadruple and triple lumbar was interpreted as a double on LLDN.[Table 3] The lumbar vein anatomy was highly variable in individual patients and the variations were more on the left side. Only one case had a double left adrenal vein in a male patient, which was detected on CT. Two male donors had double gonadal and dual ureters on the left side , which were well-interpreted before surgery. Four male patients and three female patients had RARV on the left side, coinciding with the CT findings.

The incidence of variation was more in males, left side more than the right side with respect to the renal artery, renal vein, RARV, and gonadal and lumbar veins. Double and triple artery incidences were16 and1%, respectively, and when compared to females it was 15 and <1% on the left side. Incidence of dual vein was 1%, seen only in males and only on the left side. Dual gonadal vein and dual ureter were found only in males and on the left side.

Lumbar vein variations were more in males, on the left side, with equal incidence of single and double lumbar veins. Females had a more consistent lumbar vein anatomy, with a single lumbar vein; and the next most common was the double lumbar vein.

As the CT findings were on par with the intraoperative findings, the findings on the non-operated side were considered accurate and the renal anatomy was analyzed. [Table 4] Eighty-seven (47.5%) cases had a normal anatomy. The high incidence of multiple vessels was 53.5%. The incidence of single artery was less on the left (71.5%). The incidence of a single artery on the right side was 72.5%. Similarly incidence of a solitary renal artery on one side and multiple on the other side was found to be less on the left side (18 and 19. 5%); One hundred and eighty cases had a single vein on either side with 198 (99%) on the left and 180 (90%) on the right. One percent of the cases had a double vein on both sides and 1% of the cases had a triple vein on the left side, with no incidence of a triple vein on both sides.

The lumbar veins were single in 177 cases on the right side, draining to the inferior vena cava, 19 had double, and four had a triple vein on the CT. One hundred and eight and 73 cases of the left side had single and double lumbar vein, three cases had quadrupled, eight cases had triple, and eight cases had no lumbar vein. There was no evidence of RARV or gonadal and ureteral anomalies over the non-explored sides.

Table 2: Representing intraoperative statistics

	Male (%)	Female (%)
Number	94 (47)	106 (53)
LLDN	87 (43.5)	97 (48.5)
LRDN	07 (3.5)	09 (4.5)
Single artery	78 (39)	89 (44.5)
Double artery	15 (7.5)	16 (8)
Triple artery	01 (0.5)	01 (0.5)
Single vein	92 (46)	106 (53)
Double vein	02 (1)	00 (0)

Table 1: Represents the correlation of venous and arterial anatomy in CT and LDN

Lldn (M vs. F) 184 (87 vs. 97)	Single vein (M vs. F)	One acessory vein (M vs. F)	Two acessory veins (M vs. F)	Early tributary (M vs. F)	Rarv (M vs. F)	Double gonadal (M vs. F)
CT Findings	86 vs. 97	1 vs. 0	Nil	Nil	4 vs. 3	2 vs. 0
Operative findings	85 vs. 97	2 vs. 0	Nil	Nil	4 vs. 3	2 vs. 0
LRDN 16 (7 vs. 9) (M vs. F)	Single vein (M vs. F)	One acessory vein (M vs. F)	Two acessory veins (M vs. F)	Early tributary (M vs. F)	Rarv (M vs. F)	Double gonadal (M vs. F)
CT findings	7 vs. 9	Nil	Nil	Nil	Nil	Nil
Operative findings	7 vs. 9	Nil	Nil	Nil	Nil	Nil
LRDN (M vs. F) 184 (87 vs. 97)	Single artery (M vs. F)	One acessory vein (M vs. F)	Two acessory arteries (M vs. F)	Early branching (M vs. F)		
CT Findings	71 vs. 80	15 vs. 16	1 vs. 1	1 vs. 3		
Operative findings	71 vs. 80	14 vs. 16	2 vs. 1	1 vs. 3		
LRDN 16 (7 vs. 9) (M vs. F)	Single artery (M vs. F)	One acessory vein (M vs. F)	Two acessory artery (M vs. F)	Early branching (M vs. F)		
CT findings	7 vs. 9	Nil	Nil	Nil		
Operative findings	7 vs. 9	Nil	Nil	Nil		

Positive predictive value and negative predictive value for venous anatomy in LLDN correlation is 99.5. Similarly for arterial anatomy in LLDN it is 96.8. It is 100 for arterial and venous anatomy in LRDN, LLDN: Laparoscopic left donor nephrectomy, LRDN: Laparoscopic right donor nephrectomy, CT: Computerized tomography

Table 3: Representing correlation of lumbar vein anatomy in CT and LDN

	No lumbar vein (M vs. F)	One lumbar vein (M vs. F)	Two lumbar vein (M vs. F)	Three lumbar vein (M vs. F)	Four lumbar vein (M vs. F)
LLDN	6 (4 vs. 2)	99 (39 vs. 60)	70 (37 vs. 33)	7 (5 vs. 2)	2 (2 vs. 0)
CT	6 (4 vs. 2)	99 (39 vs. 60)	72 (39 vs. 33)	6 (4 vs. 2)	1 (1 vs. 0)
LRDN	Nil	15 (6 vs. 9)	1 (1 vs. 0)	Nil	Nil
CT	Nil	15 (6 vs. 9)	1 (1 vs. 0)	Nil	Nil

CT: Computerized tomography, LDN: Laparoscopic donor nephrectomy, LLDN: Laparoscopic left donor nephrectomy, LRDN: Laparoscopic right donor nephrectomy

Table 4: Exclusive CT findings on arterial and venous anatomy of 200 cases

Single artery on left	153 (76.5%)	Single vein on left	198 (99%)
Single artery on right	155 (77.5%)	Single vein on right	180 (90%)
Single artery on both sides	87 (43.5%)	Single vein on both sides	180 (90%)
Single artery on left and multiple on right	36 (31 vs. 5) (Double artery vs. Triple artery) 18% (15.5 vs. 2.5%)	Single vein on left and multiple on right	16 (8%)
Single artery on right and multiple on left	39 (33 vs. 6) (Double artery vs. Triple artery) 19.5% (16.5 vs. 3%)	Single vein on right and multiple on left	2 (1%)
Double on both sides	11 (5.5%)	Double vein on both sides	2 (1%)
Double on right and triple on left	1 v 1 (LLDN vs. LRDN) 1% (0.5 vs. 0.5%)	Double vein on right and triple on left	NIL (0%)
Double on left and triple on right	1 v 1 (LLDN vs. LRDN) 1% (0.5 vs. 0.5%)	Double vein on left and triple on right	NIL (0%)
Triple vessel on both sides	1 v 1 (LLDN vs. LRDN) 1% (0.5 vs. 0.5%)	Triple vein on both sides	NIL (0%)
		Triple vein on right and single on left	2 (1%)
		Multiple vein on both sides	18 (9%)

CT: Computerized tomography, LLDN: Laparoscopic left donor nephrectomy, LRDN: Laparoscopic right donor nephrectomy

DISCUSSION

2D and 3D reconstruction may be valuable in showing the vascular anatomy. Most of the important information can be found on axial images. Surgeons need to know if the accessory arteries, early arterial branching, venous variants, and ureteral duplication are present.[9-12] Occasionally, an accessory vessel or early branching (variably defined in literature as within 1-2 cm of the aorta, in this study it was 1 cm) is detected only or primarily on 3D images. Detection of an accessory vessel and its course helps surgeons to avoid inadvertent laceration of an accessory vessel, which can cause a focal renal infarct. This simplifies the surgical procedure; however, missing a minute accessory vessel probably does not affect the patient outcome, because the renal volume loss and bleeding are negligible.[11]

In case of an insignificant renal vessel, this can be sacrificed, avoiding unnecessary dissection and time consumption. A 3D image gives a better orientation of this vessel. Furthermore, the width and length of the accessory vessel on a CT angiogram helps the surgeon decide the side of donor nephrectomy, and whether to save or sacrifice the accessory vessel. Early branching, which is seen well on 3D images, helps the surgeon to decide the side of donor nephrectomy.

Other incidental findings such as renal calcifications, cysts, scarring, masses, gall stones, and hepatic hemangiomas may be detected on unenhanced and enhanced CTscans.[13,14] In our study some female donors underwent vaginal-assisted donor nephrectomy. A CT helped to evaluate a fibroid or bulky uterus, thus helping in proper pre-operational planning, in terms of extraction of a kidney. Individuals with accessory renal arteries and congenital lobulation were never considered harmful, in that, they precluded donation. Even cases of ureteral duplication and gonadal vein did not complicate a successful transplant.

The incidences of single, double, and triple vessels on LLDN in our study are 82, 17, and 1%, which are higher than in the previous studies. In LRDN, all cases had a single vessel, as the right side was chosen only in cases of difficult LLDN. In LLDN, the polar arteries or arteries with less significant blood supply to the kidney parenchyma were sacrificed. In cases of significant vessels, the vessels were anastamosed separately or were tailored and anastamosed as a single vessel. In triple vessel cases a polar artery with insignificant blood supply was sacrificed and the other two arteries were dealt with in a similar fashion as the double vessel. In some cases all the three arteries were anastamosed separately or sewing of two vessels helped to anastomose the triple artery into a double vessel. These maneuvers helped to avoid right donor nephrectomy even in case of multiple vessels on the left side. In this study all cases of right donor nephrectomy had a single vessel.

Lumbar vein anatomy was highly variable in individual patients and almost always on the left side. The most consistent position draining into a main vein, in our case, was the lumbar vein arising from the posterior surface of the left renal vein. The next common location was the inferior surface of the left renal vein. In some cases double, triple, and sometimes quadruple lumbar veins became one before draining into the main vein. In rare cases the lumbar vein drained into the superior surface of the renal vein, to the gonadal vein, or to the RARV. On the right side it was more consistent draining into the inferior vena

cava, only one case had additional drainage to the right gonadal vein. The size of lumbar vein has been variable in most of the cases, often confusing it with the lymphatics .

Only one case had a double left adrenal vein in a male patient, which was detected on a helical CT. Two male donors had a double gonadal and dual ureter on the left side, which were well-interpreted before surger y. The dual ureteric lumen was tailored as a single lumen and anastamosed to bladder.

CT findings on either side in 200 cases:
The incidence of multiple vessels, 53.5% compared to 25%,[15] as reported in another study was probably due to the acceptance of multiple vessel cases for LDN, as triple vessel and double vessel cases underwent LDN. In general, the prevalence of renal artery abnormalities in our study was comparable to that found in other studies. Accessory renal arteries involved 23.5% of the left kidneys and 22.5% of the right kidneys, similar to the previously reported prevalence of 16 to 32% in the left kidneys and 22 to 39% in the right kidneys.[16-21]

The incidence of left venous abnormalities in our series is similar to that reported previously. Previous studies showed that the incidence of multiple right renal veins ranged from 11 to 28% and that of multiple left renal veins was 1-2%.[18,19] Multiple left gonadal veins were reported to occur in approximately 15% of the people,[18] but in our case it was 1%. The retroaortic renal vein was found in 3.5% of the subjects in this study, compared to the reported 2-3%.[18]

The left side showed more variation compared to the right in terms of the renal artery, renal vein, gonadal vein, lumbar vein, RARV, and ureteral duplication. On the basis of the above findings a surgeon should be well-versed with variations on the left side, as the left is more preferred for donor nephrectomy. However, the CT findings in the same donor pool cases showed renal vein anomalies, more on the right side. . The rest of variation was found more on the left side.

In general, the prevalence of renal artery abnormalities in our study was comparable to that found in other studies The accessory renal arteries involved are similar to the previously reported prevalence of 16 to 32% in the left kidneys and slightly less, 22 to 39%, in the right kidneys.[16-21]

The imaging modalities are meant to evaluate renal hilar vascular anatomy accurately for both renal donors and recipients. It should be less morbid and yet accurately predict the renal anatomy, stone disease, renal parenchymal lesions, and other intra-abdominal pathologies. Various methods for imaging of kidneys prior to nephrectomy can be done by ultrasound, conventional angiography, digital subtraction angiography, computed tomography, and magnetic resonance imaging, each of which has innate problems

Traditionally, excretory urography and renal catheter arteriography have been used to evaluate potential kidney donors. More recently, helical CT angiography has been shown to be an equally accurate alternative to more invasive methods, for surgical planning and guidance.[10] There is excellent agreement among CT angiography, catheter angiography, and surgery, in predicting the number of renal arteries and the presence of early branching.[13]

The gold standard technique is digital subtraction angiography, but with limitations of being invasive and traumatic. It has significant limitations to show renal veins andparenchymal lesions.[22] MDCT angiography offers non-invasive imaging with a minimal risk of morbidity. CT angiography has improved accuracy of venous imaging, extravascular anatomy, and intra-abdominal organs when compared to DSA.[23,24] MDCT has better venous and arterial imaging.[3,4] MDCT has an advantage over angiography in the evaluation of the venous system. MDCT is very highly accurate in evaluating donor anatomy, it is less invasive, less morbid, and provides an extrarenal anatomy when compared with the other imaging modalities.

MR angiography is another important modality for the preoperative evaluation of livingkidney donors. Recent studies of gadolinium-enhanced MR angiography have shown that it has high rates of accuracy and is comparable to conventional angiography and CT angiography in the evaluation of living kidney donors for nephrectomy. MR imaginghas the additional advantage of avoiding ionizing radiation and potentially nephrotoxic contrast agents, but it is inferior to MDCT in detecting multiple renal arteries.

CONCLUSION

Helical CT is important in delineating the arterial, venous, and ureteral anatomy, and can show important incidental findings. Left renal donors, specifically males, have more variations in their renal anatomy. Technically challenging laparoscopic nephrectomy on multiple vessel side donors is possible with the aid of the helical CT. The importance of a CT in evaluating donor renal anatomy for a technically challenging laparoscopic donor nephrectomy is commendable.

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