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Utility of 16-multidetector CT angiography in the preoperative evaluation of vascular and ureteral anatomy of donor nephrectomy

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Abstract

Objective: To evaluate the accuracy of 16-section multi-detector row computed tomography (MDCT) angiography in the preoperative evaluation of renal transplant donors in comparison with intra-operative findings.

Patients and methods: In this prospective study 89 consecutive renal donors (69 men and 20 women) underwent 16-MDCT angiography followed by open surgical donor nephrectomy from January 2008 to March 2010. We reported the number and origin of renal arteries and the presence of early branching arteries. Renal venous anatomy was evaluated for the presence of major and minor venous anomalies. The renal calyces and ureters were assessed with delayed excretory phase images. On a 3D workstation, images were evaluated by the radiologist and the urologist. These CT angiography results were compared with surgical findings.

Results: The mean age of the donors was 31 years. Open donor nephrectomy was performed on the left in 52 and on the right in 37 subjects. At surgery, accessory renal arteries were found in 14 kidneys (double arteries to 13 kidneys and triple arteries to one kidney). CT and surgical findings agreed in 92% of subjects. Seven small accessory renal arteries in seven donors were missed by radiology reviewers. Early branching

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of the renal arteries was shown in 5 arteries, and CT matched surgical findings in 88 cases (99%). Renal vein anomalies were present in six subjects, three of them were missed with the preoperative CT. The major shortcoming of MDCT angiography was noted in identifying minor venous anatomy. The presence of discrepancies between pre-operative MDCT and the findings at surgery did not affect the clinical outcome of transplantation, except in one case where intra-operative surgical distress was noted due to failure in identifying multiple major renal veins.

Conclusions: 16-MDCT angiography is a good modality in the pre-operative evaluation of live renal donors. However, it provides suboptimal information on renal vascular anatomy, particularly complex venous patterns. Surgeons should not rely fully on pre-operative CT angiography while performing donor nephrectomy.

Introduction

Living donor nephrectomy requires extensive preoperative knowledge of the renal vascular anatomy for selecting the best kidney and for planning of the surgery. Many studies have proved that the detection of arterial or venous anomalies preoperatively has a great impact on the success of the surgical procedure [1,2]. The most crucial information to be gathered before open or laparoscopic donor nephrectomy is the vascular and colleting system anatomy of the donor kidney [3].

Until recently, potential renal donors were evaluated with conventional imaging techniques that included conventional angiography for the vascular anatomy and intravenous pyelography for the collecting system. However, these imaging techniques are invasive, and less accurate for evaluation of complex renal venous anomalies, small stones, and small renal parenchymal lesions [4].

The introduction of multi-detector row computed tomography (MDCT) revolutionized the technology with regard to the speed of scanning and the quality of three-dimensional (3D) images. This technique can depict both the arterial and venous vasculature, the collecting system and renal parenchyma in a single study [5]. Although CT and magnetic resonance (MR) imaging have comparable accuracy, CT has a higher resolution than MR and is more technically robust [6,7]. The disadvantages of CT angiography are that the patient is exposed to both ionizing radiation and potentially nephrotoxic contrast material.

Donor nephrectomy is changing from the conventional open to a laparoscopic approach. Advantages of the laparoscopic technique include a decrease in morbidity, recovery time and postoperative pain, and better cosmesis [8–10]. In laparoscopic donor nephrectomy, because of the limited field of view, it is crucial to have detailed information on the vascular anatomy before surgery to avoid inadvertent vascular injuries [11].

The aim of this study was to assess the value of 16-section MDCT angiography in the preoperative evaluation of renal transplant donors by compared the scans with the intra-operative findings.

Subjects and methods

Between January 2008 and March 2010, 89 potential live kidney donors (69 men and 20 women) were evaluated with MDCT angiography at University Hospital, Alexandria, Egypt in preparation for kidney donation. Mean patient age at the time of evaluation was 31 years (range 21–52). Fourteen donors were unrelated to the recipient while 75 were related.

In Egypt, kidney donation cannot be performed except after passing through meticulous steps in the Medical Syndicate and the Ministry of Health that have strict regulations including patient consents and other legal requirements. None is allowed to do renal transplantation either in the governmental or in the private hospitals except after strict medico-legal procedures.

The approval of the local ethical committee was obtained as well all medico-legal procedures for kidney donation both for related and non-related donors were fulfilled. Donors were screened clinically and with laboratory investigations to rule out any medical contraindications for kidney donation such as mental illness, history of tuberculosis, urological disease or cancer. None of the subjects had a known history of allergy to contrast injection.

All donors were evaluated preoperatively using a 16-section MDCT scanner (LightSpeed Plus, General Electric Medical Systems, Milwaukee, Wisconsin). After fasting for at least 4 h, each candidate ingested 500 ml water 20–60 min before scanning. No oral contrast material was administered. Scanning was performed in the craniocaudal direction. Un-enhanced CT of the abdomen was performed first from vertebra T12 through mid-pelvis by using 5-mm section thickness and table speed of 15 mm per rotation. Subsequently, all donors received 70–80 ml intravenous nonionic iodinated contrast material (iopromide) containing 300 mg/ml iodine (Ultravist 370, Schering, Germany). Contrast-enhanced CT was initiated 30 s, 55 s, and 10–15 min after the injection to coincide with the arterial, venous and excretory phases, respectively. All images were transferred to a workstation and reconstructed for CT angiography and CT urography with various techniques, such as maximum intensity projection (MIP) and volume-rendering (VR). Both urologists and radiologists reviewed the images.

Un-enhanced images were done for renal morphology, exclusion of urolithiasis, and characterization of any renal masses. The presence of congenital fusion anomalies or complex cystic or solid renal lesions (angiomyolipoma or renal cell carcinoma) excluded an individual from donation.

Renal arterial anatomy was evaluated on the arterial phase images. Number of arteries, presence of early branching arteries, and presence of accessory arteries were assessed. Accessory renal arteries were those that had a separate origin from the aorta or iliac arteries that was independent of the main renal arteries. An early branching renal artery was diagnosed when any branch diverged within 2.0 cm from the lateral wall of the aorta (left kidney) or in the retrocaval segment (right kidney) [12,13].

Venous anatomy was evaluated in the arterial phase and in addition by images in the nephrographic phase, especially for assessment of accessory renal veins, including lumbar and gonadal veins, which sometimes enhanced later. Raman et al. have sub-classified renal venous anomalies as major and minor [14,15]. Major renal venous anomalies included variants that affected recipient venous anastomosis, such as duplicated IVC, circumaortic left renal vein, late confluence of renal venous trunks and supernumerary veins. Minor venous anomalies were those that did not alter recipient venous anastomosis and included anomalies associated with the lumbar, gonadal, adrenal, or retroperitoneal veins.

For the excretory phase, scanning began 5 min after the nephrographic phase. Excretory phase images were used to evaluate the anatomy and associated abnormalities of the calyces, infundibula, renal pelvis, ureters, and bladder.

After surgery and in case of discrepancy between the intraoperative and CT findings a second review of the images was done by both the surgical team and the radiologist.

Donor nephrectomy was performed in all subjects through an open approach by the same operator. Surgery was performed between 2 weeks and 4 months (median, 1 month) after the CT examination. The findings on CT angiography were used to guide the selection of the donor kidney. The left kidney was preferred if both kidneys were normal. At surgery, the transplant surgeon recorded the surgical findings, including the number of arteries, the branching distance, the number of renal veins, the presence of late confluence within veins, and the presence of major or minor renal vein anomalies. Small accessory arteries 0.5–3 mm in diameter were sacrificed at surgery. Larger arteries were anastomosed end-to-side to the main renal artery or directly into the external iliac artery.

Results

MDCT images were evaluated as technically satisfactory in all 89 donors. The renal arteries and veins were adequately enhanced in all cases. None of the donors developed hypersensitivity reaction to the contrast. None of the scanned donor kidneys were noted to have a renal stone, mass, or any other vascular or congenital abnormality.

MDCT clearly revealed a single renal artery in 82 donor kidneys – and double renal arteries in 7 kidneys (3 on the right and 4 on the left). Early branching was noted in three arteries. MDCT showed a single renal vein in all donor kidneys. There were no cases of late confluence of the renal vein. MDCT showed a complex gonadal vein system in two cases and a complex lumbar vein in one case.

Nephrectomy was performed on the left in 52 and on the right in 37 donors. The right kidney was chosen mainly because of the presence of variant anatomy in the left kidney. There were no complications and minimal blood loss. At surgery, a total of 104 renal arteries were identified in 89 donor kidneys. A single renal artery was identified in 75 kidneys, two arteries in 13 (8 left and 5 right), and three arteries in one case (on the left side). All accessory renal arteries arose from the abdominal aorta without aberrant iliac branches. In the recipients, double arteries were anastomosed together in 10, anastomosed separately in four, and the accessory artery was ligated in four patients. In the case of triple arteries, two were anastomosed together and the third was ligated.

Compared to preoperative CT angiogram, single renal arterial supply was remarked Intraoperatively in 75 cases while an accessory renal artery(s) was noted in 14 cases (13 double and one triple) (10 polar and 4 hilar arteries).

MDCT findings with regard to the arterial supply were concordant with intraoperative findings in 82 of the 89 donors (92.1%). Six donors were considered to have a single renal artery on MDCT and at surgery were found to have an accessory renal artery. Three renal arteries were found at surgery in one case where initial review of MDCT showed two renal arteries. Discrepancies with CT were more common on the left (5/52 cases) than on the right (2/37 cases).

As regards branching of the renal artery, MDCT successfully depicted 4 renal arteries with early branching. MDCT findings agreed with intraoperative findings in 88 cases. In one case an early trifurcation of the main renal artery was noted intra-operatively that was perceived on MDCT as an early bifurcating artery, completely missing the small posterior branch.

Intra-operatively, there were single renal veins in 83 and multiple renal veins in six cases; three of which were completely overlooked on MDCT. Accessory renal veins were small in four and large in two cases. CT missed 2 of 4 cases with small accessory veins and one of two cases with large accessory veins, with overall accuracy of 96.6%. Intraoperative stress of the surgical team was encountered in one case where both veins were large (diameter >6 mm) and so they could not be ligated. In this case direct anastomosis with the external iliac vein was successfully performed (Fig. 1). In four cases a small accessory renal vein was ligated.

Complex lumbar and/or gonadal venous anatomy was accurately delineated in 18 cases and completely overlooked in ten. The inability to precisely predict lumbar and/or gonadal venous anatomy in these ten cases did not cause the same stress encountered on facing major accessory renal veins as in the previously mentioned case.

At surgery all cases had a single ureter. CT findings were concordant with surgical observations in all donor kidneys (accuracy 100%) (Table 1)

The overall sensitivity and specificity of MDCT angiography compared to surgical identification were 95% and 90%, respectively. Positive and negative predictive values and accuracy of MDCT angiography were 89%, 96% and 92%, respectively.

Discussion

Preoperative imaging of living renal donors is required to detect renal anomalies so as to select candidates for living renal transplantation, to plan the surgical technique for donor nephrectomy and to reduce the risk of surgical complications that can threaten graft survival and sometimes the life of the donor [16].

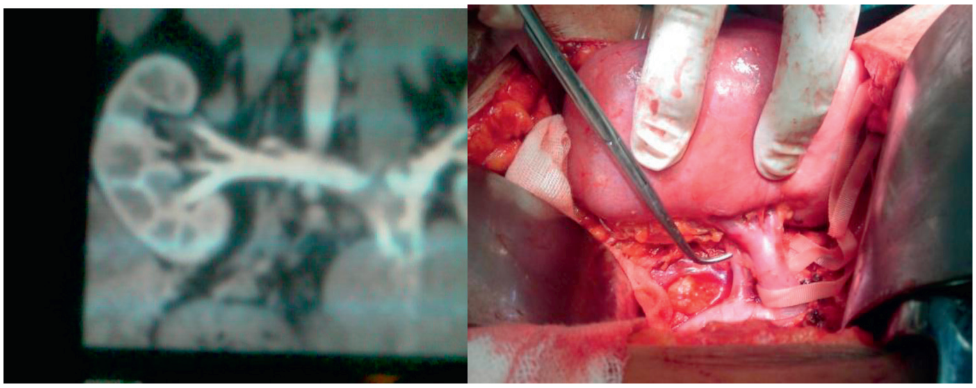

Figure 1 Multi-detector CT angiography in 26-year-old male renal donor showing single right renal vein with confluence near the renal hilum (A). During surgery a second large separate renal vein was detected (B).

Table 1 Accuracy of MDCT angiography in depicting arterial, venous and ureteral anatomy.

	Arterial anatomy				Venous anatomy				Ureteral anatomy	
	No. of arteries	%	Branching	%	No. of veins	%	Lumbar/gonadal anatomy	%	No. of donors	%
Success of detection by MDCT	82	92.1	88	98.9	86	96.6	79	88.8	89	100
Failure of detection by MDCT	7	7.9	1	1.1	3	3.4	10	11.2	0	0
Total	89	100	89	100	89	100	89	100	89	100

Accessory artery is the most common renal arterial variation. It occurs in 24–49% of cases and is more common on the left side [17–21]. Early branching is seen in about 12% of cases [22]. In our cohort accessory renal arteries were seen in 21.3% of donors and early branching was seen in 5.6%. For the renal venous anomalies, the most common are multiple renal veins in approximately 15–30% of cases, more on the right side [23,24]. In our study 6 donors (6.7%) had multiple renal veins, 4 of them on the right side.

Often the choice of surgical approach is influenced by the findings at imaging. In the past, several investigators have used single–detector row helical CT for predicting the renal vascular anatomy with accuracies reported for the depiction of accessory arteries, artery branching, and renal venous anatomy, of 78–98%, 89–99%, and 90–99%, respectively [25–28]. Since then, several advances have been made in CT technology, as well as in its reconstruction capabilities.

The recent introduction of MDCT into clinical practice has allowed radiologists to overcome most of the limitations of single-detector helical CT. Depending on the number of channels (four, eight, 16, and so on), MSCT scanners are four to 25 times faster than conventional single-slice spiral scanners. The shortened scan duration effectively reduces motion artifacts and allows scanning in the optimal arterial and venous phases separately. Moreover the real time interactive reconstruction using MIP and VR techniques has optimized the depiction of aberrant renal vasculature [29–31].

Our results are comparable to those from recently published articles about studies of 16 multi-detector row CT in evaluating potential renal donors. For example, Kawamoto et al. reported agreement between CT and surgical findings with reference to renal arteries in 69 of 74 donors [12]. Kim et al. reported that in their series of 77 renal donors multi-detector row CT had an overall depiction rate of 98% (89 of 91 arteries and 83 of 85 veins) [32].

In our study CT angiography accurately detected the number of arteries in 82/89 (92.1%) and branching of arteries in 88/89 (98.9%). Initially, we requested MIP images for all cases. However, through the course of the study it became clear that important anatomic details were often not clearly demonstrated on MIP renderings. We believe discordant findings were more common in cases in which we used only MIP images. As MIP images lack depth orientation, VR images are better for displaying complex anatomy, especially when overlapping vessels are present [29–31]. Moreover, our current experience suggests that all of the original sections should be scrutinized for small accessory arteries and branches. This has helped improving the accuracy of the pre-surgical MDCT images.

The prevalence of a supernumerary renal vein has been reported to range from 5% to 28% [22,33]. In our study six kidneys (6.7%) had multiple renal veins. Of two cases with large accessory renal veins, CT missed one. Also, in four cases with small accessory renal vein, CT missed two.

In our institution we are shifting from open to laparoscopic donor nephrectomy. Full description of the lumbar–gonadal venous pattern is very important for laparoscopic surgeons in order to identify them easily at surgery. In our study, CT missed 55.6% of cases with complex gonadal and/or lumbar venous anatomy. This dictates that surgeons should not rely completely on preoperative CT findings.

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. Stress during surgery occurred in one case where preoperative CT angiography had missed the presence of a large accessory renal vein.

There were limitations in our study. First, CT images were reviewed by one radiologist. Second, it was preferred to select kidneys with normal anatomy or a less intricate anomaly for donor nephrectomy. Therefore, the performance of MDCT in the evaluation of more complex vascular and excretory anatomy and anomalies could not be evaluated. Finally, modification of CT protocols to generate thinner sections or use of more detector rows with a smaller detector configuration, may improve the detection of small accessory arteries and veins.

Conclusion

MDCT provides accurate preoperative assessment of the renal arterial system and ureteral anatomy for potential kidney donors, without the risks of more invasive conventional angiography. However, it provides suboptimal information on renal vascular anatomy, particularly complex minor venous patterns. Surgeons should not rely fully on pre-operative CT angiography while performing donor nephrectomy.

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