

PREOPERATIVE EVALUATION OF VASCULAR AND UPPER URINARY TRACT ANATOMY OF LIVING RENAL DONORS ON MULTI-DETECTOR ROW CT

Duong Phuoc Hung¹, Le Trong Khoan², Nguyen Khoa Hung²

ABSTRACT

Objectives: Preoperative evaluation of the living renal donors vascular and upper urinary tract anatomy with Multi-Detector CT (MDCT).

Material and methods: From Jan 2017 to August 2018, when carrying out a cross-sectional study at Cardiovascular Centre of Hue Central hospital, we have performed 64-MDCT with a three-phase enhancement CT scan of the renal vessels and upper urinary tract using hyperdiuresis method via oral hydration on 154 living donors who were proceeded to nephrectomy. Renal vessels and upper urinary tract were compared with operational findings.

Results: 154 living renal donors (male/female: 83.77%/16.23%), mean age was 30.72 ± 8.21 years (Range: 20-60 years). 154 chosen kidneys were proceeded to nephrectomy (right kidneys/left kidneys: 49.35%/50.65%), 76 right chosen kidneys (artery variation/vein variation: 20.51%/32.90%) and 78 left chosen kidneys (artery variation/vein variation: 10.53%/1.28%). CT findings all corresponded with the operation, and the sensitivity, positive predictive value, specialty, and negative predictive value of CT were all 100%. A hundred percents of donors experienced no contrast-induced artifacts in renal parenchyma. There were 70.78% of visualization of contrast media (CM) of entire upper urinary tract filling and 100% of that of top half upper urinary tract filling in both kidneys. The majority of donors had single collecting system (98.08% in right kidney and 99.36% in left kidney). The rest had partial or complete duplex collecting system. 100% of living donors had normal renal function in the excretory phase at 5 minute after CM and saline 0.9% injection bolus. This allowed reducing examination time and radiation exposure with the highest effective dose 12.86mSv unenhanced and three enhanced phases CT scan.

Conclusions: MDCT contributes into more accurate diagnosis of the vascular and upper urinary tract anatomy of renal living donors, helps surgeons make appropriate planning in the operation of chosen kidneys of living donors and transplanting into patients.

Key words: -Vascular anatomy-Upper urinary tract - MDCT - CT Urography

I. INTRODUCTION

Renal transplantation is currently the best available treatment option for patients of end-stage renal failure compared with other methods such

as homeostasis and dialysis. Kidney evaluation of renal living donors for transplantation is one of the most important clinical features. Identification of anatomical characteristics of the vessels and upper

1. Doctoral student, University of Medicine and Pharmacy, Hue University
2. Hue University of Medicine and Pharmacy, Hue University

Corresponding author: Duong Phuoc Hung
Email: duongphuochung@gmail.com
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urinary tract is one of the important purposes of preoperative evaluation at living renal donors.

In recent years, with the continuous technical development of MDCT with thin slices, high resolution, good image quality and reconstruction of the vessels and entire upper urinary tract fully-filled with contrast media (CM) [8]. MDCT with hyperdiuresis measures and with radiation exposure reduction, has been able to investigate the vascular and upper urinary tract anatomy and evaluate renal functions[3].

From Jan 2017 to August 2018, Hue Central Hospital has deployed the technique of 64-MDCT on the vascular and upper urinary tract assessment to be applied on kidney transplantation. This has been contributing to the accurate diagnosis of the vascular and urinary tract anatomy, and providing useful information that helps surgeons plan their renal replacement surgery.

In this context, this research has been carried out to identify benefits of 64-MDCT in the vascular and upper urinary tract anatomical evaluation preoperative at living renal donors at Hue Central Hospital.

II. SUBJECTS AND METHODOLOGY

Subjects: 154 cases of living renal donors were assigned to experience 64-MDCT of the vessels and upper urinary tract from January 2017 to August 2018. Written informed consent was obtained from each patient.

Research facilities: Philips Brilliance 64-MDCT and Medrad Stellant dual-injection machines.

Techniques: Conducting 64 MDCT technique of the vessels and upper urinary tract at living renal donors for:

- Assessment of the vascular and upper urinary tract anatomy.
- Assessment of kidney function.

Patients preparation:

- Abstaining from food 4 to 6 hours before scanning.
- Hyperdiuresis method via oral hydration is

used. Patients are given 750-1000 ml of water each 30 minutes before scanning and abstaining from urination for the purpose of increasing urinary straining the upper urinary tract.

Multi-detector row CT protocol:

An unenhanced and three enhanced CT scan of arterial, parenchymal and secretory phase of the bilateral kidneys were performed using a 64-MDCT in all the 154 patients. The patients were taught breath-holding.

Image technique:

The following parameters were kept constant for each phase of scanning: section thickness of 2.0 mm, reconstruction interval of 1mm, 0.5 s rotation time, pitch factor of 1.171 and 120 kVp; 80 mAs (unenhanced phase scanning extent included the bilateral kidneys); 150 mAs (arterial phase scanning extent included the common iliac vascular bifurcation for fear of the omission of the tiny accessory renal artery) using Bolus tracking technique with 30mAs, locator position at the middle of bilateral kidneys hilum, section thickness of 10 mm, 1.5s rotation time and scanned at 10s after bolus injection; 100mAs (parenchymal phase scanning extent included the bilateral kidneys) and (secretory phase scanning extent included the cavitas pelvis and was scanned at the only time of 5 min after bolus injection of CM and saline 0,9%).

Subsequently, an 18-gauge antecubital cannula was placed in an antecubital vein for bolus injection 1.0-1.5 mL/kg of ultravisor xenetix containing 300 mg of iodine per milliliter at a rate of 3-5 mL/s and then bolus injection 40ml of saline 0,9%.

Image processing and analysis

The CT data sets were transferred to a workstation for the anatomical manifestation of the main vessels and upper urinary tract by maximum intensity projection (MIP), multi-planar reconstruction (MPR), and volume rendering technique (VRT) procedures.

Methodology: cross-sectional study, medical statistical analysis with SPSS version 20.0.

III. RESULTS

3.1. Living renal donors features

3.1.1. Age

Table 1: Donors (154) categorised by ages

Donor	Age		
	Youngest	Average $\pm$ SD	Oldest
	20	30.72 $\pm$ 7.21	60

The oldest living donor in our research was 60 years old

3.1.2. Gender

Table 2: Donors (154) categorized by genders

Donor	Gender			
	Male		Female	
	n	%	n	%
	129	83.77	25	16.23

The number of male living donors outnumbered that of female.

3.2. Vascular variation features in living renal donors

3.2.1. Anatomical variations of the artery preoperative

Table 3: Distribution of anatomical variations of the artery preoperative

<i>The anatomical variations of the artery</i>	Right kidney		Left Kidney	
	n	%	n	%
One artery	121	78.57	104	67.53
Two arteries (one main artery, one accessory artery)	26	16.88	45	29.22
Three arteries (one main artery, two accessory arteries)	7	4.55	4	2.60
Four arteries (one main artery, three accessory arteries)	0	0	1	0.65
Total	154	100	154	100

Kidneys had the majority of one artery, 78.57% at right kidneys and 67.53% at left kidneys.

Table 4: Distribution of anatomical variations of the early branching artery preoperative

<i>The anatomical variations of the artery</i>	Right kidney		Left Kidney	
	n	%	n	%
Normal branching artery	112	72.73	117	75.98
Early branching artery	42	27.27	37	24.02
Total	154	100	154	100

In our research, early branching artery was 27.27% at right kidneys and 24.02% at left kidneys.

3.2.2. Anatomical variations of the vein preoperative

Table 5: Distribution of anatomical variations of the vein preoperative

<i>The anatomical variations of the vein</i>	Right kidney		Left Kidney	
	n	%	n	%
One vein	102	66.23	151	98.05
Two veins (one main vein, one accessory vein)	47	30.52	3	1.95
Three veins (one main vein, two accessory veins)	5	3.25	0	0
Total	154	100	154	100

Kidneys had the majority of one vein, 66.23% at right kidneys and 98.05% at left kidneys.

Table 6: Distribution of anatomical variations of the late confluence vein preoperative

<i>The anatomical variations of the vein</i>	Right kidney		Left Kidney	
	n	%	n	%
Normal confluence vein	152	98.71	141	91.56
Late confluence vein	2	1.29	13	8.44
Total	154	100	154	100

In our research, late confluence vein was 1.29% at right kidneys and 8.44% at left kidneys.

3.2.3. Anatomical variations of the chosen kidneys artery preoperative and postoperative

Table 7: Distribution of anatomical variations of the artery preoperative and postoperative

<i>The anatomical variations of the artery</i>	Right kidney		Left Kidney	
	n	%	n	%
One artery	68	79.49	62	89.47
Two arteries (one main artery, one accessory artery)	7	19.23	15	9.21
Three arteries (one main artery, two accessory arteries)	1	1.28	1	1.32
Total	76	100	78	100

CT findings of anatomical variations of the artery preoperative all corresponded with the operation.

Table 8: Distribution of variations of the early branching artery preoperative and postoperative

<i>The anatomical variations of the artery</i>	Right kidney		Left Kidney	
	n	%	n	%
Normal branching artery	60	78.95	67	85.90
Early branching artery	16	21.05	11	14.10
Total	76	100	78	100

CT findings of anatomical variations of the early branching artery preoperative all corresponded with the operation.

3.2.4. Anatomical variations of the chosen kidneys vein preoperative and postoperative

Table 9: Distribution of anatomical variations of the vein preoperative and postoperative

The anatomical variations of the vein	Right kidney		Left Kidney	
	n	%	n	%
One vein	51	67.10	77	98.72
Two vein (one main vein, one accessory vein)	22	28.95	1	1.28
Three vein (one main vein, two accessory veins)	3	3.95	0	0
Total	76	100	78	100

CT findings of anatomical variations of the vein preoperative all corresponded with the operation.

Table 10: Distribution of variations of the late confluence vein preoperative and postoperative

The anatomical variations of the vein	Right kidney		Left Kidney	
	n	%	n	%
Normal confluence vein	75	98.69	75	96.15
Late confluence vein	1	1.31	3	3.85
Total	76	100	78	100

CT findings of anatomical variations of the late confluence vein preoperative all corresponded with the operation.

3.3. Contrast media features in the living renal donors' upper urinary tract

Table 11: Distribution of contrast media filling in the upper urinary tract

CM filling in the upper urinary tract	Right kidney		Left kidney		Both kidneys	
	n	%	n	%	n	%
Top half filling to inferior edge of L4	26	16.88	20	12.99	45	29.22
Entire filling	128	83.12	134	87.01	109	70.78
Total	154	100	154	100	154	100

In our research, 70.78% of the cases experienced CM excreted to fill the entire of the upper urinary tract and 100% of the cases experienced CM to fill the top half of the upper urinary tract in both kidneys with the scanning once only.

3.4. Upper Urinary tract features in the living renal donors

3.4.1. The anatomical variations of the upper urinary tract

Table 12: Distribution of anatomical variations of the upper urinary tract

The anatomical variations of the upper urinary tract	Right kidney		Left Kidney	
	n	%	n	%
Single collecting system	151	98.08	153	99.36
Partial duplex collecting system	2	1.28	1	0.64
Complete duplex collecting system	1	0.64	0	0
Total	154	100	154	100

Kidneys had the majority of single collecting system, 98.08% at right kidneys and 99.36% at left kidneys.

3.4.2. Upper urinary tract lesions

Table 13: Distribution of upper urinary tract lesions detected on 64-MDCT

Upper urinary tract lesions	Right kidney		Left Kidney	
	n	%	n	%
Calyceal stone	5	3.24	7	4.54
No lesion	149	96.76	147	95.46
Total	154	100	154	100

There were 12 cases of calyceal stones detected on 64-MDCT, among which 5 cases were of right kidney (accounting for 3.24%) and 7 cases were of left kidney (4.54%).

3.5. The renal function evaluation on 64-MDCT of the upper urinary tract

Table 14: Distribution of visualization time of CM in the upper urinary tract

Visualization time of CM in upper urinary tract	Right kidney		Left kidney	
	n	%	n	%
5 min after bolus injection of CM and saline	154	100	154	100
Total	154	100	154	100

We found CM excreted into the upper urinary tract in both kidneys when the secretory phase was scanned at the only time of 5 minute after bolus injection of CM and saline 0.9% in all of cases.

3.6. Evaluation of radiation exposure on 64-MDCT with four phases scanning

Table 15: Distribution of radiation exposure on 64-MDCT with four phases scanning

Effective dose(mSv)		
Lowest	Average	Highest
11.83mSv	12.34mSv	12.86mSv

The highest effective dose was 12.86mSv in our study

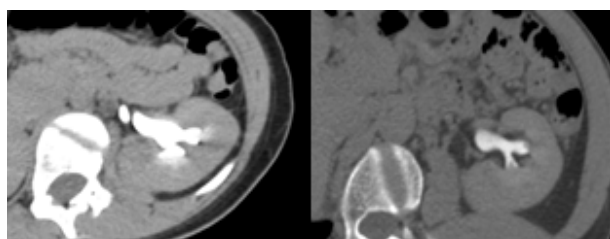
3.7. Imaging illustrations of the vascular and upper urinary tract features at living renal donors



Figure 1: Three arteries in left kidney, early branching artery in right and left kidney



Figure 2: Three veins in right kidney, late confluence vein in left kidney



Without oral hydration With oral hydration

Streaking artifact No artefact

Figure 3: Contrast-induced artifacts in renal parenchyma

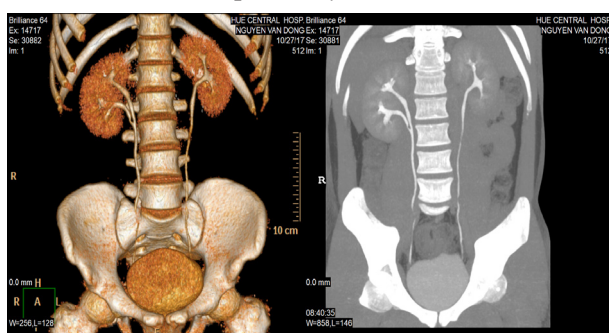


Figure 4: Partial duplex collecting system with upper half ureteral confluence in right kidney

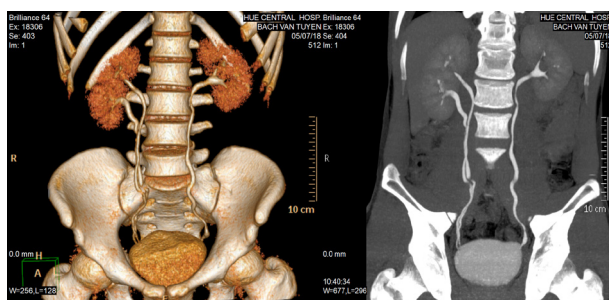


Figure 5: Complete duplex collecting system in right kidney

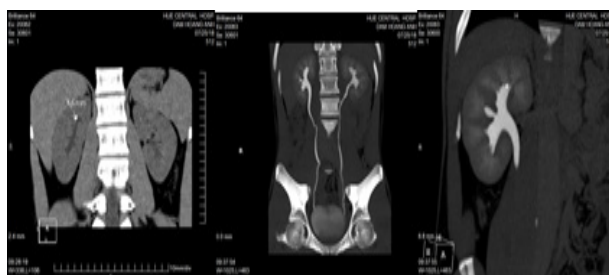


Figure 6 : Upper calyceal stone in right kidney

IV. DISCUSSION

Evaluating the anatomical characteristics of the vessels and upper urinary tract in living renal donors prior to selection of kidney for transplantation bares

critical purposes. It helps surgeons plan their renal removal surgery for renal transplantation.

In our research, CT findings of anatomical variations of the main artery, accessory artery, early branching artery; main vein, accessory vein and late confluence vein of all chosen kidneys preoperative all corresponded with the operation, and the sensitivity, positive predictive value, specialty, and negative predictive value of CT were all 100%. This result corresponds well with those of Su et al. (2010) [12], Baratali (2013) [2], Petridis (2008) [8] and Steven et al. (2006) [11].

64-MDCT of the upper urinary tract combined with hyperdiuresis is method via oral hydration to improve the upper urinary tract's distension, and with diluted CM resulting in no streaking artifact in the renal parenchyma help increase accuracy in evaluating calyceal bottoms, visualization of ureter wall and can detect submucosal small lesion in the upper urinary tract [7][9] [10], which eliminates cases of upper urinary tract lesion with contraindication for kidney transplant. In our study, 100% of the cases are free of streaking artifact in the renal parenchyma caused by CM. This is in line with the study by Claebots C. et al. [4] using MDCT for urinary tract detection combined with hyperdiuresis method with intravenous administration of furosemide (<40 mg) just prior to CM injection [4] and by Stuart G. Silverman et al. where hyperdiuresis method via oral hydration (750-1000 ml of water) or saline intravenous (0.9%) (250 ml) were utilized [10], which simultaneously better filled the urinary tract and dilute CM to avoid artefact in the renal parenchyma due to the high density of the CM 1310+/-398 HU, if there was no hyperdiuresis [4].

64-MDCT can accurately identify morphologic characteristics of the upper urinary tract from simple anatomical variations with single collecting system to complex anatomic variations with partial or complete duplex collecting system, which

contributes great deal to kidney transplant, thanks to its high-tech features with a very fast scanning time in one breath-holding, with thin slices, with curved 3D image processing programs such asMPR, MIP, and VRT.

Thus, the length of the entire renal pelvi-ureteral section cut corresponded to the length of the top half of the upper urinary tract at the level of the lower edge of the lumbar vertebral body L4 on 64-MDCT imaging. In our study, 100% of cases of CM were filled in the top half of the upper urinary tract at in both kidneys, which greatly improved the preoperative integrity of the pelvi-ureteral section.

According to a study by Claebots C. et al. using MDCT techniques, under normal conditions only 19% of cases were found to have the entire upper urinary tract fully-filled with contrast media and if injected intravenous furosemide, that was found in 83% of cases [4].

Among the methods for hyperdiuresis, intravenous furosemide is the optimal choice for CM to be excreted in distended urinary tract. Therefore, the ratio of success in the above-mentioned cases of CM fully-filling upper urinary tract in our study were lower than those of Claebots C. et al.

The purpose of preoperative assessment in living renal donors is to determine whether the donor retains a normal kidney that functions well after the other kidney is removed and to identify the transplanted kidney has no critical anomalies such as stone.

MDCT is capable of detecting almost 100% of urolithiasis cases [1]. In our study using 64 MDCT with slice thickness of 2mm and reconstruction interval of 1mm, 12/154 cases of calyceal stones were seen in both the unenhanced phase and enhanced secretory phase, which constitutes of 7.78%. Diluted CM in the distended urinary tract created optimum contrast, high density stones were seen [4]. This suggests that 64-MDCT plays an important role in the detection of upper urinary tract stones, which

contributes to the decision of selecting kidneys for transplantation of the recipients.

64-MDCT has a very high diagnostic value for upper urinary tract obstruction thanks to its ability to detect the surrounding structures of the upper urinary tract such as perirenal fatty deposits, large edematous kidney, edema of the ureter wall around the stones, perirenal fluid, edematous ureterovesical junction[9]. In our study, there were no cases of stones that obstructed the upper urinary tract.

64-MDCT can assess well the information of renal function. We scanned the secretory phase at the only time of 5min after bolus injection of CM and saline 0.9% and found that all cases of CM excretion to the upper urinary tract were observed in both kidneys. This allows us to conclude that all living donor cases in our study had well-functioning two kidneys and that results in a reduction of the examination time. Claebots C. et al. has used MDCT technique to examine urinary tract combined with hyperdiuresis method by intravenous furosemide injection (≤ 40 mg) immediately prior to CM injection, which helps reduce from 5 to 7.5 minutes of the examination time [4].

64-MDCT of upper urinary tract has been found to meet the requirement for reducing radiation doses at living donors, while also meeting the diagnostic criteria for determining upper urinary tract characteristics in limiting the scanning field, decrease kV, change mAs accordingly [13]. The highest effective dose in our study using 64-MDCT with four phases was 12.86 mSv, which was lower with three-phase scanning of the entire abdomen radiating with an effective dose of 15-25 mSv by Van Der Molen AJ. and al.[13]. It is important to note that the ideal technical procedures is to produce good quality images, but with limited radiation doses, according to the ALARA principle.

64-MDCT has been shown to be highly effective in evaluating upper urinary tract characteristics such as stones or detecting abnormal variations

of collecting system with the sensitivity and the specificity of almost 100%, according to many studies reported [1].

V. CONCLUSION

Through a study on 64-MDCT of the vascular and upper urinary tract anatomy with a combination of hyperdiuresis method on 154 living donors, we have found that MDCT offers satisfactory results in evaluating renal vessel anatomy and collecting system variations or pathological changes and has been recognized by transplantation surgeons. The diluted CM excreted into the upper urinary tract completely avoids the streaking artefact in the renal parenchyma and helps sight the renal stones in all cases in both unenhanced phase and enhanced secretory phase.

In addition, the entire upper urinary tract distended and fully-filled with CM in both kidneys was seen in the majority of cases and the upper half of the upper urinary tract was examined completely in most cases. 64-MDCT can accurately determine anatomical characteristics of the upper urinary tract, from simple anatomical variations with single collecting system to complex anatomical variations with partial or complete duplex collecting system.

64-MDCT evaluates accurately not only the vascular and upper urinary tract anatomy, but also the renal function of living donors. It helps reduce examination time and radiation dose in all cases, which helps surgeons plan for a renal operation from selected living donors and implementation of kidney transplants for patients.

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