Renal Vascular Variants in Living Related Renal Donors: Evaluation with CT Angiography

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Background: *Renal vascular variants may complicate the surgical techniques of living related renal transplantation. Renal computed tomographic (CT) angiography is now well accepted for preoperative renal vascular mapping in living related renal donors.*

Objective: *To study the prevalence of renal vascular variants in living related renal donors using CT angiography.*

Material and Method: *Preoperative renal CT angiography of 65 consecutive living related renal donors were retrospectively reviewed by two abdominal radiologists on a 3-D workstation. The number and branching patterns of bilateral renal arteries and veins, as well as the presence of renal arterial and venous variants were described.*

Results: *Supernumerary renal arteries and early branching were present in 18.5% and 12.8% respectively on the right kidneys and 27.7% and 22.4% respectively on the left kidneys. The prevalence of precaval right renal artery was 4.6%. Supernumerary renal veins were present in 35.4% and 1.5% on the right and left kidneys, respectively. Late confluences of left renal veins were identified in 1.5% of left kidneys. Other venous anomalies included 1.5% duplicated inferior vena cava (IVC), 1.5% circumaortic left renal vein, 1.5% retroaortic left renal vein, 1.5% outsized left gonadal veins drained into the left renal vein, and 6.2% right gonadal vein drained into the right renal vein.*

Conclusion: *Renal vascular anatomical variants were common. The surgeons and the radiologists should be aware of these variants to prevent postoperative complications.*

Keywords: *Renal vascular variants, CT angiography, Living related renal transplantation*

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Living related renal transplantation is now replacing the cadaveric renal transplantation as it offers many major advantages over the old technique[1]. First, it offers the better survival rates for the patients and the grafts. Second, it decreases the prolonged waiting time. Other advantages include decreasing an incidence of delayed graft function and shortening the hospital length of stay in the recipients.

Laparoscopic nephrectomy in living related renal donor has emerged since 1995 as the preferable alternative to open nephrectomy[2-4]. The new technique provides many advantages over the open technique since it decreases the morbidity, postoperative pain, the size of operative scar, and shortens the recovery time. However, laparoscopic donor nephrectomy is technically challenging because the surgical field of view is limited.

Preoperative imaging studies in living related renal donors are critical for donor selections, kidney selections, and surgical planning. Some renal anomalies or variants are unacceptable for donation. These include congenital fusion anomalies, bilateral multiple (> 3) arteries or veins, bilateral aberrant arterial supply or venous drainage (*e.g.* from iliac vessels), asymptomatic diffuse renal diseases or incidental solid masses in kidneys or other organs[3].

For a normal and healthy donor, the left kidney is usually preferable for donation due to its longer vascular pedicles than the right side. However, the right kidney may be selected if the left kidney has more complex vascular anatomy, which will complicate the nephrectomy process. If the donor has abnormality in one or both kidneys, the more normal kidney will be kept for the donor and the more abnormal kidney will be harvested for donation.

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Conventional preoperative imaging studies for living related renal donors include catheterized renal angiography and excretory urography, which are nowadays replaced with renal computed tomographic (CT) angiography provided by modern, multi-detector CT scanner[5]. CT angiography provides critical information of renal vessels (single or supernumerary renal arteries/veins, their branching patterns, arterial and venous variants), renal parenchyma, and collecting systems with high accuracy[6-8]. These anatomical details help surgeons planning the operation and avoiding possible injuries to renal vessels, especially in laparoscopic approach where the visualization of operative field is limited.

The present study was designed to illustrate the type and frequency of variant vascular anatomy in living related renal donors by using CT angiography. The data from the present study will be the basic knowledge to remind the surgeons and the radiologists to look for these anomalies, which are the critical clues for donor selection, kidney selection and surgical planning.

Material and Method

Participants

The present study was a single-centered study approved by the hospital review board. Between June 2003 and July 2007, 65 consecutive living related renal donors underwent preoperative renal CT angiography by using either 16- or 64-detector CT scanner prior to the planned nephrectomy.

CT protocol

All 65 consecutive CT angiography were performed with either 16- or 64-detector CT scanner (LightSpeed VCT, GE Healthcare, United Kingdom). The CT protocol included unenhanced, arterial, and excretory phases, scanning from hepatic dome to iliac crest.

After fasting for at least 6 hours, each participant ingested sequential four glasses of water (250 ml per glass, each glass provided every 15 minutes) for distension of the collecting system. The last glass of water was administered just before the participants entered the CT room.

Unenhanced CT scans were obtained to locate the kidneys, evaluate renal stones, and acquire the baseline density measurements for incidentally-found renal masses.

Dynamic enhanced CT scans were performed after intravascular injection of 100 ml of 370 mg/ml Iopromide (Ultravist 370, Schering, Berlin, Germany) into antecubital vein through an 18-G peripheral IV line using a power injector at a rate of 4.0 ml/second. The starting time of the arterial phase was 5 seconds after reaching a density threshold of 150 HU in the region of interest (ROI) within the abdominal aorta just above the kidneys. Arterial-phase imaging was performed to evaluate the renal arterial and venous anatomy.

For the excretory phase, the scanning started at 2-minute delay from the injection point. This phase was designed for the evaluation of the renal parenchyma with probably urothelial abnormalities. The slice collimation was 1.25 mm for unenhanced and excretory phases. For arterial phase, a thinner slice collimation of 0.625 mm was applied for the high quality CT angiographic images.

Image processing and analysis

The volumetric imaging data were reviewed individually by two abdominal radiologists on a 3-D workstation. Any discrepancies were solved in consensus which acting as a gold standard. For each CT examination, the radiologists reviewed the axial images, supplemented with 2-D multiplanar reformations (MPR), 3-D volume rendering (VR) and 3-D maximum-intensity-projection (MIP) as necessary.

Renal artery evaluation

The reviewers retrospectively evaluated the number, branching patterns, and the morphology of bilateral renal arteries. Supernumerary renal arteries were those that had separated origin from the aorta or iliac arteries. In living renal donor transplantation, identifying the distance between the aorta and the start of the first renal arterial branch is important because this length determines the number of arterial anastomoses to be performed in the recipient. A short neck, also known as “early branching renal artery”, exists when the first renal arterial branch takes off close to the origin of the renal artery (less than 2.0 cm) and may need a separated anastomosis. The reviewers also evaluated the renal arterial variants (*e.g.* precaval right renal artery), and abnormal renal vascular morphology focusing on mural calcification, stenosis, and beading pattern.

Renal venous evaluation

For renal venous evaluation, the reviewers retrospectively evaluated the number, and venous confluence patterns of renal veins, as well as the venous anomalies of IVC, left renal veins and lumbar-gonadal axis. With the same reasons with renal arterial anatomy, the number and venous confluence patterns of renal veins are important clues for determining the number of anastomoses in the recipients. If branches of the left renal veins coalesce anterior to or near left lateral wall of the aorta, so called "late confluence", then the addition of anastomoses may be necessary.

Venous anomalies observed in the present study included duplicated IVC, circumaortic left renal vein, retroaortic left renal vein, and outsized left lumbar or gonadal veins (> 10 mm) draining into the left renal vein, so called lumbar-gonadal axis. The authors also collected the prevalence of the variant right gonadal vein draining into the right renal vein.

Results

Participants

On consensus review, the CT images were technically satisfactory in all 65 donors. These included 25 men (38.5%) and 40 women (61.5%). Their ages varied from 19 to 56 years (mean age of 34.9 years). CT angiography were performed with 16- and 64-detector CT in 31 (47.7%) and 34 (52.3%) donors, respectively. These 65 donors had no underlying disease and their serum creatinine was within normal limit (range 0.4-1.5 mg/dl). Twenty-eight (43.1%) of 65 donors underwent open nephrectomy while the rest (56.9%) underwent laparoscopic nephrectomy.

Renal artery evaluation

The number and percentage of right and left kidneys with single and multiple renal arteries are described in Table 1. Supernumerary renal arteries are illustrated in Fig. 1 and 2. Early branching renal arteries were identified in 10 of 78 (12.8%) right renal arteries and in 19 of 85 (22.4%) left renal arteries (Fig. 2).

Three of 65 (4.6%) donors had precaval right renal arteries. One of these cases had single right renal artery, which was precaval in location. Other two cases had two right renal arteries and precaval right renal artery in each case was the accessory one (Fig. 3).

In the present study, the reviewers did not find any significant abnormal renal vascular morphology whether mural calcification, stenosis, or beading pattern.

Renal venous evaluation

The number and percentage of right and left kidneys with single and multiple renal veins are described in Table 2. Late confluence of left renal veins was present in 1 of 65 donors (1.5%) as shown in Fig. 4.

The prevalence of other venous anomalies such as duplicated IVC (Fig. 5), circumaortic left renal vein, retroaortic left renal vein, outsized left gonadal vein drained into the left renal vein (Fig. 6), and right gonadal vein drained into the right renal vein are described in Table 3.

In addition, abnormal low position with malrotation of right kidney was seen in one donor. She also had complex vascular anomalies including circumaortic left renal vein, single precaval right renal artery, and two left renal artery.

Table 1. The prevalence of single and supernumerary renal artery/arteries in 65 living related renal donors

No. of renal arteries	No. of participants (%)	
	Right kidney	Left kidney
1	53 (81.5)	47 (72.3)
2	11 (16.9)	16 (24.6)
3	1 (1.5)	2 (3.1)
Total	65 (100)	65 (100)

Table 2. The prevalence of single and supernumerary renal vein/veins in 65 living related renal donors

No. of renal veins	No. of participants (%)	
	Right kidney	Left kidney
1	42 (64.6)	64 (98.5)
2	19 (29.2)	1 (1.5)
3	4 (6.2)	0 (0)
Total	65 (100)	65 (100)

Table 3. The prevalence of venous anomalies in 65 living related renal donors

Venous anomalies	No. of participants (%)
Duplicated IVC	1 (1.5)
Circumaortic left renal vein	1 (1.5)
Retroaortic left renal vein	1 (1.5)
Outsized left gonadal vein (diameter > 10 mm)	1 (1.5)
Outsized left lumbar vein (diameter > 10 mm)	0 (0)
Right gonadal vein drained into right renal vein	4 (6.2)

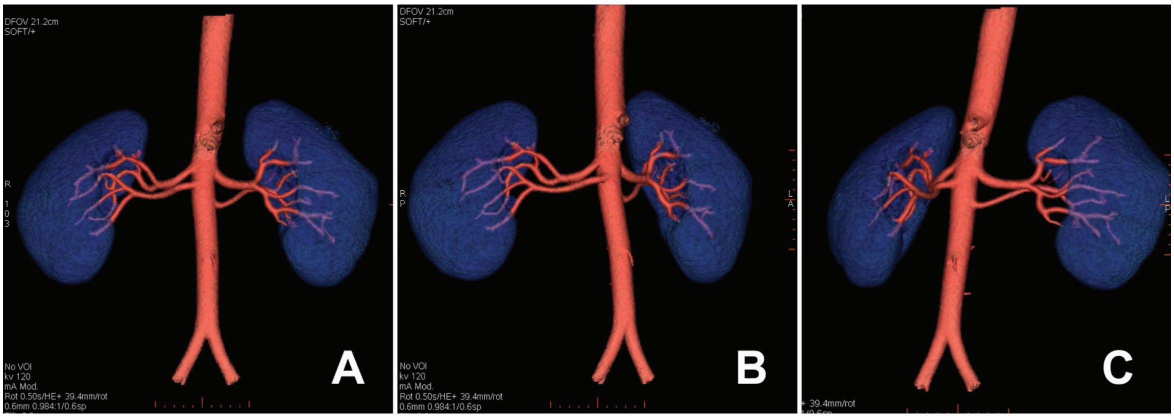

Fig. 1 34-year-old female renal donor with supernumerary renal arteries. A-C) Rotating 3-D volume-rendered CTA images demonstrate two right renal arteries and two left renal arteries

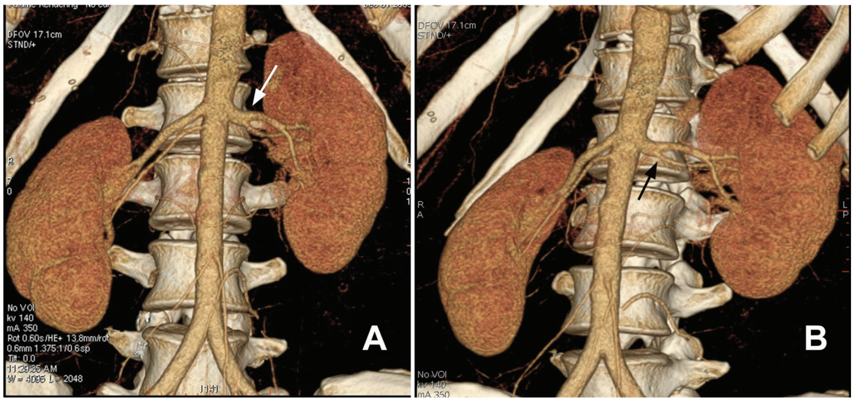

Fig. 2 32-year-old female renal donor with supernumerary right renal arteries and early branching of left renal artery. A-B) Rotating 3-D volume-rendered CTA images demonstrate two right renal arteries and early branching (8.0 mm from the origin) of single left renal artery (white arrow in A and black arrow in B)

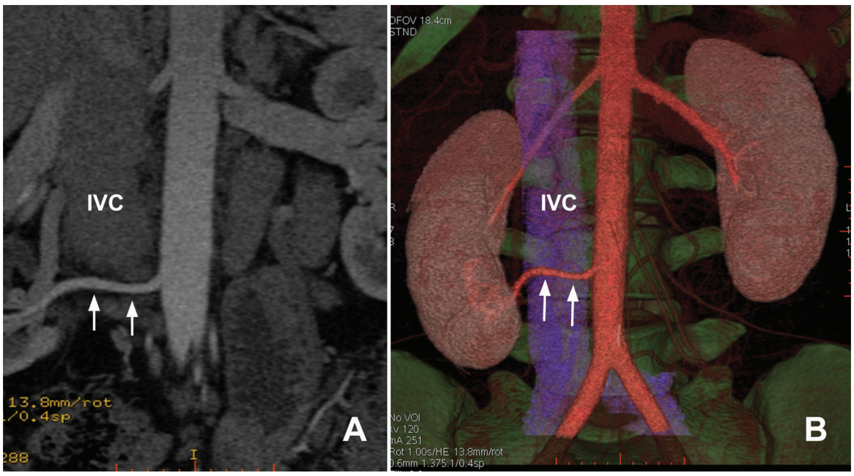

Fig. 3 23-year-old female renal donor with precaval right renal artery. A) 3-D maximum-intensity-projection (MIP) CTA image and B) 3-D volume-rendered CTA image demonstrate two right renal arteries. Lower right renal artery locates anterior to IVC (white arrows in A and B)

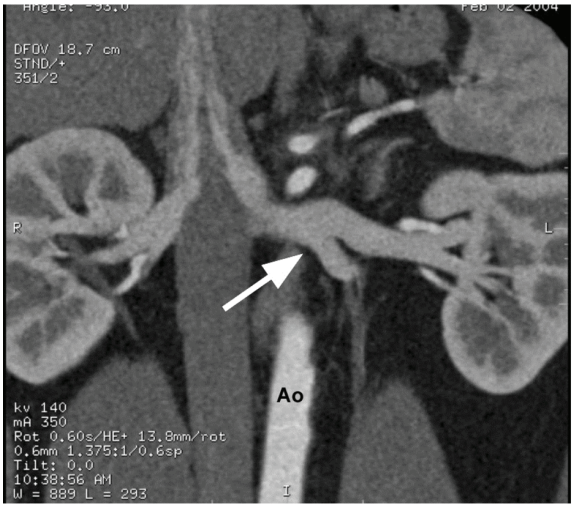

Fig. 4 40-year-old male renal donor with late confluence of left renal vein. 3-D maximum-intensity-projection (MIP) CTA image demonstrates late confluence of left renal vein (white arrow). Notice left renal venous branches coalesce anterior to aorta (Ao)

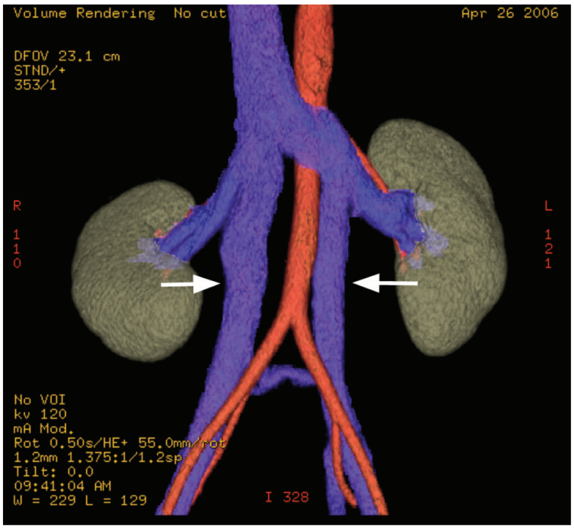

Fig. 5 27-year-old female renal donor with duplicated inferior vena cava (IVC). 3-D volume-rendered CTA image demonstrates two IVC (white arrows) joining together at left renal venous level

The results of 65 donor-participants were reported as prevalence in term of number and percentage.

Discussion

Preoperative knowledge of renal vascular anatomy is critical for donor selection, kidney selection, and surgical planning. This necessary data could be obtained by CT angiography with near-isotropic data sets enabled by new multidetector CT scanners[5-7]. Raman et al[8] reported 95.5-98% accuracy of 16-detector CT angiography for detection of single and supernumerary renal arteries and veins, using operative findings as a gold standard. They also reported 100% sensitivity for detection of early branching of renal arteries and late venous confluence. Based on these prior reports[5-8], the authors claimed that CT angiography provided by 16- and 64-detector CT scanners should have high accuracy for detection of normal and variant renal vascular anatomy. With this reason, the authors used the radiological consensus as a gold standard, not a surgical proof. The authors designed the present study different from prior studies because the authors would like to describe and quantify variant renal vascular anatomy in both kidneys on a cohort of mostly young, asymptomatic, renal donors. The studies with surgical proof would be limited as they could evaluate only the harvested kidneys, which inevitably had less complex vascular anatomy.

Fig. 6 24-year-old female renal donor with outsized left gonadal vein. 3-D maximum-intensity-projection (MIP) CTA image demonstrates the outsized left gonadal vein (11 mm in diameter, white arrows) drained into left renal vein

In the present study, supernumerary renal arteries were slightly prominent on the left side (27.7% vs. 18.5%). Since the aberrant renal arteries could arise from the common iliac arteries, therefore the CT in the present study had the coverage field downwards to iliac crests. However, all supernumerary renal arteries in the present study arose from abdominal aorta without aberrant iliac origin.

The prevalence of supernumerary renal veins in the present study was much more common on the right side (35.4%) than the left side (1.5%). This was similar to a prior study by Raman et al[9]. They reported supernumerary veins on the right and left kidneys for 24% and 8%, respectively (Table 4). These could be explained by the short distance between right kidney and IVC, limiting the chance of renal veins to join before draining into IVC. These also emphasized the preference of left kidney donation.

The prevalence of renal vascular variants reported in the autopsy and surgical series[10,11] was somehow lower than in the prior CT angiographic studies[9,12], and in the present study. Renal vessels were relatively collapsed during surgery or autopsy period, but were well distended by intravascular contrast injection during CT angiographic period. Small renal vascular variants found by CT angiography were possibly overlooked during surgery or autopsy.

Overall, the prevalence of renal vascular anatomic variants in the present study was not significantly different from the previous CT angiographic studies[9,12] as described in Table 4. However, the different criteria of late confluence of left renal veins and outsized lumbar-gonadal axis between the present study and the study by Raman et al[9] resulted in the discrepancies in the prevalence of these two categories. A late confluence of left renal veins in the present study was diagnosed when left renal venous branches coalescing anterior to or near left lateral wall of the aorta. Raman et al called late confluence of left renal vein when venous branches coalescing within 1.5 cm from left lateral wall of abdominal aorta. These were the reasons for the discrepancies of the prevalence of late confluence of left renal veins between the present study (1.5%) and the study by Raman et al (17%). Raman et al diagnosed the outsized lumbar-gonadal axis when there was/were left lumbar vein and/or left gonadal vein larger than 5 mm, while the cut point in the present study was at 10 mm. Therefore, the prevalence of outsized lumbar-gonadal axis was far higher in their study (54% vs. 1.5%).

The present study showed 61 (93.8%) cases of right gonadal vein drained into IVC and 4 (6.2%) cases drained into right renal veins. To the authors' knowledge, no previous CT study described the variation of right gonadal vein drainage. This may be explained by relatively small-sized right gonadal veins were not well visualized by conventional or old multi-detector CT. With newer CT scanners and optimized CT protocol, right gonadal vein would be more identified.

Limitations of the present study must be acknowledged. First, a surgical gold standard could

Table 4. Comparison of the prevalence of renal vascular variants with prior studies

Vascular variants	Prevalence (%)		
	The present study	Raman et al[9]	Yeh et al[12]
Supernumerary right renal arteries	18.5	22	-
Supernumerary left renal arteries	27.7	16	-
Early branching of right renal arteries	12.8	15	-
Early branching of left renal arteries	22.4	21	-
Precaval right renal arteries	4.6	-	5
Supernumerary right renal veins	35.4	24	-
Supernumerary left renal veins	1.5	8	-
Late confluence of left renal veins*	1.5	17	-
Duplicated IVC	1.5	0.8	-
Circumaortic left renal veins	1.5	8	-
Retroaortic left renal veins	1.5	2	-
Outsized lumbar-gonadal axis**	1.5	54	-
Right gonadal veins drained into right renal veins	6.2	-	-

Remarks: Different criteria between the present study and the study by Raman et al[9] resulted in the discrepancies in the prevalence of late confluence of left renal vein* and the outsized lumbar-gonadal axis** not be obtained due to the study design as mentioned above. Second, the small total numbers of kidneys (65 left and 65 right kidneys) were included in the study population. Further study with large number of kidneys will illustrate the more accurate prevalence of renal vascular anatomical variants. Third, the variants of renal collecting system and ureters were not evaluated in the present study due to the 2-minute delay time of excretory phase was too early for good visualization of renal collecting systems and ureters. Another study with increased delay time for excretory phase should be designed to enhance the opacification of excreted contrast in renal collecting systems and ureters.

In summary, renal vascular anatomical variants were common and preoperative evaluation of renal vascular anatomy with high resolution imaging technique was essential to detect these variants. The surgeons and the radiologists should be aware of these variants to avoid preventable postoperative complications.

Potential conflicts of interest

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การศึกษาลักษณะเบี่ยงเบนของหลอดเลือดไตในผู้บริจาคไตที่ยังมีชีวิตอยู่ โดยการตรวจด้วยเครื่องเอกซเรย์คอมพิวเตอร์

ปิยาภรณ์ อภิสารธนรักษ์, วรปารี สุวรรณฤกษ์, กอบกุล เมืองสมบูรณ์, ธวัชชัย ทวีมั่นคงทรัพย์, นฤมล ศรีสุธาพรรณ ฮาร์โกรฟ

ภูมิหลัง: *ลักษณะเบี่ยงเบนของหลอดเลือดไตอาจมีผลต่อการผ่าตัดปลูกถ่ายไต ในปัจจุบันการตรวจหลอดเลือดไตด้วยเครื่องเอกซเรย์คอมพิวเตอร์ได้รับการยอมรับทั่วไป ว่ามีประสิทธิภาพในการประเมินผู้บริจาคไตที่ยังมีชีวิตอยู่ก่อนการผ่าตัด การศึกษานี้ต้องการศึกษาความชุกของลักษณะเบี่ยงเบนของหลอดเลือดไตในผู้บริจาคไตที่ยังมีชีวิตอยู่ โดยการตรวจด้วยเครื่องเอกซเรย์คอมพิวเตอร์*

วัสดุและวิธีการ: *ผู้บริจาคไตที่ยังมีชีวิตอยู่จำนวน 65 ราย ได้รับการตรวจหลอดเลือดไตด้วยเครื่องเอกซเรย์คอมพิวเตอร์ ภาพเอกซเรย์คอมพิวเตอร์ดังกล่าวได้ถูกสร้างเป็นภาพ 3 มิติ และถูกประเมินย้อนหลังโดยรังสีแพทย์ที่มีความชำนาญ 2 คน เพื่อศึกษาจำนวนหลอดเลือดแดงและดำของไตแต่ละข้าง ลักษณะการแตกแขนงของหลอดเลือดไต ตลอดจนลักษณะเบี่ยงเบนของหลอดเลือดแดงและดำของไตที่มีผลต่อการวางแผนการผ่าตัด*

ผลการศึกษา: *จากการศึกษาพบมีหลอดเลือดแดงไตมากกว่า 1 เส้นมากถึงร้อยละ 18.5 และมีการแตกแขนงใกล้ขั้วหลอดเลือดถึงร้อยละ 12.8 ในไตข้างขวา ส่วนไตข้างซ้ายพบถึงร้อยละ 27.7 และ 22.4 ตามลำดับ พบมีหลอดเลือดดำไตมากกว่า 1 เส้นร้อยละ 35.4 และ 1.5 ในไตขวาและซ้ายตามลำดับ นอกจากนั้นยังพบลักษณะเบี่ยงเบนอื่น ๆ ดังนี้ precaval right renal artery ร้อยละ 4.6, late confluence of left renal veins ร้อยละ 1.5, duplicated inferior vena cava ร้อยละ 1.5, circumaortic left renal vein ร้อยละ 1.5, retroaortic left renal vein ร้อยละ 1.5, left gonadal vein ขนาดเกิน 1 เซนติเมตร ร้อยละ 1.5, และ right gonadal vein เทเข้า right renal vein ร้อยละ 6.2*

สรุป: *ลักษณะเบี่ยงเบนของหลอดเลือดไตพบได้บ่อยและมีหลากหลายรูปแบบ ศัลยแพทย์และรังสีแพทย์ควรระวังและมองหาลักษณะดังกล่าวจากการตรวจหลอดเลือดไตก่อนการผ่าตัด เพื่อป้องกันความผิดพลาดที่อาจเกิดขึ้นระหว่างการผ่าตัด*