

Evaluation of renal vascular anatomy in live renal donors: Role of multi detector computed tomography

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Abstract

Background: Evaluation of renal vascular variations is important in renal donors to avoid vascular complications during surgery. Venous variations, mainly resulting from the errors of the embryological development, are frequently observed.

Aim: This retrospective cross-sectional study aimed to investigate the renal vascular variants with multidetector computed tomography (MDCT) angiography to provide valuable information for surgery and its correlations with surgical findings.

Materials and Methods: A total of 200 patients underwent MDCT angiography as a routine work up for live renal donors. The number, course, and drainage patterns of the renal veins were retrospectively observed from the scans. Anomalies of renal veins and inferior vena cava (IVC) were recorded and classified. Multiplanar reformations (MPRs), maximum intensity projections, and volume rendering were used for analysis. The results obtained were correlated surgically.

Results: In the present study, out of 200 healthy donors, the standard pattern of drainage of renal veins was observed in only 67% of donors on the right side and 92% of donors on the left side. Supernumerary renal veins in the form of dual and triple renal veins were seen on the right side in about 32.5% of donors (dual right renal veins in 30.5% cases and triple right renal veins in 2.5% cases). Variations on the left side were classified into four groups: supernumerary, retro-aortic, circumaortic, and plexiform left renal veins in 1%, 2.5%, 4%, 0.5%, cases respectively.

Conclusions: Developmental variations in renal veins can be easily detected on computed tomography scan, which can go unnoticed and can pose a fatal threat during major surgeries such as donor nephrectomies in otherwise healthy donors if undiagnosed.

Key Words: Circumaortic, plexiform, renal vein, retroaortic, supernumerary

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INTRODUCTION

Renal transplantation is the ultimate treatment for chronic kidney disease at present. Recent advances in conservative renal surgery and transplantation surgery, a thorough knowledge of the anatomy and variations of renal veins is needed for retroperitoneal surgeries and vein reconstruction procedures. Variations in renal vein drainage mainly result from faults during embryogenesis.

According to the normal anatomy of renal veins, they lie anterior to respective renal artery and drain into inferior vena cava (IVC) at the approximate level of L2 vertebral body. Usually, the right renal vein is shorter than its counterpart, which is about 3 times longer than the right renal vein. The right renal vein usually does not receive any draining veins, whereas left renal vein receives lumbar, gonadal, and suprarenal veins.^[1]

Because of the complexity of the development of renal veins, many variations are expected. It is more seen on the left side due to its longer course and communication with tributaries such as lumbar, gonadal, suprarenal, and hemiazygos veins. These factors result in significant variations in the left renal vein drainage.^[2] Anomalous supernumerary renal veins are a relative contraindication for donor nephrectomy because they are associated with higher risk of thrombosis in graft renal vein.^[3] Proper knowledge of such variations is mandatory in various operative procedures to avoid vascular complications.

With knowledge of these factors, we have worked to study the pattern of drainage of renal veins and their variations along with incidental findings in variational anatomy of IVC. Various patterns of drainage are emphasized regarding their causative embryological processes and their importance during surgical procedures.

MATERIALS AND METHODS

Our present retrospective cross-sectional study comprised 200 healthy people being evaluated as potential renal donors by computed tomography (CT) angiography at Department of Radio Diagnosis, Institute of Kidney Disease and Research Centre, Dr. H. L. Trivedi Institute of Transplantation Sciences, Ahmedabad, Gujarat. All of the participants underwent CT renal angiography on Seimens Somatom 64 slices CT scanner with injection of 350 ml Iohexol in 60 mg/kg dose with prior written consent. Rapid injection of 70–100 ml bolus of 300–400 mg/ml contrast at the rate of 3.5 mL/s followed by 20 ml saline at the rate of 2.8 mL/s was infused. The region included was from celiac axis up to termination of common iliac arteries. Slice thickness was 5 mm, and the scans were reconstructed at 0.6 mm thickness. Arterial,

venous, and delayed phases were obtained at 10 s, 60 s, and 7–10 min, respectively. Multiplanar reformation and curved planar reformation, maximum intensity projection, and volume rendering techniques were used for postprocessing of images. Both renal veins and IVC were examined regarding their drainage patterns and the presence of anatomical variations, if present.

RESULTS

Out of 200 subjects of mean age, 42.5 years (20–65 years) studied, the standard pattern of renal veins was observed in only 67% donors on the right side and 92% donors on the left side. Rest of them showed wide variations in drainage patterns. We had divided the major variations into four main groups; supernumerary renal veins, retroaortic renal vein, circumaortic renal veins, and plexiform renal veins [Table 1]. The embryological and clinical importance of various anomalies of renal veins are as follows.

Supernumerary renal veins

It is defined as more than one vein at the hilum of kidney and draining into IVC. In our study, supernumerary renal vein was seen in 32.5% kidneys on the right side (dual right renal veins in 30.5% cases and triple right renal veins in 2.5% cases) and 1% kidneys on the left side.

Retroaortic left renal vein

In this anomaly, the left renal vein courses dorsal to aorta and drains into IVC. On its way, it may receive left suprarenal vein and left gonadal vein [Figure 1a and b]. In this study, retroaortic left renal vein was seen in 5 donors (2.5%).

Circumaortic left renal vein

In circumaortic left renal vein, two limbs of the left renal vein are seen at hilum, one of them is preaortic in course and the other courses downward and in retroaortic course to drain into IVC via two different openings. Normally, the horizontal preaortic limb drains into IVC at the same level as its origin at the hilum. Usually, retroaortic limb is larger than preaortic limb. Normally, preaortic limb may receive suprarenal vein, and retroaortic limb may receive lumbar and gonadal veins [Figure 2a-c]. In our study, circumaortic left renal vein was seen in 8 donors (4%).

Table 1: Incidence of various venous anomalies in present study

Type of variation	Number of donors	Percentage
Supernumerary right renal vein	61 (dual RV) 5 (triple RV)	30.5 2.5
Supernumerary (dual) left renal vein	2	1
Retroaortic left renal vein	5	2.5
Circumaortic left renal vein	8	4
Plexiform left renal vein	1	0.5

RV: Renal vein

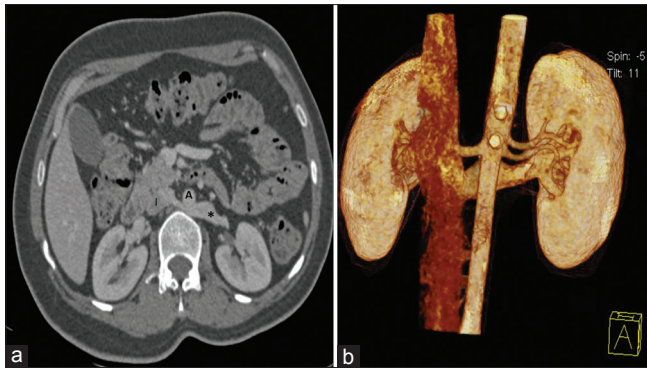


Figure 1: (a) Venous phase of contrast enhanced computed tomography scan showing left renal vein coursing in retroaortic location. (b) Multiplanar reformation of contrast enhanced computed tomography scan showing retroaortic left renal vein. Inferior vena cava -I, Aorta-A, Left renal vein-*

Plexiform left renal vein

It is a rare anomaly where the left renal vein after its origin at renal hilum, divides and redivides to form a complex network, and it again unites to drain into IVC via a single opening. Thus, it formed two hiatuses. Only one donor showed such complex venous anomaly in this study (0.5%).

DISCUSSION

Variations of renal vasculatures are usually asymptomatic and are diagnosed incidentally. In today transplant era, the thorough knowledge of such vascular anomalies is of utmost importance as they influence technical aspects of surgery, and they can affect intra- and post-operative complications of major operations such as donor nephrectomy or renal transplant. The occurrence of such anomalies can be explained through the embryological development of IVC and renal veins [Table 2].^[4]

The embryology extends from 4th week up to 8th week of Intrauterine life. In the very first phase of development, anterior and posterior cardinal veins are present which drain into a common cardinal vein to form sinus venosus. Initially, three paired parallel veins named subcardinal veins, supracardinal veins, and posterior cardinal veins are formed. Subcardinal veins; draining the caudal half of the body, lie medial to the posterior cardinal veins and communicate with multiple anastomoses. Here, the right subcardinal vein dominates, and posterior cardinal vein regresses. The cranial aspect of the left subcardinal vein forms the left adrenal vein. Supracardinal veins drain the cranial half of the body, and they unite with the regressing subcardinal veins. The right supra cardinal vein forms the infrarenal part of IVC, and the azygous vein is formed by its cranial end [Figure 3]. Caudal ends of posterior cardinal veins persist as common iliac veins and caudal ends of subcardinal veins form gonadal veins. Renal veins are formed

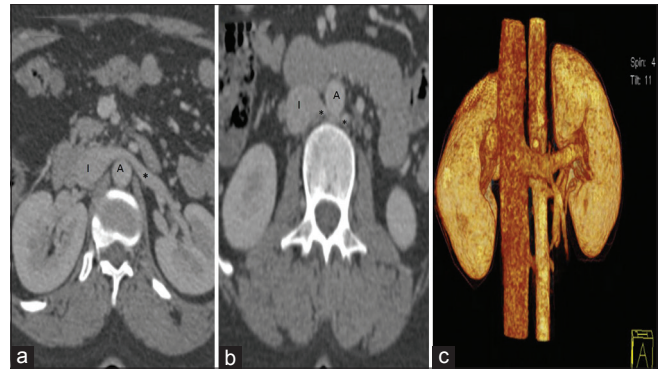


Figure 2: (a) Venous phase of contrast enhanced computed tomography scan showing left renal vein coursing in preaortic location. (b) Venous phase of contrast enhanced computed tomography scan showing left renal vein coursing in retroaortic location. (c) Multiplanar reformation of contrast enhanced computed tomography scan showing circumaortic left renal vein. Inferior vena cava-I, Aorta-A, Left renal vein-*

Table 2: Classification of anomalies of inferior vena cava and renal veins according to the causative segment

Anomalous segment	Anomaly
Posterior cardinal veins	Retrocaval ureter Circumcaval ureter
Subcardinal veins	Interruption of the IVC with azygos/hemiazygos continuation
Supracardinal veins	Persistence of the left supra cardinal vein - left IVC Persistence of both left and right supra cardinal veins - double IVC
Renal segment	Supernumerary renal veins Circumaortic renal vein Retroaortic renal vein

IVC: Inferior vena cava

by the anastomosis of supra- and sub-cardinal veins at the level of L1-L2.^[4]

Sub- and supra-cardinal veins anastomose and form the renal veins. Two renal veins are formed as ventral and dorsal veins; the dorsal vein usually degenerates, and the ventral vein forms the renal vein.

Supernumerary renal veins

The incidence of supernumerary renal veins on either side is varied, but usually, it is seen more frequently on the right side [Table 3]. In our study, it was seen in 32.5% of donors on the right side and in 1% of donors on the left side.

Embryology

Around the 8th week of intrauterine life, the parallel venous system gets converted into unilateral right-sided IVC. At this time, two renal veins are seen on either side, each on ventral and dorsal plane. Eventually, these two dorsal and ventral veins merge to form a single vein, in case they do not merge, accessory renal vein is seen.^[2] Because of shifting of vessels toward the right side during embryogenesis, and complex left-sided venous

embryology, the incidence of supernumerary renal veins are less common on the left side.

Clinical implications

The multiplicity of renal veins poses a fatal threat during major surgeries.^[2] During nephrectomy, if venous drainage of the smaller vein is <20%, the vein is sacrificed. Moreover, if two veins are of equal caliber, then side-to-side anastomosis is done. Veins can also be reinforced with donor gonadal vein graft to increase the size.^[5]

Retroaortic left renal vein

The incidence of retroaortic left renal vein is 0.5–17% as reported in different studies [Table 4]. In our study, the incidence of retroaortic left renal vein was 2.5%. It is formed, if ventral part of subsupra- and intersub-cardinal anastomoses regresses or dorsal part of subsupra anastomosis and intersupra cardinal anastomosis persists.

Embryology

The occurrence of retroaortic renal vein can be explained by the theory of regression of ventral limb of the left renal vein and persistence of dorsal limb of the left renal vein.^[2]

Clinical implications

Retroaortic left renal vein may get compressed between the aorta and adjacent vertebral body and can cause left flank and abdominal pain with or without hematuria due to left renal venous hypertension. This is known as posterior nutcracker syndrome.^[6]

Table 3: Incidence of variations of renal vein on either side according to various workers (arranged according to the year of presentation)

Workers	Right side (%)	Left side (%)
Anson <i>et al.</i> ^[15,16]	11	3
Pick and Anson ^[8]	27.8	1
Monkhouse and Khaliq ^[17]	7.2	None
Bregman ^[20]	18	9
Gupta <i>et al.</i> ^[5]	33	3.3
Present study	32.5	8

Table 4: Incidence of retroaortic and circumaortic left renal vein according to various workers (arranged according to the year of presentation)

Workers	Retroaortic LRV (%)	Circumaortic LRV (%)
Anson <i>et al.</i> ^[15,16]	-	2
Chuang <i>et al.</i> ^[7]	2-3	6-17
Reed <i>et al.</i> ^[18]	1.8	4.4
Trigaux <i>et al.</i> ^[19]	3.7	6.8
Bregman ^[20]	1.5-8.7	2
Tatar <i>et al.</i> ^[12]	0.5-6.8	0.3-3.7
Gupta <i>et al.</i> ^[2]	6.6	6.6
Dilli <i>et al.</i> ^[21]	3.1	2.1
Tao <i>et al.</i> ^[22]	1.85	2.11
Present study	2.5	4

LRV: Left renal vein

Furthermore, this compression can cause left renal to gonadal vein reflux and results into varicocele which may lead to infertility in males and can cause pelvic congestion syndrome leading to lower abdominal pain and dysmenorrhea, dyspareunia, vulval, gluteal or thigh varices, and emotional disturbances in females.^[2]

In surgical aspects, such anomalies can nullify the advantage of the left renal vein being longer during mobilization procedures, and it is also more susceptible to injury during any retroperitoneal surgery.^[7] Retroaortic left renal vein lies in close to the pancreas, so it can be directly affected by the malignant disease of pancreas, and it is crucial to be considered in evaluation and staging of retroperitoneal tumors.

Circumaortic left renal vein

The incidence of circumaortic left renal vein varies from 0.3% to 6.8%. In our study, it was 4%. Occurrence of circumaortic left renal vein is due to the persistence of inter supra cardinal anastomosis, left subsupra cardinal anastomosis, and left dorsal renal veins.

Embryology

During development when the ventral and dorsal limbs of renal vein persist, circumaortic left renal vein is formed. Ventral limb of circumaortic left renal vein shows pre-aortic course while the dorsal limb runs in retro-aortic location to drain in to IVC via two separate openings.^[2]

Clinical implications

As the preaortic limb of circumaortic left renal vein is of normal thickness, the operating surgeon may get mislead of the presence of the second retroaortic limb of circumaortic left renal vein. Hence, the chances of injury and thus changes of hemorrhage and rarely death are more associated with circumaortic left renal vein.^[8] Extensive dissection may cause potential injury to superior mesenteric artery or celiac axis and may lead to postoperative pancreatitis.^[9] Intra operative injury to retroaortic segment is reported to be as high as 40%.^[10]

During nephrectomy, same rule applied as supernumerary renal veins, smaller vein of <20% caliber is sacrificed, and otherwise side-to-side anastomosis is done.

Plexiform left renal vein

In our study, only one kidney showed such complex vascular anomaly. In literature, it is very rarely reported.

Embryology

Actually, varied opinions exist regarding the development of such complexity of left renal vein. Inter sub cardinal vein anastomosis in the form of single vascular channels passing

ventral and dorsal to aorta,^[11] and persistence of networks of veins^[12] are two theories.

Clinical implications

Plexiform vein forms hiatuses due to vascular anomalies which may transmit prevertebral venous plexus, internal spermatic vein or gonadal vessels through them, and may cause symptoms. These vascular channels may be clamped during surgeries.

Draining veins

Usually, lumbar, gonadal, and supra renal veins drain in to left renal vein. In this study, 136 (68%) donors kidneys showed drainage of the lumbar vein into the left renal vein and 173 (86.5%) donor kidneys showed drainage of gonadal vein into the left renal vein. Drainage of single or dual suprarenal vein is almost always seen into the left renal vein. In only 5 donors (2.5%) it drained directly into IVC.

Associated anomalies

Two cases of developmental anomalies of IVC in the form of dual IVC were also seen in healthy donors of our study

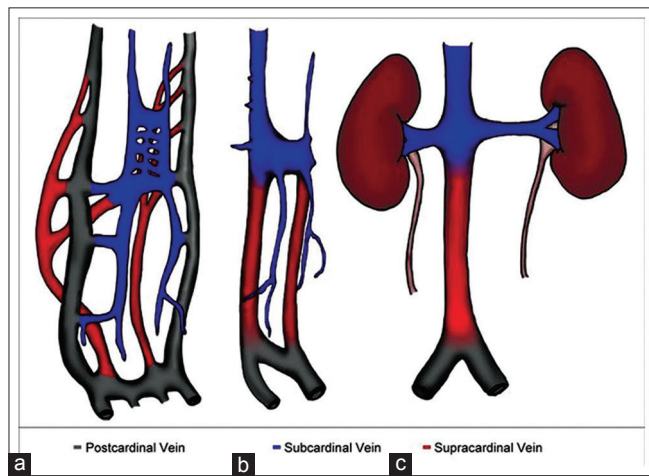


Figure 3: Diaphragmatic representation showing embryogenesis of renal veins and inferior vena cava

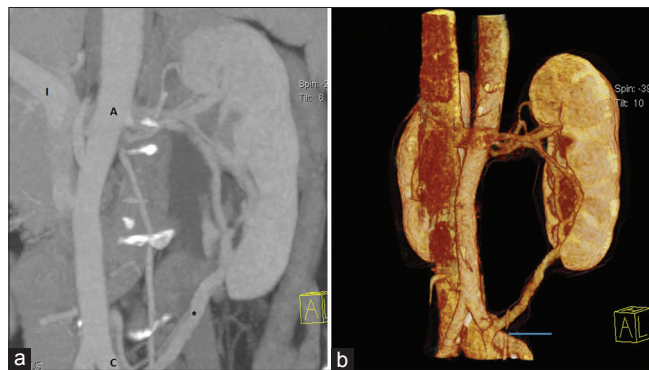


Figure 5: (a) Venous phase of contrast enhanced computed tomography scan and (b) multi planar reformation showing drainage of left renal vein directly into left common iliac vein. Inferior vena cava-I, aorta-A, Left renal vein-*, Left common iliac vein-C

[Figure 4a and b]. Patients with anatomic variations of IVC are at higher risk for developing deep venous thrombosis of the common femoral or iliac veins at early age than patients with no IVC anomalies.^[13]

Interesting cases

In one case, the left renal vein directly drained into left common iliac vein [Figure 5a and b]. Another donor showed complex venous anomaly in which dual left renal veins were seen; both of them coursed in retroaortic location, and one of the retroaortic left renal veins showed two tributaries with one tributary draining into the left common iliac vein [Figure 6a-c].

Surgical correlations

Most of the donor nephrectomies included left kidney. Out of 19 donors who had anomalies of IVC and left renal vein, two cases with retro-aortic and circumaortic left renal vein each

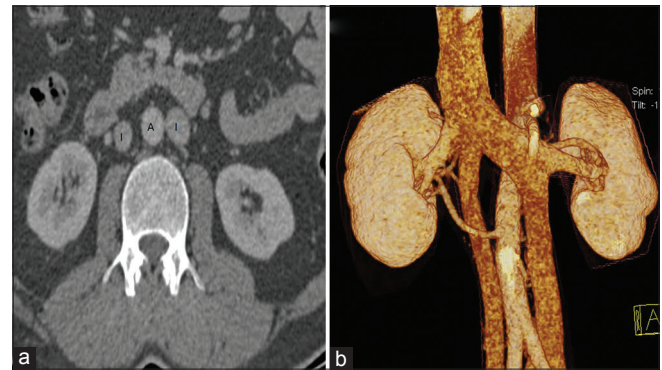


Figure 4: (a) Venous phase of contrast enhanced computed tomography scan and (b) multiplanar reformation showing inferior vena cava on both sides of aorta, left-sided inferior vena cava reaches up to the level of left renal vein, joins with it and courses toward right side to join the main right-sided inferior vena cava. Inferior vena cava-I, Aorta-A, Left renal vein-*

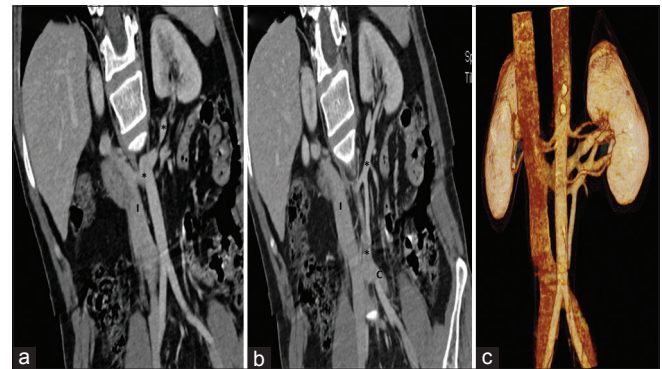


Figure 6: (a) Maximum intensity projection reformation of venous phase of contrast enhanced computed tomography scan showing one left renal vein coursing in retroaortic location. (b) Maximum intensity projection reformation of venous phase of contrast enhanced computed tomography scan showing another left retroaortic renal vein with one of its tributary draining into left common iliac vein. (c) Multiplanar reformation of contrast enhanced computed tomography scan showing dual retroaortic left renal veins with one of them draining into left common iliac vein. Inferior vena cava-I, Left renal vein-*, Left common iliac vein-C

was planned for right nephrectomies. One patient with dual left retro-aortic renal veins with drainage into left common iliac vein underwent right nephrectomy. Remaining 11 donors underwent left nephrectomy, and three of the recipients died before transplantation. Thus in the present study, the surgeon also went ahead with the cases having anomalous kidneys with no intra- or post-operative complications.

Importance of imaging

Finding such anomalies on CT scan helped the surgeon for the choice of donor and also the choice of the kidney. They preferred kidneys with either single artery or single vein. However, when it was not possible, kidneys with multiple arteries were given preference over multiple veins as veins have thinner walls which are not favorable for anastomosis. Usually, finding such anomalies did not warrant rejection of the donor. In cases with multiple arteries, if the smaller artery is sacrificed, chances of fibrosis, thrombosis, or calyceal-cutaneous fistula^[4] are increased. In cases with anomalous veins, intraoperative bleeding can occur due to inadvertent compromise of the vein. Furthermore, the wall of the vein is comparatively thin, so during anastomosis, meticulous technique must be done otherwise bleeding can occur. Thus, CT scan plays a role like a torch in a dark tunnel. It guides the surgeon in choosing the proper kidney for donation and helps in saving two lives.

Review of literature

Various workers have worked on anatomy and radiology of renal veins and its variations.

The overall incidence of variations is seen more commonly on the right side, ranging from 7.2% to 33% and 0% to 9% on the left side in various other studies.^[2,8,15-17,20] In our study, the incidence of variations of renal vein was 32.5% on the right side and 8% on the left side. The incidence of retroaortic left renal vein was 0% to 7.8% in various studies whereas it was 2.5% in our study. Similarly, the incidence of circum-aortic left renal vein was 0.3–6.8% in various other studies and 4% in our study.^[2,6,11,15,16,18-20] Incidences of variations of each renal vein and types of variations on the left side according to various authors are shown in tables [Tables 3 and 4].

CONCLUSIONS

- Variations in renal veins are more common on the right side
- Though they are more complex on the left side
- They can be accurately detected on multidetector CT
- Knowledge of vascular anomalies helps in planning of surgery and reduces complications

- Complex venous drainage is not absolute contraindications for nephrectomy.

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Conflicts of interest

There are no conflicts of interest.

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