Clinical importance of anatomical variations of renal vasculature during laparoscopic donor nephrectomy

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Abstract

Introduction
Laparoscopic live donor nephrectomy has become a well-accepted practice in most transplant units. However, the variations and complex of renal vasculature may make the surgery even more challenging during laparoscopic donor nephrectomy. The aims of this article are to review embryology of the renal vasculature development and the clinical significance of renal vasculature anomalies during laparoscopic donor nephrectomy and the consequence of kidney transplant.

Discussion
The results were interpreted and summarised as renal artery development and its anomalies and renal vein development and its anomalies including associated anomalies of the inferior vena cava. The clinical significance during laparoscopic donor nephrectomy was explored. The value of computed tomography angiography was emphasised during live donor work-up and before surgery planning.

Conclusion
It is paramount for surgeons to have a thorough knowledge of renal vasculature development and to readily identify the anomalies of renal vasculature on computed tomography angiography prior to laparoscopic donor nephrectomy. The adverse bleeding event can be therefore prevented.

Embryology of renal arteries
The kidneys ascend to the lumbar region below the adrenal glands during the embryological development between the sixth and ninth weeks possibly due to differential growth of the lumbar and sacral regions of the embryo. As the kidneys ascend they are vascularised by a succession of transient aortic sprouts that arise at higher levels progressively. These arteries do not elongate to follow the ascending kidneys; instead they are degenerated and replaced by successive new arteries. The final pair of arteries forms in the upper lumbar region as the definitive renal arteries. Sometimes, the inferior pair of arteries is not degenerated and becomes an accessory lower pole artery. The kidney may become ectopic in the pelvis if it fails to ascend adequately (Figure 1). The horseshoe kidney may be developed if the lower pole is fused and becomes trapped by the inferior mesenteric artery and thus the kidney cannot ascend to the lumbar region.

The origin of intrarenal vasculature has not yet been completely understood. It was postulated that the renal vasculature derived exclusively from the branches off the aorta and other pre-existing extrarenal vessels. However, there was evidence that the renal vessels may originate within the embryonic kidney from the protocols of these studies have been approved by the relevant ethics committees related to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in these studies.

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the vascular progenitor cells. It was also thought that both vasculogenesis and angiogenesis may play a role in the development of renal vasculature.

**Renal artery variations**

In the context of live donor work-up on computed tomography angiogram (CTA), the single normal renal artery is about 70%, two renal arteries 25% and three renal arteries 2.6%. The prevalence of multiple renal arteries on both sides is about 12%. Rarely, four renal arteries on each side may be encountered during imaging work-up of 1.3%. The most common variations of renal artery are excess renal arteries and early bifurcation. The accessory renal artery is defined as the artery that has a separate aortic ostium from the main renal artery and supply to the upper or lower pole. The aberrant renal artery is defined as the artery that has a separate aortic origin but goes into the renal hilum. The incidence of excess renal arteries ranges from 25% to 40%. In addition, the renal artery may arise at unusual aortic origin such as above the superior mesenteric artery or celiac trunk, in which the renal artery may be entrapped in the medial arcuate ligament. In this situation, the renal artery may be compressed and presented with symptoms of hypertension. The compression to renal artery may occur in the presence of low insertion of median arcuate ligament or high origin of the renal artery. As such, the donor nephrectomy should be considered on this side. The inferior renal artery usually can arise from the iliac artery or as a common trunk with the inferior mesenteric artery. In author’s experience, the one ostium usually can be obtained during laparoscopic donor nephrectomy if the early branches are beyond 10 mm from the origin of the main renal artery. Otherwise, the renal arteries can be reconstructed on the back table or separate renal artery anastomosis to the recipient can be performed successfully.

Laparoscopic donor nephrectomy can be safely performed in the donor with multiple renal arteries with equivalent transplant results to those kidney grafts with a single renal artery. The technique for reconstruction of multiple renal arteries has also been established with satisfactory results. It is essential to interpret CTA accurately prior to surgery and identify the excess renal artery during surgical dissection.

The early branching of renal artery is defined as the branches arising within 15 mm from the origin of the main renal artery ostium. The incidence is around 10%–12%. In author’s experience, the one ostium usually can be obtained during laparoscopic donor nephrectomy if the early branches are beyond 10 mm from the origin of the main renal artery. Otherwise, the renal arteries can be reconstructed on the back table or separate renal artery anastomosis to the recipient can be performed successfully.

Figure 1: Renal artery and renal vein in ectopic kidney. RA, renal artery; RV, renal vein; Lt, left.
Embryology of the renal veins
The formation of the renal vein is a complex process during embryologic development. In brief, the initial venous drainage in the embryo is by anterior paired cardinal veins draining the cranial half of the body and by posterior paired cardinal veins draining the caudal half of the body. The subcardinal veins form subsequently and gradually take over the drainage of the caudal half of the body. Then the posterior cardinal veins start to degenerate. The subcardinal veins communicate with hepatic sinusoids in the region of the liver form of the hepatic segment of the inferior vena cava (IVC). The cranial part of the right subcardinal vein becomes the supra renal IVC, while the cranial part of the left subcardinal vein forms the left adrenal vein. During the seventh week of embryo, the supracardinal veins develop and gradually take over the venous drainage of the caudal body. The right supracardinal veins extend and form the infrarenal IVC. The cranial aspect of the right supracardinal vein forms the azygous vein. The caudal aspect of the posterior cardinal vein becomes the common iliac veins. The renal veins are formed as ventral and dorsal veins as a result of the anastomosis of the supra- and subcardinal veins. The ventral vein becomes the definitive renal vein, whereas the dorsal vein is gradually degenerated. The subcardinal veins extend caudally forming the gonadal vessels. Based on the complex of venous development during gestation, it is therefore understood that renal vein anomalies are closely associated with malformation of IVC.

Multiple renal veins and lumbar veins
Clinically, conventional single renal vein is the most common anatomy in live donor work-up, but anatomy variations are identified in 5%–30%. The most common renal venous anomaly is the occurrence of dual renal veins, accounting for 15%–30%, frequently on the right side. In this case, the smaller tributary can often be ligated without significant consequence, whereas the larger vein should be preserved to maintain better venous drainage. Anomalous veins are likely to be dilated and tortuous predisposing injury to occur during surgical dissection. In addition, the lumbar veins, which are the veins communicating the left renal vein and the left ascending lumbar vein running along the inside of the posterior abdominal wall, need to be dissected and divided carefully to expose the proximal part of the renal artery for a better length, in particular if there are early renal artery branches. Lumbar vein is usually short in length and big in calibre. It can become a challenge during laparoscopic donor nephrectomy because of the risk of accidental injury and subsequent bleeding, which may lead to conversion to open surgery. Therefore, the injury to lumbar veins should be ultimately avoided. In addition, the anomalies of lumbar vein are frequently encountered during left side donor nephrectomy including agenesis and collaterals. Often, there are one or two lumbar veins, accounting for 65%–80%. Rarely, there are three lumbar veins of 3%.

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accurately during the laparoscopic dissection\(^1\). Li et al. have described a classification of lumbar veins into five main types based on their clinical cases, which may help understanding of variations of the lumbar vein and reduce the risk of surgical injury and subsequent bleeding\(^1\).

**Double IVC and left-sided IVC**

During the embryo development, the persistence of the left suprarenal vein with degeneration of the right suprarenal vein gives rise to the left IVC. As such, the left gonadal and adrenal veins drain directly into the vena cava, and the right gonadal and adrenal veins drain into the right renal vein\(^4\). The presence of both left and right suprarenal veins forms double IVC. The right vena cava is usually dominant and left vena cava anastomoses to it in front of or behind the aorta. The left IVC may drain into the left renal vein directly\(^3\). The prevalence of left-sided IVC is from 0.1% to 0.4%, and double IVC ranges from 0.3% to 0.7\(^%\)\(^2\). These anomalies were mostly incidental findings on the images or during surgery. However, these should not be contraindicated for live donor nephrectomy. There are some reports of successful laparoscopic donor nephrectomy with duplicate IVC or left-sided IVC and subsequent successful kidney transplant\(^4\). The left-sided IVC should be preserved rather than sacrificed during nephrectomy due to the risk of ipsilateral oedema in the pelvis and leg\(^6\). In addition, the left-sided IVC and duplicated IVC may increase the risk of thromboembolism due to the increased blood flow stasis. These anomalies may also complicate the management of deep vein thrombosis when consideration of filter insertion is decided\(^5\). If one IVC is missed, then recurrence of pulmonary embolism may occur\(^5\).

**Circumaortic renal vein and retroaortic renal vein**

**Circumaortic renal vein**

The persistence of the intersuprarenal anastomosis and left subsuprarenal anastomosis and left dorsal renal vein gives rise to circumaortic renal vein with two left renal veins\(^5\). The incidence ranges from 8\% to 17\% during live kidney donor work-up\(^6\). Retroaortic renal vein

It develops due to the persistence of the left subsuprarenal anastomosis, the intersuprarenal anastomosis and the dorsal left renal vein, with degeneration of ventral renal vein.\(^8\) It is classified as two types: type 1 is developed as a result of persistence of the left subsuprarenal anastomosis, the intersuprarenal anastomosis and the dorsal left renal vein and type 2 is formed due to the persistence of the left subsuprarenal anastomosis and left subsuprarenal vein\(^9\). Retroaortic renal vein ranges from 3\% to 4.7\% on CTA during live donor work-up\(^1\) while it was reported as 3.3\% in cadaver dissections\(^2\). The retroaortic renal vein is usually drained into the IVC\(^5\), but can be drained into the common iliac vein\(^2\).

Circumaortic and retroaortic variants constitute the most common anomalies of the left renal vein with incidence of 6.2\%–14\%\(^1\). However, it is not contraindicated for laparoscopic live donor left nephrectomy in the presence of these anomalies. The excellent outcomes in both donor and recipient can be achieved in the experienced units\(^6\). Care must be taken to justify which component should be preserved for graft transplantation. Usually, the posterior segment of the circumaortic renal vein has a smaller size that can be safely divided and sacrificed. In
Review

Figure 4: (a) Left retroaortic renal vein on CTA. (b) Left retroaortic renal vein. (c) Retroaortic renal vein. Lt, left; IVC, inferior vena cava; RV, renal vein. (d) Retroaortic renal vein on CTA (transverse view).

The presence of renal vein anomalies, the insertion of the lumbar veins, gonadal vein and adrenal vein may be in various fashions. Therefore, careful review of the CTA prior to the surgery is mandatory to identify possible anomalies. The meticulous dissection is preferred in dealing with these venous anomalies to avoid the risk of injury and bleeding. In the presence of a retroaortic left renal vein, the retroperitoneoscopic technique will provide an easy approach that is readily accessible to the abnormal veins.

The value of CTA

The advent of multidetector row computed tomography (MDCT) enables comprehensive evaluation of the renal vasculature and has replaced conventional digital subtraction angiography (DSA). The renal artery and segmental arteries can be well visualised in the arterial phase, and veins can be evaluated in the venous phase including adrenal, gonadal, lumbar veins and their tributaries. In addition, the variations of renal vasculature can be well assessed by MDCT prior to surgery, which can provide accurate information to guide the laparoscopic donor nephrectomy. The accuracy of MDCT in detection of the renal vascular anomalies has been well demonstrated in the literature, and it is widely employed for live laparoscopic donor nephrectomy to minimize the risk of injury to the renal vasculature, in particular in the presence of vascular variations.

Conclusion

The renal vasculature anomalies are commonly encountered during live kidney donor work-up. The overall incidence is added to about 70% including supernumerary renal arteries, early renal artery bifurcation, dual renal veins, dual IVC and circumaortic/retroaortic renal veins. The accuracy of MDCT in detection of the renal vascular anomalies has been well demonstrated in the literature, and it is widely employed for live laparoscopic donor nephrectomy.
Anatomical variations of renal vasculature during kidney donor work-up. In general, these variations are not contraindicated for consideration of laparoscopic donor nephrectomy and consequence of kidney transplant. However, it is paramount for surgeons to have thorough knowledge of renal vasculature development and to readily identify these anomalies of renal vasculature on CTA prior to laparoscopic donor nephrectomy. The surgical safety should be analysed on every individual case within the transplant unit. The adverse bleeding event can therefore be prevented.

References


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