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When one becomes more: minimum renal artery length in laparoscopic live donor nephrectomy

Iype S, David S, Hilliard S, Shaw A, Jamieson NV, Praseedom RK, Butler AJ, Huguet EL, Parker RA, Bradley JA, Watson CJE. When one becomes more: minimum renal artery length in laparoscopic live donor nephrectomy.

Abstract: Background: Laparoscopic donor nephrectomy may convert short main arteries into multiple arteries, increasing the technical challenge of implantation. We evaluated our experience to identify factors predictive of multiple arteries after laparoscopic nephrectomy.
Methods: All laparoscopic nephrectomies from the start of our program in November 2002 until June 2013 were studied, and preoperative imaging reviewed for donor artery length and multiplicity together with operative findings.
Results: A total of 287 consecutive laparoscopic live donor nephrectomies (64 right and 223 left nephrectomies) were studied. Renal artery length was measured from preoperative donor magnetic resonance or computed tomography angiogram and nephrectomy performed using a laparoscopic stapling device. Nine left kidneys with a single artery (6, 7, 9, 10, 11, 12, 13, 14, and 16 mm in length) and five right kidneys with a single artery (5, 13, 15, 20, and 26 mm) on imaging resulted in multiple renal arteries at implantation. Complex renal vein anatomy was associated with multiple arteries following retrieval.
Conclusion: A main renal artery length of more than 16 mm on the left and 26 mm on the right is unlikely to result in multiple arteries to implant. The possibility of multiple arteries should be borne in mind when the donor renal artery is short.

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Key words: artery length – living donor kidney transplantation – magnetic resonance angiography – multiple renal arteries – renal artery

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Live donor kidney transplantation can be a technically challenging surgical procedure, particularly if the donor kidney has multiple renal arteries. When transplantation of kidneys with multiple arteries is undertaken, the reported results are broadly comparable to those after transplantation of kidneys with a single artery, albeit with more short-term complications (1). The surgical preference is to select a donor kidney with a single artery to implant. This is not possible in the 5–10% of donors where both kidneys have multiple arteries (2–4) nor where the main renal artery stem is so short that nephrectomy results in multiple arteries. The latter consideration has been highlighted as the widespread adoption of laparoscopic live donor nephrectomy where use of a vascular stapling device results in a significant loss of renal artery length.

Preoperative imaging of the potential live donor is important to accurately identify the number of renal arteries and to help predict the likelihood of multiple vessels arising because of a short renal artery main stem. However, it is not clear what length of renal artery main stem on imaging is needed to safely provide a single vessel for anastomosis after laparoscopic live donor nephrectomy and to ensure secure ligation of the renal artery in the donor.

To address this, we undertook a retrospective single center review of the results of magnetic resonance angiography (MRA) performed prior to live donor laparoscopic nephrectomy and correlated the renal artery length with the operative findings following cold perfusion of the donor kidney.

Materials and methods

All live donor nephrectomies performed at our institution since the adoption of the laparoscopic technique in November 2002 until June 2013 were studied. Donor renal vascular anatomy was assessed using either MRA (n = 279) or computed tomographic angiography (n = 8). Details of the vascular anatomy of the donor kidney prior to implantation were obtained from the surgical operation note, which in all cases detailed and illustrated the relevant vascular anatomy and operative reconstruction when undertaken.

Left donor nephrectomy was performed preferentially as the longer renal vein facilitated implantation, but there was a relatively low threshold for performing right nephrectomy if there were anatomical concerns relating to the left kidney such as multiple arteries or an early renal artery bifurcation. Where right nephrectomy was performed, the renal artery was preferentially divided at the right margin of the inferior vena cava (IVC).

Continuous variables were summarized as median (range) and categorical variables as count (percentage). Fisher's exact test was used to determine whether there was an association between the event of a renal artery being surgically divided beyond its division and each of the following donor factors: gender, body mass index (BMI), previous abdominal surgery, presence of complex renal vein anatomy (defined as accessory renal vein or retro-aortic renal vein or multiple lumbar veins attached to the renal vein on MRA), and the side of the kidney used. Analysis was performed using SPSS version 18 (SPSS/PASW for Windows, Rel. 18.0.3. 2010.; SPSS Inc., Chicago, IL, USA).

Laparoscopic donor nephrectomy

All kidneys were removed using a transperitoneal laparoscopic approach essentially as described by Ratner et al. (5, 6). Following the initial laparoscopic dissection of the renal artery, vein, and ureter, a subumbilical hand port was placed. The stapling of the renal vessels was performed with hand assistance. The donor renal artery and vein were divided individually using an articulating endoscopic linear cutter/stapling device (Endopath ETS-Flex45; Ethicon Endo-Surgery) (7–9). This device delivers six staggered rows of staples which encompass approximately 8 mm of the artery length. The kidney was extracted through a subumbilical hand port. Following removal and transfer of the kidney to the back table, the arterial and venous staple lines were excised as close to the staple line as possible and the kidney perfused with Marshall's hyperosmolar citrate solution (Soltran; Baxter Healthcare, Berkshire, UK) containing 5000 units/L of unfractionated heparin.

Assessment of renal artery anatomy from preoperative imaging

The preoperative renal vascular imaging of the donor was reviewed, and the number of renal arteries and veins to each kidney was recorded. Renal artery length was measured from the lateral wall of the aorta to the origin of the first branch using the curvilinear method, which measures the length of an artery on the reconstructed image by following the contour of the artery. Aortic wall thickness was estimated to be 1 mm. The actual length of renal artery was calculated by subtracting the aortic wall thickness (1 mm) from the measured renal artery length (length of contrast within the artery). In most cases (97%), assessment was with MRA.

Results

During the 10 and a half year period of study, 323 consecutive laparoscopic live donor nephrectomies were performed of which 287 were included in this analysis (Table 1). Four donors who were converted from laparoscopic to open surgery were excluded from the analysis, along with one case where the donor renal artery was found to be aneurysmal and required resection and reconstruction. Other cases excluded from study included kidneys where recipient information was not available (i.e., 11 kidneys exported to the UK national paired exchange program and three exported altruistic donors), 10 donors whose preoperative scans were not suitable for reformatting, and seven donors who had an accessory (polar) artery arising from aorta undiagnosed on preoperative scans. Of the 287 cases studied, 223 (78%) underwent left nephrectomy and 64 (22%) right nephrectomy. All kidneys were transplanted locally.

The median age of patients undergoing a left laparoscopic nephrectomy was 50 yr (range 23–71 yr) and that of patients undergoing right laparoscopic nephrectomy was 47 yr (range 21–68 yr). Median BMI was the same in both groups

Table 1. Comparison of donors of left and right kidneys

	Left kidney	Right kidney
Total number (n)	223	64
Age[a]	49 (23–71)	47 (21–68)
Males:females	112:111 (50%:50%)	28:36 (44%:56%)
Body mass index (kg/m^2)[a]	26 (16–33)	26 (20–34)
Previous abdominal surgery (%)	3 (1)	2 (3)
Relationship (%)		
Genetically related	112 (50)	38 (59)
Unrelated	111 (50)	26 (41)
Accessory/complex venous anatomy (%)	10 (4)	2 (3)

[a]Values are medians (range).

(26 kg/m^2). Further comparisons of left and right kidney donors are shown in Table 1. Because of the different technical challenges in securing the full length of right renal arteries from behind the IVC, the results for right and left nephrectomy were considered separately.

Left-sided donor kidneys

Of the 223 left-sided donor kidneys, 174 (78%) had a single renal artery on preoperative imaging (Fig. 1). Following nephrectomy and removal of the arterial staple line to permit perfusion of the kidney with cold preservation solution, 166 (74%) kidneys still had a single artery for anastomosis. Eight kidneys (4.6%) with a main stem renal artery length of 6, 7, 10, 11, 12, 13, 14, and 16 mm on MRA had two arterial branches after nephrectomy, excision of staple line and perfusion, and one with a main stem length of 9 mm resulted in three arterial branches. All left-sided donor kidneys with a main artery length of more than 16 mm on imaging retained a single renal artery for implantation; seven of the donor kidneys with renal artery length 16 mm or less on MRA also retained a single artery for implantation. For single left renal arteries 16 mm or less in length on preoperative imaging, nine of 16 (56%) were converted to two renal arteries prior to implantation. Fig. 2 shows the distribution of renal artery lengths determined from MRA and indicates those that resulted in multiple branches after cold perfusion.

Forty-five (20%) kidneys had two left renal arteries identified on MRA, with the length of each artery ranging from 6 to 83 mm before branching; no additional arteries were identified following cold perfusion. Four donors (2%) had three arteries identified on preoperative imaging. Three of them had same number of arteries after nephrectomy. However, one donor had five arteries found following nephrectomy and removal of the arterial staple lines. Two of the renal arteries with length of 40 mm before further division resulted in two

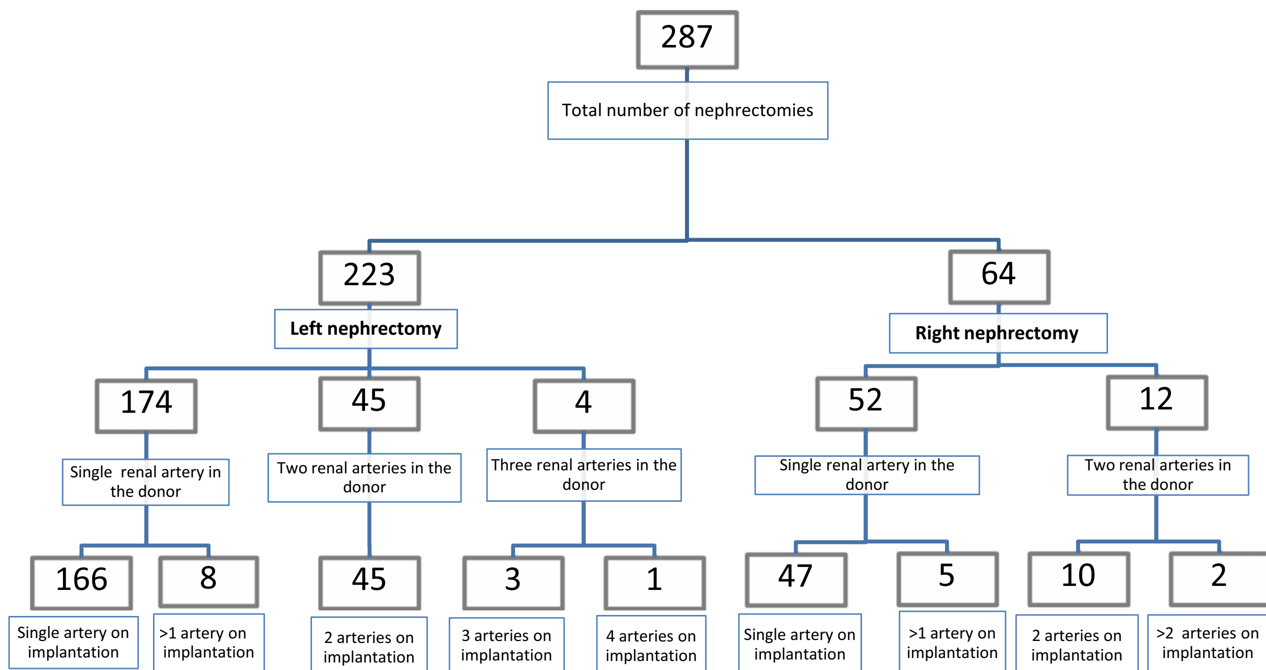

Fig. 1. Flowchart showing outcome of renal arteries in donor nephrectomy.

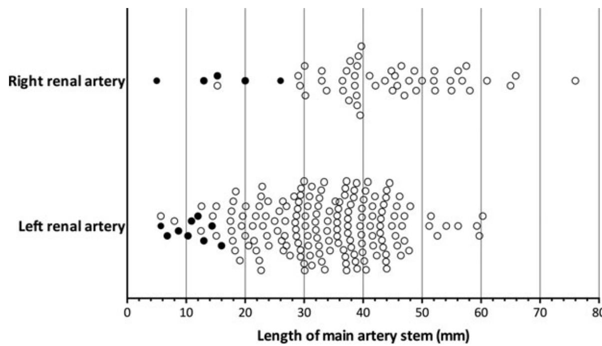

Fig. 2. Lengths of right renal arteries (n = 52) and left renal arteries (n = 174) with single main artery stem on preoperative imaging. The full circles are cases where more than one artery resulted from a single main artery stem.

arteries each, and one renal artery with length 56 mm retained as single artery in this case.

Right-sided donor nephrectomy

Of the 64 right-sided donor kidneys, 52 (81%) had a single renal artery on preoperative MRA. Following nephrectomy and removal of the staple line, 47 (73%) still had a single artery for anastomosis. Four (7.7%) right-sided kidneys with a single artery on MRA (artery lengths 5, 13, 15, and 26 mm before branching) were found to have two branches, and one right kidney (main artery length 20 mm) was found to have three arteries after nephrectomy and removal of the arterial staple lines. All donor right kidneys with a main artery length of over 26 mm retained a single artery for implantation (Fig. 2). For single right renal arteries 26 mm or less in length on preoperative imaging, five of six (83%) were converted into two renal arteries.

Twelve donors had two right renal arteries identified on MRA of which two donor kidneys (renal artery lengths 35 and 18 mm) resulted in three arteries after nephrectomy; the other 10 kidneys retained the same number of arteries after donor nephrectomy.

Other factors potentially leading to multiple renal arteries

The 15 cases (nine left, six right kidneys) where a renal artery was surgically divided beyond its division were compared with the remaining 272 cases to determine whether there was any difference between the groups for donor factors that might be associated with operative difficulty. The donor factors examined were gender, BMI, previous abdominal surgery, presence of complex renal vein anatomy (defined as accessory renal vein or retro-aortic renal vein or multiple lumbar veins attached to the renal vein on MRA), and the side of the kidney used. Of these, only complex venous anatomy (Fisher's exact test, $p = 0.003$) was significantly associated with division of a renal artery beyond its bifurcation.

Renal artery complications

Three patients suffered early thrombosis of a renal artery following transplantation. One main renal artery thrombosis occurred within the first 12 h and underwent a successful surgical thrombectomy. Two patients who had reconstruction of multiple renal arteries had occlusion of one arterial branch (polar artery) detected by Duplex ultrasound scan at six wk and three months, respectively. Overall, 0.5% (one of 212) kidneys with a single artery on implantation suffered arterial thrombosis compared to 2.7% (two of 75) where multiple arteries required reconstruction; importantly, no recipient lost their kidney. In addition, one patient who had three renal artery branches reconstructed with an autologous saphenous vein graft developed a stenosis at the renal artery anastomosis requiring surgical revision. A further patient who developed post-operative renal vein thrombosis had thrombectomy and re-implantation, successfully salvaging the transplant.

Discussion

The increase in the number of donor nephrectomies performed laparoscopically has led to an increase in the proportion of kidneys with multiple renal arteries to re-implant (10). Early experience with laparoscopic nephrectomy demonstrated an increase in vascular and urological complications in recipients of kidneys in which reconstruction of multiple renal arteries was undertaken (11). However, large volume centers have reported good long-term outcomes even after reconstruction of multiple renal arteries (12). A disadvantage of laparoscopic nephrectomy is that the use of a vascular stapling device results in significant loss of arterial length. In our series, the laparoscopic stapler (Endopath ETS-Flex45; Ethicon Endo-Surgery) that we used incorporated a footprint of 8 mm length of artery from its origin. It is acknowledged that some staplers are produced with fewer rows of staples and may therefore permit shorter main stems to be preserved. Nevertheless, it is important, when planning the donor operation and choosing which kidney to remove, to consider the length of the renal arterial main stems prior to its bifurcation in relation to the width of the stapler to be used to

retain a single artery for implantation whenever possible.

The results of the present study suggest that the renal artery length measurements from MRA can be used to help predict the final number of renal arteries. In our cohort of 223 patients undergoing left nephrectomy, no kidneys with a left arterial main stem >16 mm in length had multiple arteries following nephrectomy and excision of the arterial staple line. In the case of the right kidney, longer lengths of renal artery main stem were observed to result in multiple arteries following nephrectomy, and this, in part, reflects the local surgical practice of not routinely dissecting the retrocaval renal artery. Interaorto-caval dissection by division of lumbar branches of the IVC and exposure of the origin of right renal artery from aorta has been described in an attempt to achieve longer length of right renal artery (13). Stretching the renal artery in an attempt to preserve the arterial division is potentially hazardous and may disrupt the intima or result in avulsion of the artery from the aorta with the potential for catastrophic hemorrhage.

None of the cases in our series with a left renal artery length longer than 16 mm on imaging resulted in multiple renal arteries. For donors undergoing right nephrectomy, a single artery longer than 26 mm ensured a single artery for implantation. Although the IVC may hinder dissection and stapling of the right renal artery, a longer length may be achieved by rolling and compressing the cava before stapling (14).

Donor factors such as gender, BMI, previous abdominal surgery, presence of complex renal vein anatomy, and side of nephrectomy may influence the length of renal artery following nephrectomy (9). However, in our series, only the presence of complex renal vein anatomy including accessory renal veins was associated with a significantly higher incidence of multiple renal arteries after procurement. The observation that complex vein anatomy is associated with multiple arteries probably reflects an increased likelihood of anatomical variance in these donors rather than a technical factor relating to the presence of venous anomalies. Other factors such as accuracy of measurement of the renal artery length from the scan, stretching of the vessel, and the angle of stapler application could potentially affect the final length of renal artery on the graft. Alternatives to vascular staplers such as Hem-o-lok clips may permit longer renal artery lengths to be procured, but such devices may be associated with risk of technical failure and as per recent FDA recommendation Hem-o-lok clips are not licensed for this purpose (15). Laparoscopic nephrectomy carries a smaller, but significant risk of morbidity and mortality in healthy donors (16). So the focus of this procedure should be to procure grafts, which ensure excellent outcome in recipients and maintain donor safety.

In conclusion, when preoperative arterial imaging shows that the main stem renal artery is <26 mm for the right kidney, and less than 16 mm for the left kidney, then surgeons should consider the possibility that nephrectomy may result in multiple renal arteries for implantation. Alternative approaches such as conversion to an open surgical approach or the use of a stapling device with a smaller staple footprint may be considered if it is thought necessary to preserve a single renal artery.

Authors' contributions

Satheesh Iype: Participated in the performance of the research, design, analysis, and writing up; Sarojini David: Participated in the performance of the research (measurement of artery length); Simon Hilliard: Participated in the performance of the research (measurement of artery length); Ashley Shaw: Participated in the performance of the research (measurement of artery length); Neville V. Jamieson: Participated in research design; Raaj K. Praseedom: Participated in research design; Andrew J. Butler: Participated in research design; Emmanuel L. Huguet: Participated in research design; Richard A. Parker: Participated in data analysis; Andrew Bradley: Participated in research design and writing up; Christopher J. E. Watson: Participated in research design, data analysis, and writing paper. Dr Shaw received research support from National Institute of Health Research Cambridge Biomedical Research Centre

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