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Preoperative CT-Angiography Predicts *Ex Vivo* Vein Length for Right Kidneys After Laparoscopic Donor Nephrectomy

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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Background: Implantation of a kidney with a short renal vein is technically more challenging and therefore prone for technique-related complications. It remains unclear whether pre-operative computed tomography angiography (CTA), to assess vascular anatomy of the donor kidney, can be used to predict renal vein length.

Material/Methods: Right and left renal vein lengths of 100 consecutive kidney donors were measured in an oblique-coronal plane multiplanar reconstruction image of 100 consecutive kidney donors in whom *ex vivo* vein length was measured after recovery. In a second retrospective cohort of 100 consecutive kidney donors donating a right kidney, pre-operative CTA vein length measurements were correlated to anastomosis time and early graft outcome.

Results: Left and right renal vein lengths, measured on CTA, were 43.2 mm and 30.0 mm, respectively. No correlation was found between CTA and *ex vivo* measurements for the left renal vein ($p=.610$), whereas a significant correlation was found for the right renal vein ($p=.021$). In the retrospective cohort, right renal vein length was significantly correlated with the anastomosis time but not with early graft outcome.

Conclusions: The length of the right, but not the left, renal vein can be predicted by preoperative CTA, but this does not hold true for the left renal vein.

MeSH Keywords: **Kidney Transplantation • Living Donors • Renal Veins • Tomography Scanners, X-Ray Computed**

Abbreviations: **WIT2** – second warm ischemia time; **CRR2** – creatinine reduction rate day 1 to day 2; **CTA** – 2-dimensional computed tomography angiography; **DGF** – delayed graft function; **SGF** – slow graft function; **MPR** – multiplanar reconstruction

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Background

The number of living donor kidney transplantations is increasing and living donor kidneys have become indispensable to overcome the organ shortage. In general, organ quality of living donor kidneys is superior when compared to kidneys from deceased donors. This is reflected by a longer graft and patient survival [1]. In order to obtain as much kidneys as possible, many transplant centers are extending their criteria for live kidney donation, *e.g.* with regard to donor age and complex arterial and venous anatomy. With regard to renal vein anatomy, most centers preferentially perform left sided donor nephrectomy, since left kidneys have longer veins than their right counterparts. The relatively shorter right renal veins may complicate the venous anastomosis during implantation.

However, the left renal vein has more side branches, *e.g.* adrenal, lumbar and gonadal veins, which require more time for dissection and clipping during laparoscopic donor nephrectomy. In cases where the left kidney is not available for donation *e.g.* complex left arterial anatomy or marginal estimated remaining kidney function, the right kidney will be considered. The short and long term results after transplantation of the right and left renal graft is similar [2–5].

Therefore, the choice for the left or right donor kidney, in case both kidneys are available from the donors' point of view, is based on centers' or surgeons' preference. However, the general opinion is that implantation of a kidney with a very short renal vein is technically more challenging and therefore prone for technique related complications. Especially in recipients with obesity it might be better to avoid transplantation of right kidneys with short renal veins.

Many centers perform computed tomography angiography (CTA) scans in all potential living kidney donors, to assess vascular anatomy; however the two-dimensional CTA measurement of renal vein length does not necessarily correlate with *ex vivo* renal vein length after kidney extraction and back table preparation. Therefore, the first research question is whether CTA measurement of renal vein length prior to laparoscopic donor nephrectomy correlates with *ex vivo* renal vein length measurement after kidney extraction and back table preparation. To address this question, a prospective cohort of 100 consecutive living donor kidney transplantations will be analyzed. If CTA measurements indeed correlate with *ex vivo* measurements, the second question that arises is whether renal vein lengths, as measured by preoperative CTA, correlates with early kidney allograft outcome (*e.g.* delayed graft function, slow graft function and graft loss due to technical failure). To address this question a retrospective cohort of 100 consecutive living kidney donors, donating a right kidney, at our center were assessed.

Material and Methods

Patients

All potential live kidney donors were evaluated by a nephrologist, urologist and vascular surgeon. During a multidisciplinary discussion the pre-operative CTA of the donor was used for decision making with regard the donors' eligibility for living kidney donation. With regard to the side of donor nephrectomy, preoperative CTA also plays a pivotal role and provides information regarding arterial and venous anatomy, presence of renal cysts (or other parenchymal lesions) and estimated remaining renal function (kidney size). The first cohort consisted of 100 consecutive adult kidney donors operated on between May 2011 and November 2012, in who *ex vivo* measurements of the renal vein were performed. These measurements were correlated to pre-operative CTA measurements.

A second cohort was assessed, containing all patients who underwent a right laparoscopic donor nephrectomy performed in the period between January 2003 and August 2014 (n=100). Patients were divided into three equal groups based upon the length of the right renal vein measured on CTA (≤ 22.3 ; 22.3–31.8; ≥ 31.8 mm) and correlated to recipient outcome parameters.

Computed tomography angiography

The Siemens SOMATOM Sensation 64 was used for all CTA measurements. The Siemens SOMATOM Sensation 64 CT scanner is a 64-slice scanner, with a slice width of 1.0 mm and an effective mAs of 105. Contrast was given after a delay of 10–15 seconds at a flow rate of 3.0–3.5 mL/sec. Multiplanar MPR reconstructions (MPRs) in an oblique-coronal plane were made on a TeraRecon iNtuiton workstation (TeraRecon Inc., Foster City, USA).

CTA measurements of the renal vein length

Oblique-coronal plane MPR images were used for renal vein length measurements. Two independent researchers (SR and JO) performed 3 measurements for each donor:

- Length of right renal vein: a straight line between both poles of the right kidney (line A) and a straight line at the lateral border of the inferior vena cava (line B) were drawn. The length of the right renal vein was defined as the centre-lumen distance between line A and B (Figure 1A).
- Length of the left renal vein: a straight line between both poles of the left kidney (line C) and a straight line at the medial side of the inferior vena cava (line D) were drawn. The length of the left renal vein was defined as the centre-lumen distance between line C and D (Figure 1B).

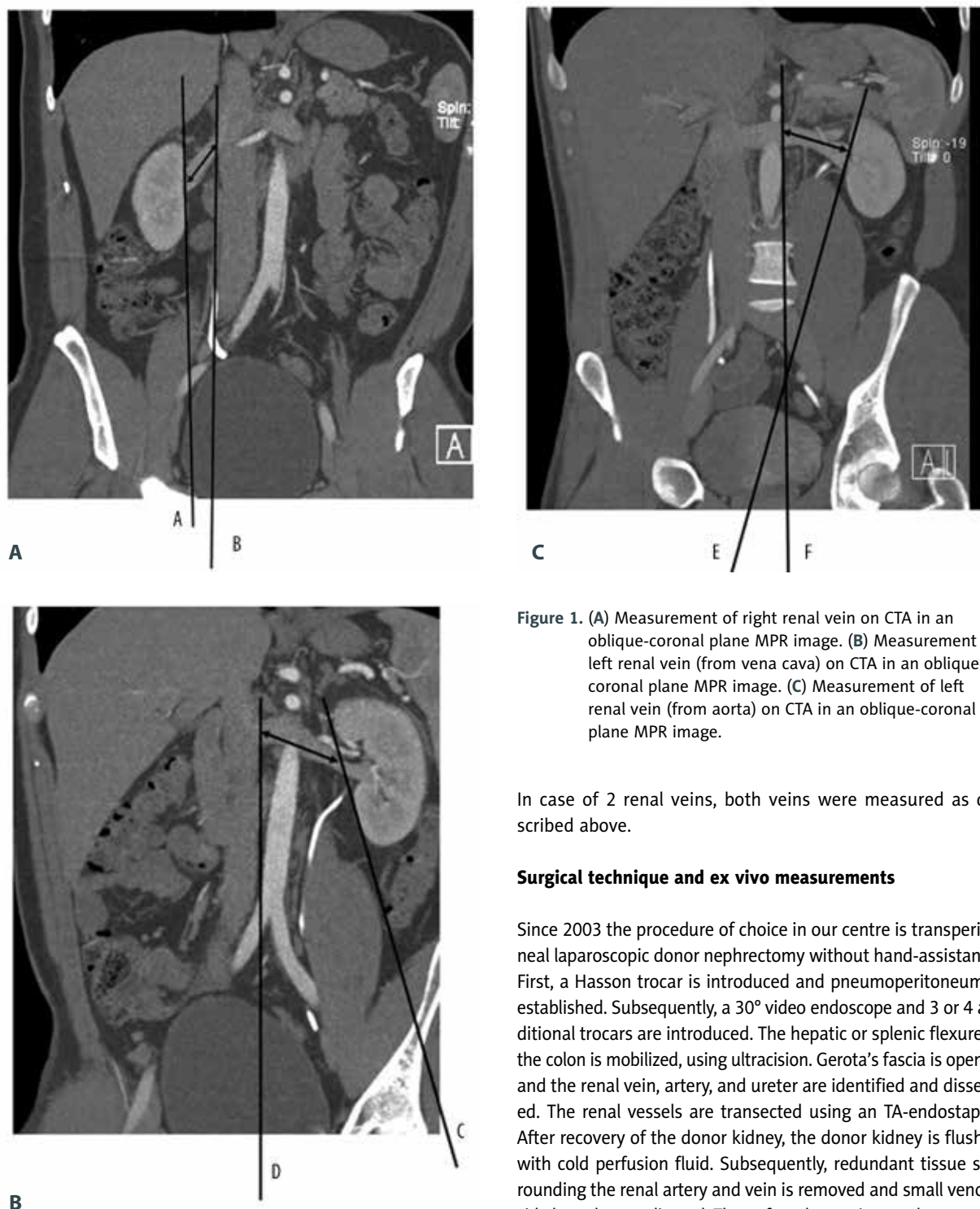


Figure 1. (A) Measurement of right renal vein on CTA in an oblique-coronal plane MPR image. (B) Measurement of left renal vein (from vena cava) on CTA in an oblique-coronal plane MPR image. (C) Measurement of left renal vein (from aorta) on CTA in an oblique-coronal plane MPR image.

In case of 2 renal veins, both veins were measured as described above.

Surgical technique and ex vivo measurements

Since 2003 the procedure of choice in our centre is transperitoneal laparoscopic donor nephrectomy without hand-assistance. First, a Hasson trocar is introduced and pneumoperitoneum is established. Subsequently, a 30° video endoscope and 3 or 4 additional trocars are introduced. The hepatic or splenic flexure of the colon is mobilized, using ultracision. Gerota's fascia is opened and the renal vein, artery, and ureter are identified and dissected. The renal vessels are transected using an TA-endostapler. After recovery of the donor kidney, the donor kidney is flushed with cold perfusion fluid. Subsequently, redundant tissue surrounding the renal artery and vein is removed and small venous side branches are ligated. Thereafter, the *ex vivo* renal artery and vein lengths are measured under slight traction by 2 surgeons (M) or (MW). All procedures were performed by a surgical team consisting of a fixed combination of 2 urologists (Fd'A and HL) and 2 vascular surgeons (MvdJ and MW) [6]. Regarding the implantation of the renal allografts, the vascular part of all procedures was performed by 2 vascular surgeons (MvdJ and MW).

- Length of the left renal vein to the lateral border of the aorta: a straight line between both poles of the left kidney (line E) and a straight line at the lateral border of the aorta (line F) were drawn. During donor nephrectomy line F represents the transection zone of the left renal vein (Figure 1C).

Table 1. Demographics of donors and recipients; consecutive, prospective cohort (n=100).

		Mean (SD)	Range
Donor	Age (years)	52.5 (11.4)	25–76
	Male/female	48/52	
	Body mass index	25.5 (3.1)	18.0–34.5
Recipient	Age (years)	45.6 (15.6)	6–73
	Male/female	53/47	
	Body mass index	24.3 (4.1)	15.3–35.2
Side of nephrectomy	Left/right	86/14	

Data are presented as number or mean ±SD (standard deviation) and range or number.

Table 2. CTA and *ex vivo* renal vein measurements; consecutive, prospective cohort (n=100).

	CTA in recovered kidneys		<i>Ex vivo</i>		n	Difference CTA & <i>ex vivo</i> measurements	CTA in all kidneys		n
Left renal vein (total)	69.8	(48–104)	–	–	86	–	70.2	(48–104)	100
Left renal vein (aorta)	43.0	(22–70)	30.7	(19–55)	86	12.6 (–33.8–9.8)	43.2	(22–70)	100
Right renal vein	38.3	(27–57)	26.3	(18–43)	14	11.7 (–9–24.1)	30.0	(9–57)	100

CTA – computed tomography angiography. All measurements expressed as mm, data expressed as mean (range).

Recipient demographics and outcomes

Recipient outcome measures include: creatinine reduction ratio (CRR2), post-operative creatinine at day 5, slow graft function (SGF), delayed graft function (DGF), graft loss due to technical failure. Technical failure was defined as transplantectomy within 10 days, without signs of perfusion on ultrasound and without evidence of rejection. DGF is the need for dialysis in the first week after surgery [7], SGF as serum creatinine >3.0 mg/dl at day 5 without the need for dialysis [8].

CRR2 from day 1 to 2 (crr2) is predictor for long-term graft outcomes and was calculated according to the following formula [9]:

$$CRR2 (\%) = \frac{(\text{creatinine day 1} - \text{creatinine day 2}) \times 100}{\text{creatinine day 1}}$$

Statistical analyses

All statistical tests were performed with SPSS version 20.0 (SPSS Inc. Chicago, IL, USA). Continuous variables were expressed as mean ± SD, numerical data was expressed as number and percentage. Numerical data were compared with Kruskal-Wallis test, categorical data with Fisher exact test. Correlations between CTA and *ex vivo* measurements was determined by

Spearman's correlation analysis. A *p*-value of 0.05 or less was considered to be significant.

Results

CTA and *ex vivo* renal vein length measurements

Baseline characteristics of the first, prospective cohort are shown in Table 1. Reasons to select the right instead of the left kidney for recovery were: multiple arterial anatomy (9 cases) or multiple venous anatomy (1 case) on the left side; renal cysts in the right kidney (2 cases) and small kidney stones in the right kidney (2 cases).

The CTA and *ex vivo* measurements are shown in Table 2. The length of the left renal vein measured on CTA was significantly longer when compared to the right renal vein, respectively 43.2 mm (range, 22 to 70) versus 30.0 (range, 9 to 57) (*p*<.05). Also, length of the left renal vein when measured *ex vivo* was longer, 30.7 mm versus 26.3 mm (*p*=.05).

The mean difference between CTA and *ex vivo* measurements was 12.6 mm (range, –33.8 to 9.8) for left renal veins and 11.7 mm (range, –9 to 24.1) for right renal veins. Spearman

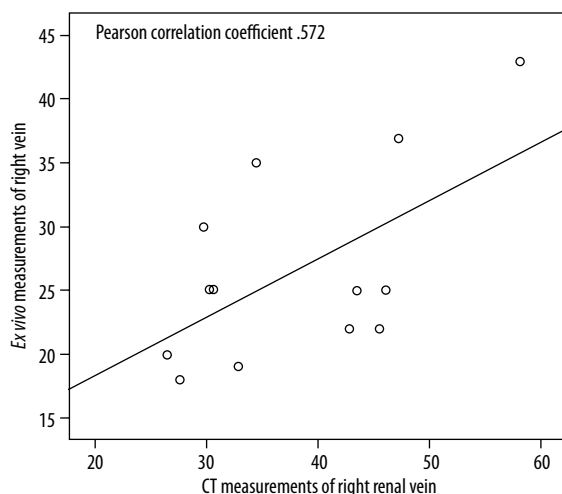


Figure 2. *Ex vivo* measurements and CT measurements of the right renal vein.

correlation coefficients (ρ) between CTA and *ex vivo* measurements were 0.058 ($p=0.610$) for left renal veins and 0.572 ($p=0.041$) for right veins (Figure 2).

Right renal vein and recipient outcome

Donor and recipient characteristics of the second, retrospective cohort are shown in Table 3. The right renal veins were divided in 3 equal groups (<22.3; 22.3 to 31.8, and >31.8 mm) and correlated to recipient outcomes (Table 4). In 100 patients, we found 6 technical failures. Of these 6 technical failures, 4 technical failures were present in the group with a length of 22.3 to 31.8 mm. A significant shorter anastomosis time was seen in the group with the long renal veins ($p=0.021$). Shorter right renal veins were not associated with graft loss due to technical failure.

Table 3. Demographics of donors and recipients and perioperative data, all right donor nephrectomies since 2003; retrospective cohort ($n=100$).

		Mean (SD)		Range
Donor	Age (years)	53.1	(11.4)	19.8–72.9
	Male/female	48/52		
	Body mass index	25.3	(3.3)	17.0–31.9
Recipient	Age (years)	42.1	(17.0)	4.1–73.7
	Male/female	54/46		
	Body mass index	23.5		14.3–44.0

Data are presented as mean \pm standard deviation and range or number.

Discussion

We believe this is the first study exploring the clinical value of renal vein length measurements on CTA. In a consecutive, prospective cohort, the length of the right renal vein based on CTA was significantly correlated with *ex vivo* measurements after back Table preparation, while the length of the left renal vein was not. The main explanation for this discrepancy is that the right renal vein is almost without exception transected, using the endostapler, at the level just lateral of the caval vein, whereas the level of transection of the left renal vein is much more variable. In some cases the left renal vein is transected at the distal side of the adrenal vein, whereas in other cases it is transected much more proximal, e.g. 1 to 2 cm medial to the lateral border of the juxtarenal aorta.

The mean difference between CTA and *ex vivo* measurements was 12.6 mm (range, –48.6 to 16.4) for left and 11.7 mm (range, –9 to 24.1) for right renal veins. This difference can be explained by the loss of length caused by the use of the TA stapling device. Jellison et al. have reported a loss of 10.0 mm when using an endo-TA stapler [10]. The right and left renal vein measured on CTA have a mean difference of 14.7 mm, *ex vivo* the right and left renal vein differ by 4.1 mm. This can be explained by the fact that right kidneys with very short renal veins (i.e. 15 mm) are not accepted for donor nephrectomy in our center.

In many centers, including ours, preferably the left kidney is recovered. The left kidney is preferred since in general right kidneys have a shorter renal veins. The general opinion among transplant surgeons is that an implantation of kidneys with short renal veins is technically more challenging and may be associated with vascular complications. To overcome these technical difficulties associated with shorter renal veins, surgical modifications have been proposed, for example the use of Hem-o-locks instead of Endo-GIA for vein dissection and the use of hand-assistance for lateral traction [11].

Table 4. CTA renal length of right renal allografts and recipient outcomes; retrospective cohort (n=100).

		≤22.3 (n=33)	22.3–31.8 (n=33)	≥31.8 (n=34)	P-value (kruskal wallis or fisher exact)
Donor	Age (years)	48.1 (11.0)	51.8 (13.0)	54.2 (9.6)	.077
	Male/female	16/17	15/18	17/17	.931
	Body mass index	25.4 (3.3)	25.8 (2.7)	24.6 (3.7)	.275
Recipient	Age (years)	41.7 (17.3)	42.5 (17.6)	42.1 (16.7)	.990
	Male/female	19/14	17/16	18/16	.875
	Body mass index	23.0 (3.8)	23.1 (4.5)	24.2 (5.3)	.557
Outcome parameters	WIT2 (minutes)	28.6 (9.2)	24.2 (9.1)	23.7 (8.6)	.021
	CRR2 (%)	36.0 (20.1)	39.5 (21.2)	38.2 (19.2)	.522
	Creatinine day 5 (micromol/l)	197 (183)	199 (228)	164 (185)	.183
	Creatinine year 1 (micromol/l)	114 (30)	117 (28)	144 (150)	.888
	Delayed graft function	0	2	1	.353
	Slow graft function	0	1	2	.369
	Technical failure	1	4	1	.195

Data represented as mean (standard deviation) or number. CTA – computed tomography angiography; WIT2 – second warm ischemia time; CRR – creatinine reduction.

In literature, no obvious differences in graft survival were found when comparing the implantation of right or left renal allografts [3,4,11,12]. However, some authors have described an association of the right kidney and prolonged second warm ischemia time [4,13,14]. This illustrates that the implantation of right donor kidneys is technically more demanding. Some transplant centers preferably recover right kidneys. The main reason for this is that during right laparoscopic donor nephrectomy dissection of side branches is seldom necessary [4] and therefore right kidney are easier to procure than left kidneys.

In our second, retrospective cohort the length of right renal veins, measured on CTA, was compared to recipient outcome measures. A significant longer WIT2 was observed for the group with the short renal veins, implying that the implantation of right allografts with shorter veins is technically more demanding. We observed no significant difference in recipient outcome parameters.

Conclusions

Important strengths of this study with regard to the primary research question, are related to its design as a consecutive,

prospective cohort study. *Ex vivo* measurements of all the renal veins were performed by two surgeons (MW and MvdJ). Furthermore, to our knowledge, no other studies have been conducted exploring the clinical value of CTA vein measurements prior to laparoscopic donor nephrectomy. The limitation of our study is related to the retrospective nature of the second cohort. This may have introduced a certain degree of selection bias, as kidneys with short renal veins may have been avoided during the preoperative work-up. However, one would expect that the negative impact of short renal vein lengths would have been higher if this potential selection bias did not exist. Finally, our retrospective cohort was too small to allow a meaningful analysis of delayed graft function, slow graft function, and technical failure. In conclusion, the length of the right renal vein on CTA correlates with *ex vivo* length after laparoscopic kidney procurement, but this does not hold true for the left renal vein. Our data indicate that there was no significant influence of right renal vein length on recipient outcome measures.

Conflict of interest

The authors state no conflict of interest.

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