A 2-mm Cutoff Value Is Reasonable and Feasible for Vascular Reconstruction in a Kidney Allograft With Multiple Arteries

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ABSTRACT

Background. Multiple renal arteries are found in approximately 20% of living donor kidneys. We have been using an accessory artery cutoff diameter of 2 mm on preoperative computed tomography angiography to determine whether to sacrifice or reconstruct the artery. In this study, we assessed the validity and feasibility of this cutoff value.

Methods. Living related kidney recipients from 2005 to 2013 were enrolled in this retrospective study. The diameter of the accessory artery and adverse events were evaluated. The lost parenchymal volume (%) due to vascular obstruction or branch ligation was calculated by computed tomography volumetry.

Results. Among 128 kidney transplants, 30 donor kidneys had multiple arteries. Accessory arteries were reconstructed in 18 cases and intentionally ligated in 12 cases (mean diameter of accessory arteries, 3.10 [SD, 0.75] mm and 1.81 [SD, 0.28] mm, respectively). The mean estimated glomerular filtration rate at 1 or 12 months after transplant was not significantly different between the groups. Among reconstructed cases, 14 cases (77.8%) had good patency in the reconstructed arteries whereas the other 4 had vascular complications. The percentage of lost parenchymal volume due to ligation or occlusion of the reconstructed artery (calculated in 16 cases) was predictable with the following formula: lost volume (%) = 9.09 × diameter (mm) − 10.5 ($P = .03$, $r_s = 0.533$ by Spearman rank correlation coefficient). This formula indicated that ligation of a 2-mm accessory artery leads to 7.68% loss of the renal parenchyma.

Conclusions. Reconstruction using a cutoff diameter of 2 mm is worth attempting in terms of the success rate and graft function. Sacrifice of a 2-mm accessory artery leads to parenchymal loss of <8%.

MULTIPLE renal arteries are found in approximately 20% of living donor kidneys [1–5]. Preoperative computed tomography (CT) angiography with improved resolution enables detection of thin accessory arteries in living donor kidneys, resulting in better recognition of the vascular anatomy and a safer donor operation. However, the optimal thickness of the accessory arteries used for reconstruction to preserve maximal graft function remains controversial. Several factors must be considered. Although simple transection can lead to loss of a substantial amount of renal parenchyma (ie, renal function) perfused by the branch, a longer ischemia time for vascular reconstruction may cause acute kidney injury requiring dialysis and consequent adverse events, such as allograft rejection and graft loss. Additionally, satisfactory patency after vascular reconstruction may be difficult to achieve when using thinner arteries. Thus, it is important to establish a cutoff diameter that determines whether to transect or preserve each accessory artery in a kidney allograft with multiple

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arteries. Several reports empirically have used a 2-mm cutoff value for vascular reconstruction or ligation of accessary arteries [6–8]. Similarly, in our institution, accessory arteries of ≥2 mm on preoperative CT angiography should be preserved, and accessory arteries of <2 mm can be transected unless the branches feed the lower pole of the kidney or the ureter. In the present study, we evaluated the success rate of revascularization according to the thickness of the accessory arteries and the relationship between the thickness and perfused kidney parenchyma to determine the optimal cutoff value for preservation of thinner branches in terms of validity and feasibility.

STUDY DESIGN AND PATIENTS

Kidney transplant recipients with multiple renal arteries who received kidneys from living related donors from 2005 to 2013 were included in this retrospective study. Recipients younger than 15 years at the time of transplant were excluded. Patients who did not undergo enhanced CT evaluation within 3 months after kidney transplant were also excluded. The study was conducted with the approval of the Institutional Review Board.

The patients were divided into 2 groups: those who underwent vascular reconstruction and those who underwent transection of their accessory arteries. For kidney allografts with 3 arteries, the thinnest accessory artery was defined as the accessory artery. In patients who underwent reconstruction, the success rate of vascular reconstruction (patency of the reconstructed arteries) and adverse events of vascular reconstruction in association with the diameter of the accessory arteries were compared according to the reconstruction procedures. Kidney allograft function at 1 and 12 months after transplant (estimated glomerular filtration rate [eGFR]) was compared between the groups.

In another analysis of patients whose accessory arteries were intentionally sacrificed or obstructed despite vascular reconstruction, the lost parenchymal volume (mm^3) was determined by CT volumetry (Ziostation 2; Ziosoft Inc, Tokyo, Japan), and the percentage of the lost total kidney graft volume was calculated (n = 16). The relationship between the diameter of the accessory arteries on pretransplant CT angiography and the volume (mm^3) and percentage of the lost parenchyma of the transplanted kidney detected on posttransplant CT were calculated with Spearman rank correlation coefficient.

All statistical analyses were performed with GraphPad Prism ver. 6.0 (GraphPad Software Inc, La Jolla, Calif, United States) or JMP Pro 12 (SAS Institute Inc, Cary, NC, United States).

RESULTS

Success Rate of Vascular Reconstruction in Accessory Arteries

Thirty of 128 donors who underwent surgery during the study period had multiple renal arteries on the donated side. The recipients' and donors' characteristics are shown in Table 1. The recipients' and donors' mean age at transplant was 40.3 (SD, 15.6) years and 58.7 (SD, 9.3) years, respectively. The mean pretransplant dialysis period was 2.6 (SD, 3.1) years, including 9 cases of pre-emptive kidney transplant. Eight patients had an immunologically high risk (6 were ABO-incompatible and 2 were undergoing their second kidney transplant with preformed antidonor-HLA antibody). The donated kidney side was the right in 3 patients and the left in 27 patients. Twenty-seven kidneys had 2 arteries, and 3 kidneys had 3 arteries.

Table 1. Patient Demographics

	Donor	Recipient
Age at transplant, mean (SD), y	58.7 (9.3)	40.3 (15.6)
Sex, male:female, No.	12:18	16:14
Pretransplant dialysis period, mean (SD), y	2.6 (3.1) (9 cases of pre-emptive)	
Immunologic high risk, No.	ABO-incompatible 6 cases 2nd transplant with DSA 2 cases	
Laterality of donated kidney	R 3:L 27	
Arteries, No.	2 arteries in 27 cases and 3 arteries in 3 cases	

Abbreviations: DSA, donor-specific antibody; L, left; R, right.

In the vascular reconstruction group (n = 18), 14 patients (77.8%) had satisfactory patency in the reconstructed artery as confirmed by post-transplant CT angiography. The other 4 patients (22.2%) had complications requiring radiologic intervention (obstruction of reconstructed branches, n = 3; anastomotic stenosis, n = 1); their reconstructive procedures were hypogastric arterial grafting (n = 2), conjoined reconstruction (n = 1), and end-to-side anastomosis to the main trunk (n = 1). No hemorrhagic complications occurred. There was no significant relationship between the diameter of the accessory arteries and the success rate of vascular reconstruction (Table 2).

The diameter of the accessory artery was significantly greater in the reconstruction group (3.10 [SD, 0.75] mm) than in the transection group (1.81 [SD, 0.28] mm), reflected from our cutoff value for vascular reconstruction ($P < .05$, unpaired t test). The warm ischemia time was not significantly different between the reconstruction and transection groups (5.5 [SD, 2.4] minutes and 4.9 [SD, 1.7] minutes, respectively) (Table 2). However, the total ischemia time was significantly longer in the reconstruction group than the transection group (166 [SD, 62] minutes and 106 [SD, 32] minutes, respectively; $P < .05$, unpaired t test) because of the additional time required for vascular reconstruction (Table 2).

Kidney allograft function was compared between the reconstruction and transection groups. There was no significant difference in eGFR between the reconstruction and transection groups at either 1 or 12 months after transplant (53.7 [SD, 22.4] mL/min/1.73 m^2 and 52.4 [SD, 20.5] mL/min/1.73 m^2, respectively, at 1 month and 52.4 [SD, 20.5] mL/min/1.73 m^2 and 51.5 [SD, 13.0] mL/min/1.73 m^2, respectively, at 12 months; unpaired t test). The patients were divided into 3 groups: reconstruction with good patency (47.9 [SD, 16.5] mL/min/1.73 m^2 and 49.8 [SD, 17.7] mL/min/1.73 m^2 at 1 and 12 months, respectively), reconstruction complicated by obstruction or stenosis (74.0 [SD, 30.8] mL/min/1.73 m^2 and 64.6 [SD, 22.0] mL/min/1.73 m^2

Table 2. Management of Renal Accessary Artery and Graft Outcome

	Reconstruction (n = 18)			
	Patent (n = 14)	Stenotic/Obstructive (n = 4)	Transection (n = 12)	*P* Value
Diameter of the accessory artery, (SD), mm	3.21 (0.75)	3.27 (1.10)	1.82 (0.28)	NS*
	3.10 (1.75)			<.05†
Warm ischemia time, (SD), min	5.5 (2.4)		4.9 (1.7)	NS†
Total ischemia time, mean (SD), min	166 (62)		106 (32)	<.05†
eGFR at 1 month, mean (SD), mL/min/1.73m^2	53.7 (22.4)		52.4 (20.5)	NS†
	47.9 (16.5)	74.0 (30.8)		NS*
eGFR at 1 year, mean (SD), mL/min/1.73m^2	52.5 (20.5)		51.5 (13.0)	NS†
	49.8 (17.7)	64.6 (22.0)		NS*

Abbreviations: eGFR, estimated glomerular filtration rate; NS, not significant.
*Unpaired *t* test.
†Kruskal-Wallis test.

at 1 and 12 months, respectively), and transection (52.4 [SD, 20.5] mL/min/1.73 m^2 and 51.5 [SD, 13.0] mL/min/1.73 m^2 at 1 and 12 months, respectively). There was no significant difference among the 3 groups at either 1 or 12 months (Kruskal-Wallis test). In terms of adverse events associated with vascular reconstruction, 1 patient in the reconstruction group developed acute tubular necrosis requiring temporary hemodialysis.

RELATIONSHIP BETWEEN DIAMETER OF ACCESSORY ARTERIES AND LOST PARENCHYMAL VOLUME

Next, we sought to determine the relationship between the diameter of the accessory arteries that were intentionally transected or obstructed despite vascular reconstruction. Among cases in which the accessory arteries were intentionally transected (n = 12) or compromised despite vascular reconstruction (n = 4), the relationship between the lost parenchyma in terms of volume and percentage was evaluated. The lost parenchymal percentage was estimated with the following formula: volume (%) = 9.09 × diameter (mm) − 10.50 (by Spearman rank correlation coefficient, $P = .03$, $r_s = 0.533$) (Fig 1). Based on this formula, the lost parenchyma due to intentional ligation of the accessory artery was 7.68% of the total volume.

DISCUSSION

In the present study, the success rate of vascular reconstruction was around 80%, and there was no relationship between the diameter of the branch and success rate. These findings indicate that a cutoff value of 2 mm does not result in technically difficult revascularization. We also showed that intentional transection of a 2-mm accessory artery led to parenchymal loss of 8%. There was no significant difference in kidney allograft function between the 2 groups (vascular reconstruction and transection of the accessory artery) at either 1 or 12 months after transplant. Many authors have reported the success rate of vascular reconstruction [9,10]. In most reports, however, the success rate was evaluated by renal function (eGFR, creatinine clearance rate, and serum creatinine level) and by the occurrence of vascular complications requiring radiologic and surgical interventions, implicating that occlusion of such thin branches can be overlooked without precise imaging evaluation. Furthermore, in several reports, because the patency was determined with operative findings immediately after reperfusion, the success rate may have been overestimated unless CT was performed after transplant [8]. Therefore, the surgeon should consider that a substantial volume of parenchyma perfused by a compromised branch is lost even if the eGFR does not seem to change. Because the cortical volume ratio of the bilateral kidneys calculated by CT volumetry reflects the functional ratio of the bilateral kidneys [11], the functional loss ratio of the kidney allograft can be calculated by the volume ratio of the hypoperfused or occluded cortical parenchyma in the total cortical volume of the kidney allograft. Renal scintigraphy and ultrasonography can also detect functional defects in the kidney allograft; however, they are inferior to CT volumetry with respect to quantitative analysis.

The results of the present study indicate that tailor-made treatment can be proposed for individual patients. The thickness of the accessory artery did not affect the success rate of vascular reconstruction when the branch was thicker than 2 mm. Thus, a 2-mm diameter is technically acceptable

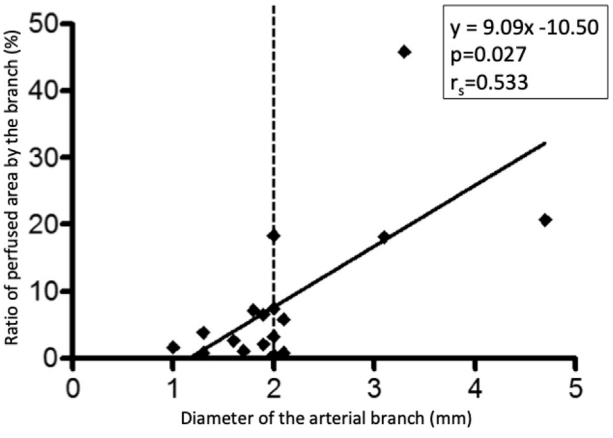

Fig 1. Relationship between thickness of the accessory artery and its perfused parenchymal volume ratio calculated by computed tomography volumetry.

for reconstruction. Reconstruction of arterial branches thinner than 2 mm may also be worthwhile in cases of marginal graft function or donor-recipient body size discrepancy. Moreover, accessory arteries can be transected in recipients of advanced age to avoid a longer operative time and longer ischemia time and thus reduce the risk of subsequent acute tubular necrosis requiring temporary hemodialysis. In contrast, thinner branches might need to be preserved to obtain maximal allograft function in pediatric recipients in whom a very long-term prognosis is required and in cases of a large donor-recipient body size discrepancy.

The main limitation of this study is its retrospective design and small number of patients, which led to weak statistical power. However, our cases covered a wide range of vascular thickness of the arterial branches, allowing estimation of the relationship between the arterial thickness and the perfused parenchymal volume. In addition, the lost volume can be calculated only in biasedly selected patients whose accessory artery was ligated or obstructed despite an attempt to reconstruct. Precise evaluation of the relationship between the diameter of an accessory artery and its perfused volume is difficult without CT volumetry. As long as we searched, there is no study evaluating thickness of branch and its perfused volume with CT volumetry. Based on the formula shown above, ligation of a 2-mm accessory artery is estimated to cause 8% loss of total kidney function.

In conclusion, our study demonstrated that reconstruction of arteries with a cutoff diameter of 2 mm is worth attempting regarding success rate and graft function. Sacrifice of a 2-mm accessory artery leads to parenchymal loss of <8%.

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REFERENCES

[1] Hiramitsu T, Futamura K, Okada M, et al. Impact of arterial reconstruction with recipient's own internal iliac artery for multiple graft arteries on living donor kidney transplantation: strobe study. Medicine (Baltimore) 2015;94:e1811.

[2] Antonopoulos IM, Yamacake KG, Oliveira LM, Piovesan AC, Kanashiro H, Nahas WC. Revascularization of living-donor kidney transplant with multiple arteries: long-term outcomes using the inferior epigastric artery. Urology 2014;84:955–9.

[3] Omoto K, Nozaki T, Inui M, et al. Retroperitoneoscopic donor nephrectomy with multiple renal arteries does not affect graft survival and ureteral complications. Transplantation 2014;98:1175–81.

[4] Cooper M, Kramer A, Nogueira JM, Phelan M. Recipient outcomes of dual and multiple renal arteries following 1000 consecutive laparoscopic donor nephrectomies at a single institution. Clin Transplant 2013;27:261–6.

[5] Meyer F, Nichele SA, Adamy A, Santos LS, Machado C. Early outcomes of laparoscopic donor nephrectomy with multiple renal arteries. Int Braz J Urol 2012;38:496–503.

[6] Carter JT, Freise CE, McTaggart RA, et al. Laparoscopic procurement of kidneys with multiple renal arteries is associated with increased ureteral complications in the recipient. Am J Transplant 2005;5:1312–8.

[7] Harraz AM, Shokeir AA, Soliman SA, et al. Fate of accessory renal arteries in grafts with multiple renal arteries during live-donor renal allo-transplantation. Transplant Proc 2013;45:1232–6.

[8] Hiramitsu T, Okada M, Futamura K, et al. Impact of grafting using thin upper pole artery ligation on living-donor adult kidney transplantation: the STROBE study. Medicine (Baltimore) 2016;95:e5188.

[9] Benedetti E, Troppmann C, Gillingham K, et al. Short- and long-term outcomes of kidney transplants with multiple renal arteries. Ann Surg 1995;221:406–14.

[10] Miura M, Seki T, Harada H, Chikaraishi T, Nonomura K, Koyanagi T. Clinical evaluation of donor renal artery reconstruction in kidney transplantation. Transplant Proc 1996;28:1611–3.

[11] Kato F, Kamishima T, Morita K, et al. Rapid estimation of split renal function in kidney donors using software developed for computed tomographic renal volumetry. Eur J Radiol 2011;79:15–20.