Revascularization of Living-Donor Kidney Transplant With Multiple Arteries: Long-term Outcomes Using the Inferior Epigastric Artery

Ioannis M. Antonopoulos, Kleiton Gabriel Ribeiro Yamaçake, Lorena M. Oliveira, Affonso C. Piovesan, Hideki Kanashiro, and Willian C. Nahas

OBJECTIVE To study the safety and long-term outcomes of use of the inferior epigastric artery (IEA) for revascularization of small accessory kidney arteries (3 mm or less).

MATERIALS AND METHODS Data of 602 living-donor kidney transplants were reviewed. Age was 37.4 ± 15 years (range, 3-78 years). Multiple arteries were present in 98 kidneys (16.3%); of these, 83 (84.7%) had 2 and arteries and 15 (15.3%) had 3 arteries. In 21 kidneys (21.4%) with multiple arteries (group I [GI]), the IEA was used for reconstruction. Four (14.3%) had 3 arteries, and 17 (85.7%) had 2 arteries. In 77 patients (group II [GII]), the inferior accessory renal artery was reconstructed with a side-to-side or an end-to-side anastomosis to the main renal artery. Follow-up was 43.8 ± 38.1 months (range, 1-124 months). The Fisher exact test and the 2-tailed *t* test were used for statistical analysis.

RESULTS Delayed graft function occurred in 1 GI patient (4.8%) and in 5 GII patients (6.5%; $P > .05$). One partial renal infarction occurred in each group (4.8% vs 1.3%; $P > .05$). There was 1 urinary fistula in GI and 3 urinary fistulas and 1 ureteral stenosis in GII ($P > .05$). One graft (4.8%) lost function in GI and 5 (6.5%) in GII ($P > .05$). Eleven patients (53.4%) were hypertensive in GI and 53 (68.8%) in GII ($P > .05$).

CONCLUSION The use of the IEA for revascularization of a living-donor kidney transplant with multiple arteries is safe and effective, yielding similar long-term outcomes compared with the standard technique. Use of the IEA avoids the risks of manipulation of the main renal artery. UROLOGY 84: 955—959, 2014.

The number of kidney transplants from living donors has increased in recent times.[1] Anomalous arterial anatomy, such as the presence of multiple arteries, occurs in up to 30% of donated kidneys. In these cases, the surgeon is required to use special vascular surgical techniques to perform the transplant, but the revascularization of these small arteries may be challenging. They should not be ligated if located in the lower pole or if they supply significant areas of the renal parenchyma. Failure to preserve an accessory renal artery may eventuate in ureteral necrosis, graft rupture, segmental renal infarction, postoperative hypertension, or calyceal fistula formation.[2,3] Traditionally, a side-to-side anastomosis during bench surgery is preferred for reconstruction. This type of reconstruction may jeopardize or pose a threat to the main renal artery when the anastomosis is done end-to-side instead of side-to-side.

The anastomosis of a lower pole artery to the inferior epigastric artery (IEA) after declamping leaves the main renal artery intact, preserving it from the risks of manipulation. It allows the revascularization of the bulk of the kidney, leaving a small portion of the renal parenchyma to be revascularized some minutes later. We retrospectively reviewed the results of the sequential revascularization of the lower or upper pole of the living-donor kidney using the recipient's IEA after the kidney was revascularized through the main artery.

MATERIALS AND METHODS

The records of 602 consecutive living-donor kidney transplants (March 2000 to September 2010) were reviewed. Patients were aged 37.4 ± 15 years (range, 3-78 years). There were 451 white (74.9%), 142 black (23.6%), and 9 Asian (1.5%) patients.

Financial Disclosure: *The authors declare that they have no relevant financial interests.*

From the Division of Urology, Renal Transplantation Unit, University of São Paulo Medical School, São Paulo, SP, Brazil

Reprint requests: Kleiton Gabriel Ribeiro Yamaçake, M.D., Renal Transplantation Unit, Division of Urology, University of Sao Paulo (USP), Av. Dr. Enéas de Carvalho Aguiar, 255. 7° andar, Sala 710F, 05403-000 Cerqueira César, São Paulo—SP, Brazil. E-mail: kleiton_med91@yahoo.com.br

Submitted: February 6, 2014, accepted (with revisions): June 13, 2014

http://dx.doi.org/10.1016/j.urology.2014.06.022
0090-4295/14

Table 1. Demographic data

Variables	Group I (n = 21)	Group II (n = 77)	*P*
Age, y	40.5 ± 12.3 (22-58)	35.6 ± 14.8 (8-61)	>.05
Sex			
Male	16 (76.2)	37 (48)	
Female	5 (23.8)	40 (52)	<.05
Race			
White	18 (85.7)	60 (80)	
Black	3 (14.3)	16 (80)	
Asian	0	1 (1.3)	>.05
Body mass index, kg/m^2	25.87 ± 5.12 (17-35.46)	22.62 ± 4.72 (12.6-33.98)	>.05
Related donor	12 (57)	58 (75.3)	
Unrelated donors	9 (43)	19 (24.7)	>.05
Rewarm ischemia time, min	66.09 ± 23.32 (53-115)	71.75 ± 23.25 (30-180)	>.05
Delayed graft function	1 (4.8)	5 (6.5)	>.05
Glomerular filtration rate, mL/min	52.9 ± 17.7 (19.4-92.6)	62 ± 21.2 (18.4-131.5)	>.05
Post-transplant hypertension	11 (53.4)	53 (68.8)	>.05
Follow-up, mo	43.8 ± 38.1 (1-124)	52.6 ± 33.5 (2-128)	>.05

Continuous data are shown as the mean ± standard deviation (range) and categoric data as number (%).

There were 324 male (53.8%) and 278 female (46.2%) patients. There were 440 transplants (73.1%) from related donors and 162 (26.9%) from unrelated donors.

Multiple arteries were present in 98 kidneys (16.3%). Of these, 83 (84.7%) had 2 arteries, and 15 (15.3%) had 3 arteries. In 21 kidneys (21.4%) with multiple arteries (group I [GI]), the IEA was used for vascular reconstruction. In the remaining 77 patients (group II [GII]), reconstruction was made with the standard technique (side-to-side anastomosis). In GI, 4 patients (14.3%) had 3 arteries, and 17 patients (85.7%) had 2 arteries. The demographic data are summarized in Table 1.

After preparation of the iliac fossa for the kidney transplant, the IEA was meticulously dissected. Local 2% lidocaine sprinkling and surgical magnification helped in performing the anastomosis. After the main renal artery was declamped and the bulk of the kidney was revascularized, the IEA was ligated and divided as medially as possible because the blood flows from the lateral to the medial aspect. Bulldog clamps were applied to the IEA and to the accessory renal artery to avoid bleeding. After spatulation of both vessels, the IEA was anastomosed to the accessory renal artery using a running 7-0 polypropylene suture with an end-to-end technique, as shown in Figure 1. Low-molecular-weight heparin or acetylsalicylic acid were given after the surgery only to patients considered at risk for thrombosis or to those in whom the anastomosis was more difficult to perform.

The immediate success of the anastomosis could be easily noticed due to the change of color of the ischemic renal parenchyma from dark blue to red, which occurred almost immediately in most patients after IEA was declamped. The amount of ischemic renal mass varied from 10% to 25% of the bulk of the kidney. The vascular reconstruction techniques of GI and GII cases are, respectively, summarized in Tables 2 and 3. Color Doppler ultrasonography was routinely performed on the first or second day after the renal transplant.

Immunosuppression was achieved with the triple-drug regimen of tacrolimus, mycophenolate mofetil, and prednisone. The details of immunosuppression therapy have been published elsewhere.[4] Successful revascularization of all areas of the transplanted graft was confirmed by Doppler ultrasonography during follow-up. Mean serum creatinine levels, warm and total ischemia times, and the incidence of acute rejection and post-transplantation hypertension (defined as any value >140/90 mm Hg) were compared. Early and late vascular or urologic complications were also assessed. Urologic complications included ureteral obstruction, ureteral necrosis, and urinary fistula. Vascular complications included vascular thrombosis or arterial stenosis. Incidence of rejection was based on the first biopsy-proven rejection episode. Graft function was measured by the estimated glomerular filtration rate.

Graft loss was defined as the return to permanent dialysis. The Fisher exact test and the 2-tailed *t* test were used for the statistical analysis.

RESULTS

Delayed graft function (defined as the need for dialysis in the first week after transplantation) occurred in 1 G1 patient (4.8%) and in 5 GII patients (6.5%; *P* >.05). Rewarm ischemia time was 66.09 ± 23.32 minutes (range, 53-115 minutes) in GI and 71.75 ± 23.25 minutes (range, 30-180 minutes) in GII (*P* >.05) One partial renal infarction occurred in each group (4.8% vs 1.3%; *P* >.05). No thrombus developed in the anastomosis with the IEA. There was one urinary fistula in GI and 3 urinary fistulas plus 1 ureteral stenosis in GII (*P* >.05). All complications were grade 3 according to the Clavien classification system. One graft (4.8%) lost function in GI and 5 (6.5%) in GII during follow-up (*P* >.05). Eleven patients (53.4%) were hypertensive in GI and 53 (68.8%) in GII (*P* >.05). Three patients in GII required a blood transfusion. One patient received a transfusion on postoperative day 7 after a biopsy of the allograft developed a hematoma, and was managed conservatively. The other 2 patients required a blood transfusion on postoperative day 1 and day 5, respectively, due to symptomatic anemia. Four patients in GII died of unrelated causes with a functioning allograft (1 acute myocardial infarction, 1 sepsis, 1 trauma, and 1 pulmonary thromboembolism).

Acute rejection was observed in 5 patients (23.8%) in GI and in 17 (22.07%) in GII (*P* >.05). The mean

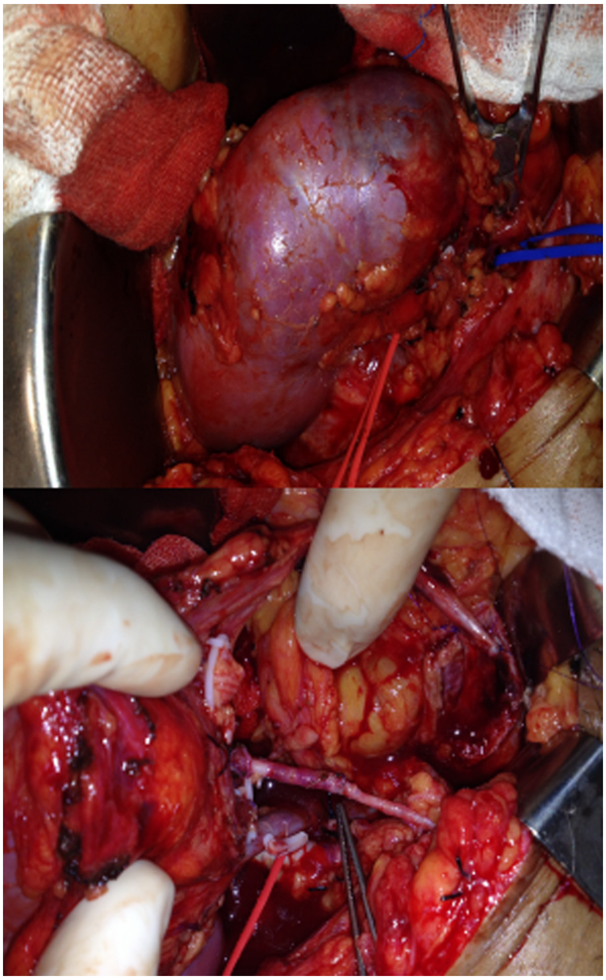

Figure 1. Intraoperative image shows **(upper panel)** the ischemic area in the lower pole of the kidney after the main renal artery anastomosis and **(lower panel)** the accessory lower polar artery anastomosed to the inferior epigastric artery. (Color version available online.)

hospital stay was 11.04 ± 6.19 days in GI and 11.42 ± 6.31 days in GII (P >.05).

One graft was lost after 1 year, whereas the others continued to function between 1 and 5 years, with serum creatinine ranging from 1.1 to 3.5 mg/dL. Good perfusion by duplex ultrasonography of the graft, including the small polar artery, was present in all patients with follow-up studies of 4 months to 4 years, with 6 patients imaged more than 1 year after operation.

COMMENT

Renal transplantation is the optimal treatment for most patients with end-stage renal disease.[5] The results of renal transplantation have improved dramatically in recent years due to refinements in surgical techniques, new immunosuppressive regimens, improved kidney preservation, and advances in antimicrobial therapy. The donor supply is limited in relation to the large number of patients with chronic renal failure. In 2012, 91,314 patients were on dialysis in Brazil and 21,686 were registered on

Table 2. Vascular reconstruction in group I

Arteries	Patients (No.)	Group I
2 arteries	17	MRA: T-L to the EIA IRA: T-T to the IEA
3 arteries	3	SRA+MRA: L-L double-barreled reconstruction to EIA IRA: T-T to the IEA
3 arteries	1	SRA: T-L to the MRA IRA: T-T to the IEA

EIA, external iliac artery; IEA, inferior epigastric artery; IRA, inferior renal artery; MRA, main renal artery; SRA, superior renal artery; T-L, termino-lateral; T-T, termino-terminal.

Table 3. Vascular reconstruction in group II

Arteries	Patients (No.)	Group II
2 arteries	39	SRA: T-L to the MRA MRA: T-L to the EIA
2 arteries	19	L-L Double-barreled reconstruction to EIA
2 arteries	8	SRA: ligated MRA: T-L to the EIA
3 arteries	6	SRA + MRA: L-L Double-barreled reconstruction to EIA IRA: T-L to the MRA
3 arteries	5	SRA: ligated IRA + MRA: Double-barreled reconstruction to EIA

the kidney transplant waiting list.[6] In the United States, by the end of 2009 there were 398,891 patients on dialysis and as of late 2010, 93,000 patients were registered on the kidney transplant waiting list.[7] This shortage of organs led to alternatives, such as the use of kidneys that were previously judged to be unsuitable for transplantation (marginal donors), and new schedules of organ procurement such as paired donation.[8]

Grafts with anatomic variations, such as double ureters and multiple renal vessels, still pose a challenge to the implanting surgeon. Of these variants, multiple renal arteries are the most common and are found in 8% to 30% of all potential donor kidneys.[9,10] Despite the advances in vascular surgical techniques and materials, surgeons usually prefer kidneys with single arteries. A variety of techniques are available for performing multiple artery renal transplantation. Anastomosis of a Carrel aortic patch encompassing all renal arteries to the recipient's common or external iliac artery is the preferred method for arterial anastomosis of cadaveric kidneys with multiple arteries. In living-donor kidney transplants, when 2 adjacent renal arteries of comparable size are present, the preferred method is extracorporeal side-to-side anastomosis of the 2 vessels to create a common ostium. This is done just before implantation, with the kidney cooled in ice-saline solution. When 2 renal arteries of disparate caliber are present, the preferred technique is end-to-side reimplantation of the smaller artery into the larger one.

Another method for transplanting kidneys with multiple renal arteries involves fashioning them into a single artery before implantation with a branched graft of autogenous hypogastric artery. Additional techniques can be considered, including arterial anastomoses to the branches of the hypogastric artery, separate arterial anastomoses to the external and common iliac arteries, separate arterial anastomoses to the hypogastric and external iliac arteries, and polar artery anastomosis to the IEA.[11-14] Transplanting a kidney with multiple arteries may have drawbacks, including prolonged warm ischemia time and an increased incidence of acute tubular necrosis.[15]

The accessory lower polar artery should not be sacrificed because it may be the main blood supply to the graft ureter. Ureteral necrosis after renal transplantation is often the result of impaired perfusion due to loss of donor polar arteries.[16] In the presence of an accessory lower polar renal artery, the IEA is an interesting option for revascularization. The use of the IEA as a source of arterial inflow to the kidney was first described by Dubernard et al[17] in 1976. Reports by El-Sherbiny et al[18] and Young et al[19] reemphasized the selection of arterial revascularization of kidneys with multiple arteries using the IEA. The main advantage of using the IEA for revascularization of the lower polar branch of the graft is that declamping of the main artery and vein and restoration of the graft circulation can be performed before commencing the anastomosis, thus decreasing the ischemia time.[20]

The IEA is readily available, has an adequate length, and can be used as an alternative to standard donor-recipient arterial anastomoses. It is usually healthy and compatible in size with polar vessels. The anastomosis may also be redone safely without reperfusion injury. The downside is that this type of anastomosis should be reserved for renal vessels that are smaller than 2 to 3 mm. The procedure also requires excellence in microvascular surgery, with avoidance of kinking of the vessels. The body mass index was similar between groups in our study, and there was no limitation to perform the anastomosis at the IEA even in obese patients with a body mass index of up to 35.5 kg/m^2. In addition, we should point out that despite the mean age of the patients in GI and G2II (40.5 and 35.6 years, respectively), referring to a younger population with a lower incidence of arteriosclerosis, the mean age of the patients at renal transplant in our study is comparable to larger series in the literature.[21,22]

Long-term results may vary in the literature. We did not notice a difference in the incidence of hypertension between the groups. Most authors have confirmed this finding.[11,23] Long-term patency in those patients was 95%.[24] In our series, there was no difference in the incidence of acute tubular necrosis. Kumar et al[25] used the same arteries and found a decreased rewarm ischemia time and a reduced incidence of acute tubular necrosis.

CONCLUSION

The use of the IEA was as effective as extracorporeal bench surgery for the anastomosis of multiple renal arteries, especially, lower polar arteries, without an increase in the incidence of relevant complications. Moreover, the anastomosis may be performed after declamping without prolongation of ischemia time. The management of multiple renal arteries in a living-donor kidney transplant can be technically demanding and used to be considered a relative contraindication because of the increased risk of vascular and urologic complications. Overall, patient survival and graft survival were excellent (100% and 96%). The rewarm ischemia time was similar between groups. The incidence of acute tubular necrosis and rejection episodes was also similar. We conclude that allografts with multiple renal arteries can be used successfully in a living-related renal transplantation program. Bench reconstruction should be done whenever possible. For reconstruction of an accessory vessel, the IEA with sequential revascularization is recommended.

References

1. Barry JM, Conlin M, Golconda M, et al. Strategies to increase living donor kidney transplants. *Urology*. 2005;66(5 Suppl):43-46.
2. Novick AC. Microvascular reconstruction of complex branch renal artery disease. *Urol Clin North Am*. 1984;11:465-475.
3. Novick AC, Magnusson M, Braun WE. Multiple-artery renal transplantation: emphasis on extracorporeal methods of donor arterial reconstruction. *J Urol*. 1979;122:731-735.
4. David-Neto E, David DS, Ginani GF, et al. C4d staining in post-reperfusion renal biopsy is not useful for the early detection of antibody-mediated rejection when CDC crossmatching is negative. *Nephrol Dial Transpl*. 2011;26:1388-1392.
5. Wolfe RA, Ashby VB, Milford EL, et al. Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant. *N Engl J Med*. 1999; 341:1725-1730.
6. Associação Brasileira de Transplante de Órgãos (ABTO). Diretoria e Conselho ABTO. Available at http://www.abto.org.br/abtov02/portugues/populacao/rbt/mensagemRestrita.aspx?id Categoria=2. Accessed September 14, 2012.
7. National Institute of Diabetes & Digestive & Kidney Diseases. US Renal Data System annual data report. Available at http://kidney.niddk.nih.gov/kudiseases/pubs/kustats/. Accessed September 14, 2012.
8. Leeser DB, Aull MJ, Afaneh C, et al. Living donor kidney paired donation transplantation: experience as a founding member center of the National Kidney Registry. *Clin Transpl*. 2012;26:E213-E222.
9. Saidi R, Kawai T, Kennealey P, et al. Living donor kidney transplantation with multiple arteries: recent increase in modern era of laparoscopic donor nephrectomy. *Arch Surg*. 2009;144:472-475.
10. Ugurel MS, Battal B, Bozlar U, et al. Anatomical variations of hepatic arterial system, coeliac trunk and renal arteries: an analysis with multidetector CT angiography. *Br J Radiol*. 2010;83:661-667.
11. Ali-El-Dein B, Osman Y, Shokeir AA, et al. Multiple arteries in live donor renal transplantation: surgical aspects and outcomes. *J Urol*. 2003;169:2013-2017.
12. Emiroglu R, Koseoglu F, Karakayali H, et al. Multiple-artery anastomosis in kidney transplantation. *Transpl Proc*. 2000;32:617-619.
13. Kadotani Y, Okamoto M, Akioka K, et al. Renovascular reconstruction of grafts with renal artery variations in living kidney transplantation. *Transpl Proc*. 2005;37:1049-1051.
14. Bakirtas H, Guvence N, Eroglu M, et al. Surgical approach to cases with multiple renal arteries in renal transplantation. *Urol Int*. 2006; 76:169-172.
15. Benedetti E, Troppmann C, Gillingham K, et al. Short- and long-term outcomes of kidney transplants with multiple renal arteries. *Ann Surg*. 1995;221:406-414.

16. Wolters HH, Schult M, Heidenreich S, et al. The anastomosis between renal polar arteries and arteria epigastrica inferior in kidney transplantation: an option to decrease the risk of ureter necrosis? *Transpl Int*. 2001;14:442-444.
17. Dubernard JM, Pin J, Gignoux N, et al. [Use of the epigastric artery in renal transplantation (author's transl)]. *J Urol Nephrol (Paris)*. 1976;82:469-472.
18. El-Sherbiny M, Abou-Elela A, Morsy A, et al. The use of the inferior epigastric artery for accessory lower polar artery revascularization in live donor renal transplantation. *Int Urol Nephrol*. 2008;40:283-287.
19. Young JS, Rohr MS. Use of the inferior epigastric artery to revascularize a lower pole renal artery in renal transplant. *Am Surg*. 1995; 61:185-186.
20. Gomes LJ, Goldstein MJ, Hardy MA. The use of inferior epigastric artery in renal transplantation. *Transplantation*. 2009;88:748-749.
21. Tasaki M, Saito K, Nakagawa Y, et al. 20-year analysis of kidney transplantation: a single center in Japan. *Transpl Proc*. 2014;46: 437-441.
22. Ahn C, Koo TY, Jeong JC, et al. Initial report of the Korean Organ Transplant Registry: the first report of national kidney transplantation data. *Transpl Proc*. 2014;46:425-430.
23. Başaran O, Moray G, Emiroğlu R, et al. Graft and patient outcomes among recipients of renal grafts with multiple arteries. *Transpl Proc*. 2004;36:102-104.
24. Merkel FK, Straus AK, Andersen O, et al. Microvascular techniques for polar artery reconstruction in kidney transplants. *Surgery*. 1976; 79:253-261.
25. Kumar A, Gupta RS, Srivastava A, et al. Sequential anastomosis of accessory renal artery to inferior epigastric artery in the management of multiple arteries in live related renal transplantation: a critical appraisal. *Clin Transpl*. 2001;15:131-135.