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Short- and Long-Term Outcomes of Kidney Transplants with Multiple Renal Arteries

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Objective

The authors determined whether the use of kidney allografts with multiple renal arteries adversely affects post-transplant graft and patient outcome or increases the incidence of vascular and urologic complications.

Background

Kidney grafts with multiple renal arteries have been associated with an increased incidence of early vascular and urologic complications. Kidney transplants with single *versus* multiple renal arteries have not been compared in regard to long-term graft and patient outcome or post-transplant incidence of hypertension, acute tubular necrosis, rejection, and late vascular and urologic complications.

Methods

We analyzed 998 adult kidney transplants done from December 1, 1985 through June 30, 1993, in which only the recipient's external or internal iliac artery was used for anastomosis. We divided the study population into 3 groups: Group A—1 renal artery, 1 arterial anastomosis (n = 835), Group B—>1 renal artery, 1 arterial anastomosis (n = 112), Group C—>1 renal artery, >1 arterial anastomosis (n = 51). We compared the incidence of post-transplant hypertension, acute tubular necrosis, acute rejection, and vascular and urologic complications; mean creatinine levels at 1, 3, and 5 years post-transplant; and patient and graft survival. Univariate and multivariate analyses were done to identify risk factors for vascular complications.

Results

We found no significant differences among the three groups for the following variables: post-transplant hypertension, acute tubular necrosis, acute rejection, creatinine levels, early vascular and urologic complications, and graft and patient survival. In kidneys with single arteries, the presence (*vs.* absence) of an aortic patch and the type of the arterial anastomosis (end-to-end to the hypogastric *vs.* end-to-side to the external iliac artery) did not have an impact on the incidence of early or late vascular complications. In kidneys with multiple arteries, only the rate of late renal artery stenosis was higher, the rate of early vascular and urologic complications was not different. Our multivariate analysis identified acute tubular necrosis as a risk factor for renal artery and vein thrombosis; graft placement on the left side for arterial thrombosis; and preservation time ≥ 24 hours and multiple renal arteries for renal artery stenosis.

Conclusions

Results of kidney transplants using allografts with multiple *versus* single arteries are similar.

Table 1. KIDNEY TRANSPLANT CATEGORIES (12/85–6/93)

Kidney transplants alone	1244
Simultaneous kidney/pancreas transplants	175
Simultaneous kidney/liver transplants	10
Simultaneous kidney/islet transplants	10
Simultaneous kidney/heart transplants	1
Total	1440

Kidney transplantation is the treatment of choice for the vast majority of patients with end-stage renal disease. During the last three decades, graft and patient outcome has significantly improved because of standardization in surgical technique and refinements in immunosuppressive therapy, organ preservation, and antimicrobial therapy. Kidney allografts that formerly were not considered transplantable currently are engrafted with success. Many current challenges with donor grafts are the result of anatomic variants, including multiple renal arteries, multiple ureters, *en bloc* pediatric kidney grafts, or ureteral anastomosis to an ileal or colon conduit.[1–8] Of these variants, multiple renal arteries are the most common; they are found in 18% to 30% of all potential kidney donors.[3] Although the use of these grafts has been associated with an increased incidence of vascular and urologic complications,[3,6] their long-term outcome has not been studied well. Therefore, we retrospectively reviewed our experience with multiple renal arteries in the cyclosporine era and compared both short- and long-term outcomes of kidney grafts with multiple *versus* single renal arteries.

MATERIALS AND METHODS

Between December 1, 1985 and June 30, 1993, a total of 1440 kidney transplants were performed at the University of Minnesota (Table 1). To obtain a homogenous transplant study population, we excluded 1) recipients of kidney transplants done in conjunction with other organs (n = 196); 2) recipients of *en bloc* pediatric kidney transplants (n = 11); and 3) pediatric kidney recipients with arterial anastomoses done to the infrarenal aorta or to the common iliac artery through an abdominal incision (n = 235). We included only primary or secondary adult kidney recipients whose grafts were placed retroperitoneally, with arterial anastomoses to the external or internal iliac arteries (n = 998). Of these 998 patients, 504 (50.5%) received grafts from cadaver donors, 494 (49.5%) received grafts from living, related (n = 448) or living, unrelated (n = 46) donors. There were 952 (95.4%) primary transplants and 46 (4.6%) first retransplants. Average recipient age was 44 ± 4.6 years (range 16–74 years); 62% were male, 38% were female. All patients received standard triple immunosuppression: cyclosporine, azathioprine, and prednisone for maintenance. In addition, recipients of cadaver or living, unrelated donor grafts received a 7-day induction course of either polyclonal or monoclonal antibodies.

We divided patients into 3 groups, according to their vascular reconstruction. Group A (n = 835, 83.7%) comprised recipients of single-artery grafts anastomosed either end-to-end to the internal iliac, or end-to-side to the external iliac artery, with a single anastomosis. Included were graft renal arteries with or without a common aortic patch. Group A represents our control group (Fig. 1). Group B (n = 112; 11.2%) comprised recipients of multiple renal artery grafts anastomosed end-to-end to

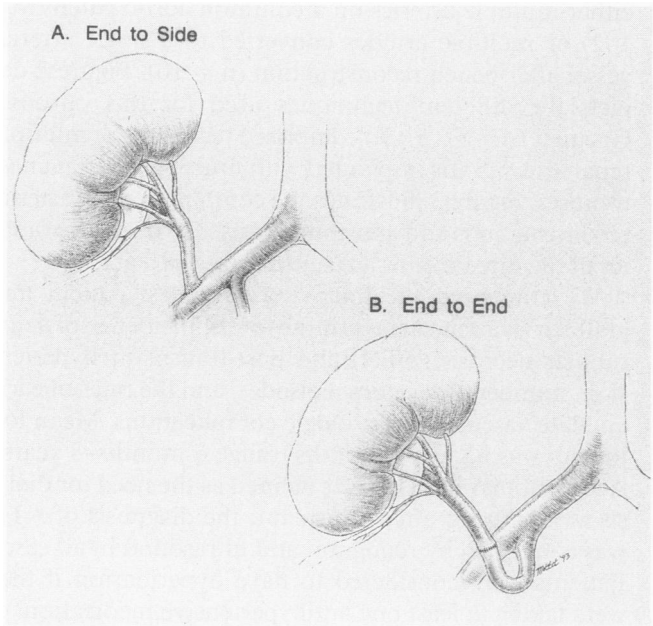

Figure 1. Single renal artery anastomosis (end-to-side or end-to-end).

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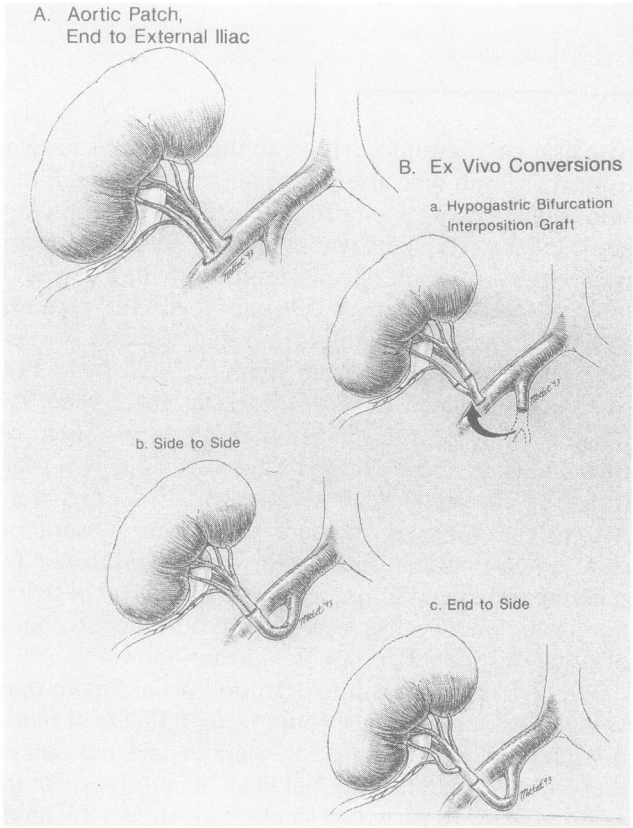

Figure 2. Multiple renal arteries converted to single anastomosis (aortic patch or *ex vivo* conversion).

the internal iliac artery or end-to-side to the external iliac artery with a single anastomosis. Included are grafts with either multiple arteries on a common aortic patch (n = 102) or multiple arteries converted to a single arterial vessel after bench reconstruction (n = 10). Figure 2 depicts the different techniques used for this purpose. Group C (n = 51; 5.1%) comprised recipients of multiple renal artery grafts implanted with multiple arterial anastomoses. Figure 3 illustrates the combinations of arterial reconstructions and anastomoses used. The demographics of the three groups are summarized in Table 2.

We compared the following variables: patient and graft survival, mean creatinine levels, incidence of acute tubular necrosis (ATN) and post-transplant hypertension, number of rejection episodes, and the rates of early and late vascular and urologic complications. Mean follow-up was 62 ± 6.5 months (range 6 months–8 years). Acute tubular necrosis was defined as the need for dialysis at least once after transplant; the diagnosis of ATN was confirmed by renogram and ultrasound in all cases. Patients were considered to have hypertension if they were taking at least one antihypertensive medication, or had a blood pressure ≥ 160/90 mm Hg. The incidence of rejection was based on the first biopsy-proven rejection episode. Urologic complications included ureteral obstruction, urinary leak, calyceal fistula, and ureteral necrosis. Vascular complications included renal artery or renal vein thrombosis, bleeding, and late arterial stenosis.

Data were obtained from the computerized database for kidney transplants at the University of Minnesota and from chart reviews. Actuarial patient and graft survival rates were calculated according to Kaplan-Meier. Univariate analysis was performed using Fisher's exact test or chi square test. A multivariate analysis (Cox regression analysis) also was performed to detect risk factors for vascular complications.

RESULTS

Graft and Patient Survival

Graft survival rates at 1 and 5 years post-transplant were 88.3% and 71.7% in Group A, 94.4% and 72.8% in Group B, and 82.8% and 77.4% in Group C (p = 0.9013), respectively (Fig. 4A). Patient survival rates at 1 and 5 years post-transplant were 94.6% and 85.8% in Group A, 97.2% and 83.4% in Group B, and 92.2% and 92.2% in Group C recipients (p = 0.3864) respectively (Fig. 4B). Further analysis of survival data by donor source (living related *vs.* cadaver donors) also failed to show any statis-

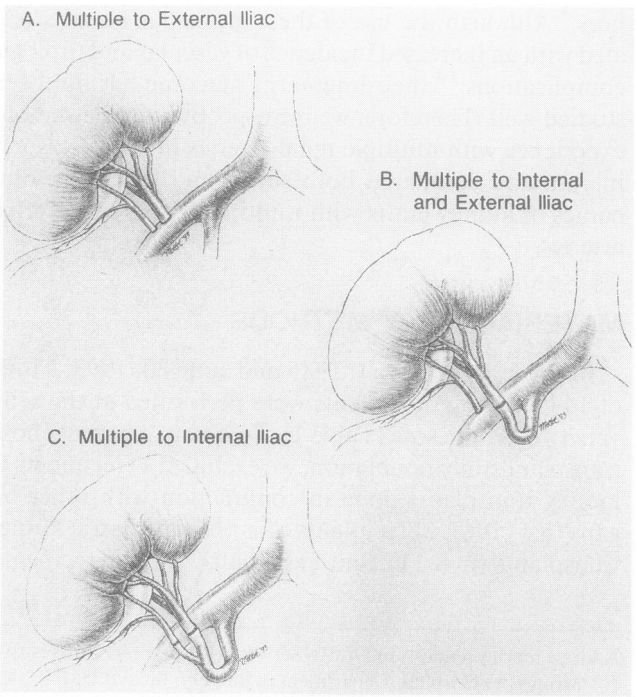

Figure 3. Multiple renal arteries with multiple anastomoses.

Table 2. ANATOMY OF DONOR RENAL ARTERIES AND TYPE OF ARTERIAL ANASTOMOSIS

	Group A	Group B	Group C
Type of donor renal artery anatomy	Single renal artery with single anastomosis (n = 835)	Multiple renal arteries with single anastomosis (n = 112)	Multiple renal arteries with multiple anastomoses (n = 51)
Donor source	447 LRD + LURD (53.5%) 388 CAD (46.5%)	10 LRD (8.9%) 102 CAD (91.1%)	37 LRD (72.5%) 14 CAD (17.5%)
Type of arterial anastomosis/ reconstruction	End-to-end hypogastric, n = 132 (15.8%) End-to-side to external iliac artery, n = 703 (84.2%) Without cuff, n = 480 (57.5%) With cuff, n = 223 (26.7%)	Multiple arteries on aortic patch, n = 102 (91.1%) Multiple arteries converted ex-vivo to single artery, n = 10 (8.9%) 2 side to side 6 end to side 2 donor hypogastric bifurcation	Multiple anastomoses to both external and internal iliac artery, n = 21 (41.2%) Multiple anastomoses to external iliac artery, n = 28 (54.9%) Multiple anastomosis to internal iliac artery, n = 2 (3.9%)

LRD = Living related donor; LURD = living unrelated donor; CAD = cadaver donor.

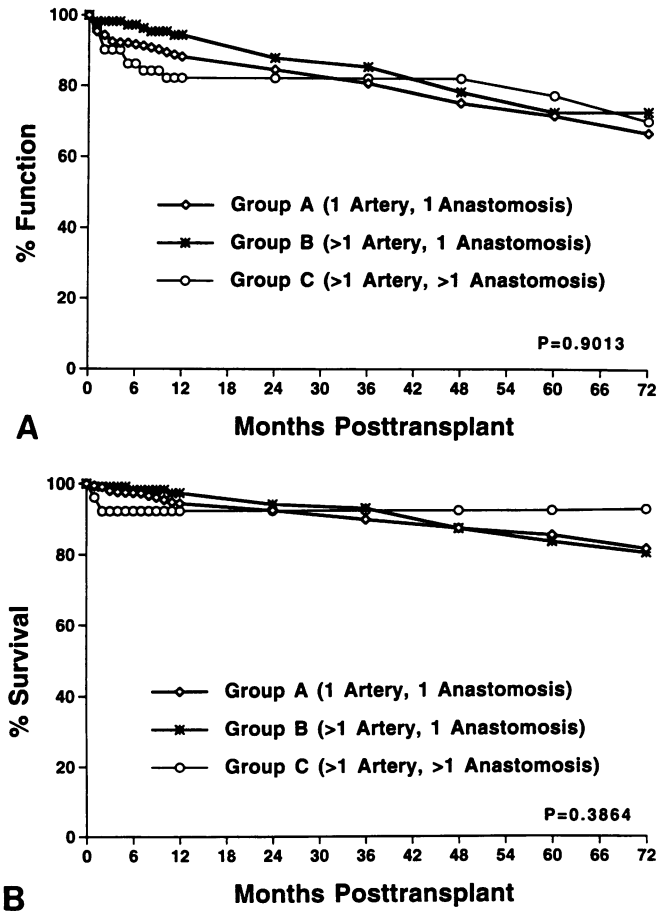

Figure 4. (A) Graft survival in Groups A, B, and C. (B) Patient survival in Groups A, B, and C.

tical difference between the three groups (p = 0.123 for graft survival, p = 0.216 for patient survival).

Creatinine Levels

As a measure of graft function, we compared mean creatinine values among the three groups, i.e., the values at 1, 3, and 5 years post-transplant; they did not differ significantly (p = 0.45) (Table 3). Over time (1 year *vs.* 5 years), we noted a decrease in mean creatinine levels in all three groups.

Acute Tubular Necrosis

The incidence of post-transplant ATN was 12.6% in Group A, 14.3% in Group B, and 15.7% in Group C and was not significantly different (p = 0.73).

Table 3. MEAN CREATININE LEVELS (IN MG/DL) AT 1, 3, AND 5 YEARS IN GROUPS A, B, AND C (p = 0.45)

Creatinine	Group A 1 Artery, 1 Anastomosis	Group B >1 Artery, 1 Anastomosis	Group C >1 Artery, >1 Anastomosis
1 yr	1.66	1.70	1.76
3 yrs	1.69	1.61	1.74
5 yrs	1.58	1.52	1.60

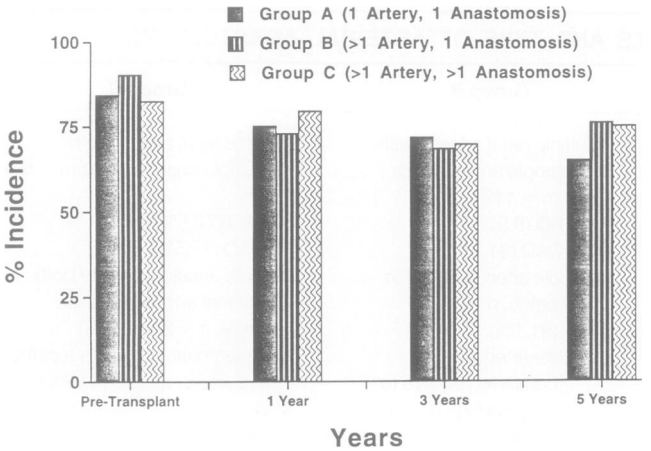

Figure 5. Incidence of hypertension pre- and post-transplant in Groups A, B, and C.

Post-Transplant Hypertension

The incidence of pretransplant hypertension was remarkably high— 80.2% in Group A, 98.2% in Group B, and 82.4% in Group C. Over time (1 *vs.* 5 years), the incidence of hypertension decreased slightly in all groups (Fig. 5), but not significantly ($p = 0.76$).

Rejection

The incidence of acute rejection episodes was 41.8% in Group A, 42% in Group B, and 29.4% in Group C. The difference, particularly between Groups B and C, was not significant ($p = 0.2142$).

Urologic Complications

The rate of urologic complications is shown in Table 4. We found no difference in regard to the incidence of ureteral obstruction, late strictures, and anastomotic or bladder leakage among the three groups ($p \geq 0.1038$). Complications of lower pole artery injuries, such as ureteral necrosis or calyceal cutaneous fistulas, were not observed in any group.

Vascular Complications

The incidence of vascular complications is shown in Table 5. Overall, the most common vascular complication was renal artery stenosis—i.e., 2% ($n = 20$) of all cases. In Group A, 13 patients (1.4%) developed renal artery stenosis; this complication occurred in 1 of 132 cases of end-to-end anastomoses to the hypogastric artery (0.4%) and in 12 of 703 cases of end-to-side anastomoses to the external iliac artery (1.7%, $p = 0.7308$). In the latter group, renal artery stenosis occurred in 4 of 223 cases (0.8%) with the renal artery on an aortic patch and in 7 of 408 cases (1.45%) without an aortic patch on the renal artery; the presence of an aortic patch did not protect against the development of renal artery stenosis ($p = 0.962$). Group B had the highest rate of arterial stenosis (5.35%), significantly higher than Group A ($p = 0.019$). Arterial stenosis was found only in grafts with multiple arteries on a common aortic patch and not in grafts with multiple arteries converted to a single artery by bench reconstruction. Group C had only one renal artery stenosis (1.9%); in this case, the two renal arteries were anastomosed to the internal and external iliac arteries. Renal artery stenosis always was a late event, diagnosed 6 months to 3 years after transplant. All patients with renal artery stenosis presented with worsening or new-onset hypertension that was difficult to control with standard medical therapy; 8 of the 20 patients (40%) had deterioration of graft function. Diagnosis was made by color Doppler flow studies initially, then by selective angiography. Between 1983 and 1989, patients with renal artery stenosis underwent surgery ($n = 8$); re-implantation of the renal artery to the hypogastric artery was done in five cases and to the external iliac artery in three cases. Of these eight patients, two developed recurrent stenosis, which was treated successfully by surgical re-anastomosis in one case and by balloon dilatation in the other. Of

Table 4. UROLOGIC COMPLICATIONS IN GROUPS A, B, AND C

	Group A 1 Artery, 1 Anastomosis	Group B >1 Artery, 1 Anastomosis	Group C >1 Artery, >1 Anastomosis	p Value
Early ureteral obstruction	4.2%	6.3%	5.8%	0.2950
Anastomotic or bladder leak	1.0%	0.9%	2.0%	0.1038
Late stricture	1.6%	0.9%	2.0%	0.2020
Total	6.8%	8.1%	9.8%	0.1261

Table 5. VASCULAR COMPLICATIONS IN GROUPS A, B, AND C

	Group A 1 Artery, 1 Anastomosis	Group B >1 Artery, 1 Anastomosis	Group C >1 Artery, >1 Anastomosis	Total	p Value
Renal artery thrombosis	4 (0.47%)*	0	0	4 (0.40%)	NS
Renal vein thrombosis	10 (1.19%)	0	0	10 (1.00%)	NS
Renal artery stenosis	13 (1.43%)	6 (5.35%)	1 (1.96%)	20 (2.00%)	(0.0196) A *vs.* B (0.5966) B *vs.* C
Bleeding from renal artery	1 (0.11%)	0	1 (1.96%)	2 (0.20%)	NS
Bleeding from renal vein	0	1 (0.89%)	0	1	NS
Renal artery aneurysm	1 (0.11%)	0	0	1 (0.10%)	NS
Infarction	5 (0.54%)	0	0	5 (0.50%)	NS
Others	2 (0.47%)	1 (0.89%)	2 (3.92%)	3 (0.30%)	NS
Total	36 (4.31%)	8 (7.14%)	2 (3.92%)	46 (4.60%)	0.2950

* Percentage given in relation to the total number of patients in each group.

the 20 patients with renal artery stenosis, 6 (30%) were treated primarily with balloon angioplasty; one patient with recurrent stenosis required surgical repair 8 months later. The remaining six (30%) patients needed medical therapy only.

Renal artery thrombosis caused graft loss in 4 patients (0.4%). This complication occurred exclusively in Group A in 1 of the 132 (0.7%) grafts with end-to-end anastomoses to the internal and in 3 of 703 (0.4%) grafts with end-to-side anastomoses to the external iliac artery ($p = 0.9864$). In all cases, renal artery thrombosis was diagnosed clinically by sudden onset of oliguria or anuria and confirmed by color Doppler flow studies. In all cases, transplant nephrectomy was performed within 1 day after establishing the diagnosis. Surprisingly, post-transplant renal artery thrombosis did not occur in recipients of multiple renal artery grafts (Groups B and C).

Renal vein thrombosis caused graft loss in 1% of all cases ($n = 10$); like renal artery thrombosis, all 10 cases of renal vein thrombosis occurred in Group A. Transplant nephrectomy was performed in all cases. Renal vein thrombosis was not observed in Group B or C. The difference among the three groups was not significant (p = NS)

Three patients had post-transplant bleeding (0.3%). In two cases, the bleeding originated from the renal artery and required immediate surgical re-exploration. Both grafts were saved, although one of the two patients subsequently developed renal artery stenosis requiring surgical repair 8 months later. In the third case (Group B), significant bleeding from the renal vein occurred, eventually resulting in transplant nephrectomy.

An aneurysmatic dilatation of the renal artery was documented angiographically in a Group B patient with end-to-side anastomosis to the external iliac artery. The initial diagnosis was made by Doppler flow study as part of rejection workup. The aneurysmatic dilatation was 25 mm in diameter and did not require surgery.

In Group A, five patients had massive necrosis of the graft without evidence of thrombosis of the renal artery or vein (listed as "infarction" in Table 5); on histopathologic examination, after transplant nephrectomy, all of these grafts showed evidence of ongoing acute rejection.

The overall incidence of early vascular complications (within 10 days post-transplant)—all of which required surgical intervention—was 2.2% (22 of 998 patients). Late complications (≥10 days post-transplant) were diagnosed in 2.4% (24 of 998 patients). Thus, the incidence of all vascular complications was 4.6% for the entire patient population. In 20 of 46 (43.4%) patients with vascular complications, transplant nephrectomies were done, accounting for 2% of all graft loss. Vascular complications were noted in 3.4% of living, related recipients and in 5.7% of cadaver recipients ($p = 0.1115$). None of the patients died as a consequence of their vascular complications.

Cox Regression

A Cox regression analysis (Table 6) was performed to assess the impact of nine risk factors (donor age, recipient age, primary *vs.* retransplant, preservation time, multiple arteries *vs.* single arteries, ATN *vs.* no ATN, living *vs.* cadaver donor, rejection *vs.* no rejection, and graft placement on the left *vs.* right side) on the incidence of the following three major vascular complications: renal vein thrombosis, renal artery thrombosis, and late arterial stenosis. Acute tubular necrosis was the only significant risk factor for renal vein thrombosis ($p = 0.008$). For arterial thrombosis, the two factors that approached

Table 6. MULTIVARIATE ANALYSIS OF RISK FACTORS FOR RENAL ARTERY THROMBOSIS, RENAL VEIN THROMBOSIS, AND (LATE) RENAL ARTERY STENOSIS

	Renal Vein Thrombosis	Renal Artery Thrombosis	Renal Artery Stenosis
Donor age >45 yrs *vs.* <45 yrs	0.39	0.27	0.19
Recipient age 18–50 yrs *vs.* >50 yrs	0.75	0.43	0.35
1st transplant *vs.* retransplant	0.84	0.73	0.60
Preservation time >24 hrs *vs.* <24 hrs	0.21	0.91	0.02
Multiple arteries *vs.* single arteries	0.10	0.30	0.04
ATN *vs.* no ATN	0.008	0.08	0.88
Living donor *vs.* cadaveric donor	0.27	0.57	0.43
Rejection *vs.* no rejection	0.18	0.95	0.15
Graft placement: right side *vs.* left side	0.38	0.07	0.79

statistical significance were ATN (0.08) and graft placement on the left side ($p = 0.07$). Finally, we defined two risk factors for late arterial stenosis—multiple donor arteries ($p = 0.04$) and preservation time of more than 24 hours ($p = 0.02$). As noted previously, the increased incidence of renal artery stenosis in grafts with multiple arteries is the result of the high rate of this complication in cadaver grafts with multiple arteries on a common aortic patch.

DISCUSSION

According to several large autopsy series, the incidence of multiple renal arteries ranges from 18% to 30%.[3] Pollack et al.[8] studied 400 cadaver donors and in 23% found double arteries, in 4% found triple arteries, and in 1% found quadruple arteries; in 15% of all cases, multiple renal arteries were present bilaterally. Transplanting a kidney with multiple arteries has several theoretical disadvantages: it may prolong the warm ischemia time, increase the incidence of ATN and rejection episodes, decrease graft function, and prolong hospitalization. Multiple renal arteries reportedly have been associated with a higher rate of vascular complications, including arterial thrombosis and renal artery stenosis.[3,5,6] In particular, polar arteries can cause infarction, infection, and urologic complications, such as calyceal or ureteral fistulas and ureteral necrosis, increasing morbidity and graft loss.[3] Cadaver kidney procurement using the *en bloc* technique, as originally described by Ackerman et al. in 1968,[9] have helped to significantly decrease accidental injury to polar arteries during donor nephrectomy. Results of renal artery reconstruction improved with the introduction of extracorporeal microsurgical repair of arterial injuries; bench reconstruction of multiple arteries has become commonplace in the major transplant centers around the world.[3,6,10] These technical refinements have significantly expanded the pool of cadaver, living, related and living, unrelated donors.

Several techniques for bench reconstruction of multiple renal arteries have been described in kidneys from living related donors with (bilateral) multiple arteries. The smaller artery usually is anastomosed in an end-to-side fashion to the main artery; if both renal arteries are of similar size, the ends of the two vessels can be sutured together side to side. Rossi et al.[11] used a polytef patch to anastomose multiple renal arteries, with a single anastomosis to the recipient external iliac artery. Chervenkov et al.[12] recommend the use of the recipient hypogastric artery, open and fashioned as a Carrel patch to implant multiple renal arteries; alternatively, the hypogastric artery, with its branches, can be used as a conduit for bench reconstruction. The proximal and distal end of the inferior epigastric artery has also been used successfully for end-to-end anastomosis to a small polar vessel—with arterial inflow inferiorly from the femoral artery and superiorly from the internal mammary artery.[4]

Our 16.3% incidence of kidney allografts with multiple renal arteries is lower than most reports in the literature. The low rate reflects the large number of living, related and living, unrelated donors in our program. Based on pretransplant donor angiogram, we generally use kidneys with multiple arteries only if they are bilateral or if the kidney with one renal artery cannot be used for medical reasons. More than half (62.6%) of kidney grafts with multiple arteries had an aortic patch; in all of these cases, a single end-to-side anastomosis to the external iliac artery was created. In 6.1% of kidneys with multiple arteries, we did bench reconstruction, with *ex vivo* conversion to a single-donor artery. We created multiple anastomoses in only 31.3% of the kidneys with multiple renal arteries: multiple anastomoses were done end-to-side to the external iliac artery in 54.9% of these cases and end-to-end to the internal iliac artery in 3.9%; in the remaining 41.2% both external and internal iliac arteries were used. With polar arteries, our approach has been to aggressively revascularize arterial vessels directed to the lower pole of the kidney—regardless of the size—because these vessels potentially supply the ureter. We also revascularize upper polar arteries, except for extremely small vessels feeding <5% of the upper pole of the kidney and not contiguous to the collecting system.

Table 7. INCIDENCE OF VASCULAR COMPLICATIONS AFTER KIDNEY TRANSPLANT—REVIEW OF LITERATURE

Author and Institution	Year	Total No. of Cases	Arterial Thrombosis	Vein Thrombosis	Renal Artery Stenosis	Arterial or Venous Bleeding	Total Vascular Complications
Palleschi et al., Cleveland Clinic	1980	600	5 (0.8%)	2 (0.3%)	9 (1.5%)	5 (0.5%)	21 (3.5%)
Rijksen et al., University of Leiden, The Netherlands	1982	400	7 (1.8%)	2 (0.5%)	40 (10%)	1 (0.2%)	50 (12.5%)
Höhnke et al., University of Munich, Germany	1987	1203	5 (0.4%)	Not Reported	45 (3.7%)	10 (0.8%)	65 (5.4%)
Vanroye et al., St. Raboud University, The Netherlands	1993	1300	11 (0.8%)	17 (1.3%)	Late complications not assessed	36 (2.8%)	68 (5.2%)
Present series	1995	998	4 (0.4%)	10 (1.0%)	20 (2%)	3 (0.3%)	46 (4.6%)

For cadaver kidney grafts, our preferred approach has been to re-implant multiple renal arteries on a common Carrel patch; when the arteries are on separate patches, we sew the patches together without tension after properly aligning the vessels. The common Carrel patch cannot be engrafted if the distance between the renal artery does not allow for creation of a tension-free common patch, if severe atherosclerotic disease is present at the aortic takeoff, or if an accidental trans-section of an accessory renal artery occurred during procurement.

In kidney transplants with multiple anastomoses, revascularization can be done either simultaneously after the entire arterial engraftment is completed or sequentially. Using the latter technique, the main renal artery is revascularized first. Then, the vascular clamps are released and the kidney is partially revascularized. The other artery is anastomosed to a convenient site, maintaining perfusion of the kidney by the main artery. We did not find any difference between simultaneous and sequential revascularization in regard to the incidence of ATN or any other complications.

In our series, we found no difference in short- and long-term kidney graft outcomes based on the number of renal arteries and the technique used for reconstruction and anastomosis. Graft survival was excellent with multiple anastomoses and with multiple arteries converted to a single artery by bench reconstruction. Urologic complications did not increase in our series of multiple artery grafts; not one case of calyceal fistula or ureteral necrosis occurred. Our overall 4.6% incidence of vascular complications (2.2% early and 2.4% late) compares favorably with the literature, where the rate ranges between 3.5% and 12.5% (Table 7).[13-16] Furthermore, we did not find a difference in the vascular complication rate between cadaver and living, related donor kidney grafts. In an earlier study, Roza et al.[6] reported on 42 living related donor grafts with multiple renal arteries. They noted two graft losses due to thrombosis or ligation of a polar artery and three ureteral fistulas related to injury of the lower polar arteries. In contrast to our study, they concluded that kidney grafts with multiple arteries increased post-transplant morbidity and graft loss. Guerra et al.[5] compared patient and graft survival and the incidence of ATN in 61 kidney transplants with multiple renal arteries *versus* 299 grafts with single arteries; they found no difference between the two groups. Likewise, Bouchou et al.[4] studied the vascular patency rate in 109 kidney grafts with multiple renal arteries; they compared 64 grafts without a common aortic patch and separate engraftment with 45 grafts on an aortic patch and single anastomosis. The patency rate was similar between the two groups, i.e., 96.8% *versus* 97.7%.

In our series, we did not find any vascular thrombosis in kidney grafts with multiple arteries, with or without a common aortic patch. Vanroye et al.,[16] in a more recent review of early vascular complications in 1300 kidney transplants (including pediatric patients), reported a vascular thrombosis rate of 5.2% during the first 10 days post-transplant; the mortality rate was 0.08% and transplant nephrectomy was necessary in 66% of the cases requiring re-intervention. Their graft loss rate of 3.5% (due to early vascular complications) compares with 2% in our series. According to their multivariate analysis, size discrepancy between donor organ and recipient weight, as well as the necessity to partially or completely redo a vascular anastomosis intraoperatively, was associated with a significantly increased risk of graft loss; the presence of multiple arteries was not a risk factor. Our univariate and multivariate analyses confirm this finding; the presence of multiple renal arteries with

or without multiple anastomoses does not increase the risk of early vascular complications.

Arterial thrombosis is a dismal event and, in our series, always led to graft loss; overall, our rate of 0.4% is low compared with other reports.[13–15] We found no significant difference in the incidence of arterial thrombosis between graft anastomosis end-to-end to the hypogastric artery or end-to-side to the external iliac artery. In contrast, in the literature, the rate of arterial thrombosis is higher when the hypogastric artery is used as inflow vessel.[16,17] Likewise, we found no difference in the incidence of late vascular complications between end-to-end or end-to-side anastomoses. Arterial stenosis may not be related directly to the technique used for the arterial anastomosis. Even though an aortic patch theoretically should make the vascular anastomosis easier and prevent stenosis, the presence of a patch did not decrease the incidence of renal artery stenosis for grafts with a single artery in our series. In contrast, the incidence of arterial stenosis in grafts with multiple arteries on an aortic patch transplanted with a single anastomosis was significantly higher than in grafts with a single artery and single anastomosis. Alteration of the flow or preservation injuries may explain this finding in the absence of a different incidence of vascular rejection and cyclosporine levels. Stenosis as a complication of cannulating small renal arteries for pulsatile perfusion also has been described.[18]

Our multivariate analysis defined few significant risk factors for vascular complications. We found that ATN increases the risk for renal vein thrombosis; a preservation of ≥24 hours and the presence of multiple arteries are risk factors for late renal artery stenosis. It should be stressed again that all our cases of renal artery stenosis in grafts with multiple arteries were in kidneys with multiple arteries on an aortic patch (cadaver donor with longer preservation time). For renal artery thrombosis, we found that graft placement on the left (*vs.* the right) side and ATN approached significance as risk factors.

Based on our results, kidney grafts with multiple arteries can be implanted with short- and long-term results equal to those with single arteries: we found no difference between patient and graft survival, incidence of ATN, postoperative hypertension, rejection, vascular and urologic complications, or serum creatinine levels. The presence of multiple arteries does not increase the incidence of early vascular complications; however, it is a risk for late renal artery stenosis, especially in grafts with prolonged preservation time. Multiple arteries can either be reconstructed on the bench to a single vessel or engrafted with multiple anastomoses—the outcome is equally successful. The presence of an aortic patch does not have an impact on graft outcome or on the rate of complications. Kidney grafts with single arteries can be anastomosed either end-to-end to the hypogastric or end-to-side to the external iliac artery with equal results; furthermore, results are equal whether an aortic patch is available or not. Therefore, kidneys with multiple arteries should be implanted, using the technique that best fits a particular situation and with which the individual transplant surgeon feels most comfortable.

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