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Complex Surgical Reconstruction of Upper Pole Artery in Living-Donor Kidney Transplantation

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Background: The use of allografts with multiple renal arteries has increased in the era of laparoscopic donor nephrectomy. Although several studies recommend reconstructing lower pole arteries (LPAs) to reduce risk of urologic complications, it is common opinion to ligate upper pole arteries (UPAs) with a diameter less than 2 mm because of increased risk of thrombosis related to their reconstruction. This retrospective study evaluates the feasibility and safety of reconstructing thin UPAs during living-donor kidney transplantation, with the goal of maintaining the integrity of the graft and assuring its maximal function.

Material/Methods: Data from 922 living-donor kidney transplants performed between 2009 and 2019 were reviewed. Six cases with UPAs were identified (0.65%). The study endpoints were incidence of allograft vascular and urologic complications, slow graft function, delayed graft function, graft failure, and graft and patient survival.

Results: The UPAs had a mean diameter of 1.8±0.28 mm. Methods of reconstruction included: interposition graft (n=2), end-to-side anastomosis inside the renal hilum to a branch of the main renal artery (n=3), and side-to-side anastomosis with the main renal artery (n=1). Additional reconstruction of LPAs (n=2) and main renal arteries (n=2) was performed. During a median (range) follow-up of 14.5 (9–49) months no complications were observed.

Conclusions: *Ex vivo* reconstruction of UPAs with a diameter less than 2 mm is worth attempting, particularly in the setting of living-donor kidney transplantation.

MeSH Keywords: **Kidney Transplantation • Living Donors • Reconstructive Surgical Procedures • Renal Artery**

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Background

Kidney transplantation remains the treatment of choice in patients with end-stage renal disease and leads to improved survival and quality of life [1]. Because of a continuing shortage of donors there is growing pressure to find suitable organs. Different strategies have been used to try to resolve this issue by extending donor criteria and establishing living-donor programs [2–4]. In addition, minimally invasive techniques, such as laparoscopic nephrectomy, have made it more attractive to potential donors to donate a kidney, which has led to an increase in the donor pool and overall graft quality [5]. The presence of multiple graft arteries is the most frequently detected anatomical variation during kidney transplantation. Unilateral multiple renal arteries were detected in 23% of donors, whereas they were detected bilaterally in 10% [6]. With the improvements made in surgical techniques and better imaging modalities, the use of allografts with multiple renal arteries (MRA) has increased in the era of laparoscopic donor nephrectomy [7,8].

Nevertheless, transplantation of allografts with MRA is technically more challenging and has been associated with increased vascular and urologic complications such as arterial thrombosis and ureteral leak and stricture, together with an increased risk of delayed graft function (DGF), and decreased 1-year graft survival compared with the group of single renal artery allografts as shown in the most recent meta-analyses [9,10]. However, no significant differences were observed in 5-year patient and graft survival between the 2 groups, suggesting wider use of living-donor kidneys with MRA because of equivalent long-term outcomes.

The most difficult decision in renal transplantation with MRA is when to preserve or ligate polar arteries. It has been advocated to ligate the polar artery when it supplies less than 5–10% of renal parenchyma or its diameter is less than 2 mm on the basis of the assumption that long-term graft function will not be affected and the vascular reconstruction of these small branches could be responsible for a significant increased risk of arterial thrombosis [11–14]. Conversely, the ligation of arteries supplying the upper or lower pole in MRA grafts, which ranges from 1.6 to 20.5% [9], may be associated with a higher incidence of renal artery stenosis of the allograft [15,16].

At our center we try to preserve any polar artery, regardless of its location (upper or lower pole) to preserve as much renal parenchyma as possible and to maintain graft integrity. Here, we present our experience in complex surgical reconstruction of upper pole arteries (UPAs) in living-donor kidney transplantation.

Material and Methods

Between January 1, 2009 and December 31, 2019, a total of 922 living-donor kidney transplants was performed at the Miami Transplant Institute/Jackson Memorial Hospital, Miami, Florida, of which 880 (95.4%) were adult and 42 (4.6%) pediatric. The aim of the study was to identify exclusively the renal allografts with at least one UPA and to review the type of *ex vivo* reconstruction performed. Data were obtained from a prospectively maintained electronic database and complemented by review of recipient and donor operative notes. The study was approved by the University of Miami Institutional Review Board, and written informed consent was obtained from all subjects or a legal surrogate. The donor renal anatomy was delineated in the preoperative period through computed tomographic angiography (CTA). Because of anatomical reasons, the left kidney was generally procured except if a particular underlying reason justified the use of the right kidney. Among all the renal allografts with MRA, only 6 presenting 1 UPA were identified.

Study endpoints analyzed included the incidence of allograft vascular and urologic complications, slow graft function (SGF), delayed graft function (DGF), graft failure, and graft and patient survival. Vascular complications included graft arterial thrombosis, stenosis, and significant bleeding requiring surgical re-exploration, whereas urologic complications included urinary leaks, ureteral necrosis, and stricture. SGF was defined as a serum creatinine of 3.0 mg/dL or higher on postoperative day 5 but not requiring dialysis [17], whereas DGF was defined as the requirement of dialysis within the first postoperative week [18]. Graft failure was defined as the date of return to chronic dialysis, graft nephrectomy, or death with a functioning graft [19].

Surgical technique

All living-donor nephrectomies were performed using the hand-assisted laparoscopic technique. After removal from the donor, renal allografts were flushed with Custodiol HTK® solution until the efflux was clear. The recipient operation was performed using the standard extraperitoneal approach, and the right iliac fossa was the site for allograft implantation when possible.

Two renal allografts had a very short UPA; the recipient inferior epigastric artery (IEA) or the donor gonadal vein were used as an extension graft to perform an end-to-side anastomosis between the UPA and the main renal artery in running suture of 8-0 Prolene respectively (**Figures 1, 2**). In 3 renal allografts, a meticulous dissection of the main renal artery was carried out inside the hilum to identify a suitable hilar branch to conduct an end-to-side anastomosis with the UPA with running 7-0 or 8-0 Prolene (**Figure 3**).

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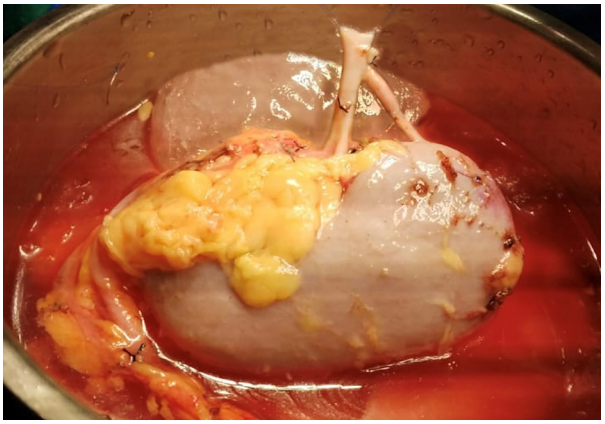

Figure 1. Reconstruction of upper pole artery using recipient internal epigastric artery as extension graft.

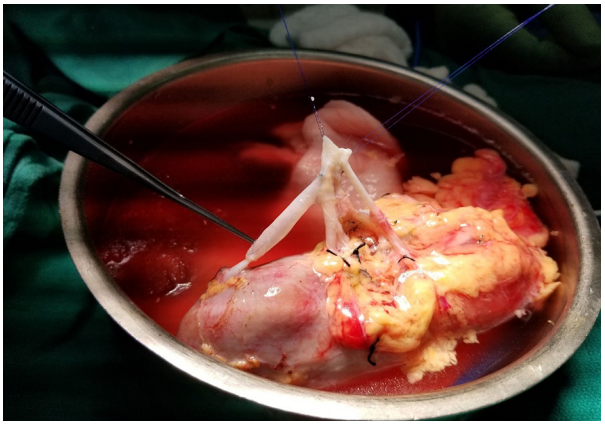

Figure 2. Reconstruction of upper pole artery using donor ovarian vein as extension graft and reconstruction of lower pole artery through side-to-side anastomosis with the main renal artery

In the last case, the UPA had a significant length and it was anastomosed directly with the main renal artery in a side-to-end fashion with running suture of 8-0 Prolene (**Figure 4**). A lower pole artery (LPA) was identified in 2 kidneys and they were anastomosed in an end-to-side manner or side-to-side (double-barreled) reconstruction, respectively, in running fashion manner with 8-0 Prolene (**Figure 3**).

Two other renal grafts were vascularized by 2 main arteries that were conjoined in a single large orifice, adopting the double-barreled reconstruction, with running 7-0 Prolene (**Figure 4**). The single renal artery and renal vein were anastomosed end-to-side to the external iliac artery and vein respectively, using 6-0 and 5-0 Prolene respectively. We performed an extravesical ureteroneocystostomy with 6-0 PDS.

Microsurgical arterial reconstruction was always performed through 3.5× magnification loupe.

Figure 3. End-to-side anastomosis between upper pole artery and one hilar branch of the main renal artery and end-to-side anastomosis between lower pole artery and the main renal artery

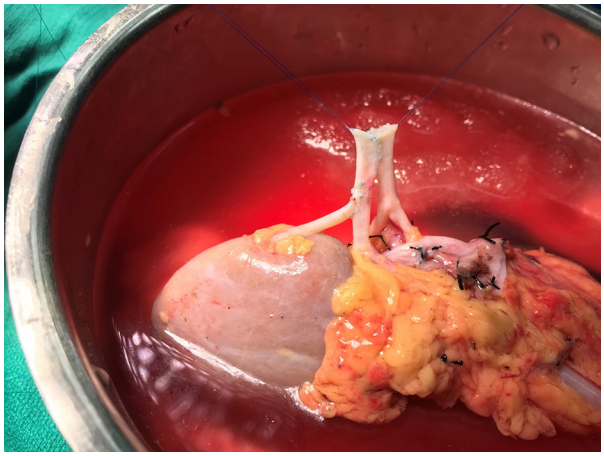

Figure 4. End-to-side anastomosis between upper pole artery and major trunk of the upper main renal artery and side-to-side anastomosis between the 2 dominant renal arteries.

All recipients received immunosuppressant therapy according to protocols at our center, with induction consisting of intravenous antithymocyte globulin 1 mg/kg, basiliximab 20 mg, and methylprednisolone 500 mg administered intraoperatively before organ reperfusion. Maintenance immunosuppression included a steroid-free regimen consisting of tacrolimus and mycophenolate mofetil, starting on postoperative day 1 [20].

After surgery and before hospital discharge, patients had daily measurements of serum blood urea nitrogen (BUN), creatinine, electrolytes, a complete blood count, and routine color-Doppler and gray-scale ultrasonography (US). In the presence of MRA, a specific request was made to evaluate and identify each single renal artery, including those reconstructed. If there was any doubt or suspicion on their patency during color-Doppler US, a contrast-enhanced ultrasound (CEUS) and a

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Table 1. Demographics of recipient and donor.

Recipient	Age (years)	Gender	BMI (kg/m²)	Etiology ESRD	Living donor	Age (years)	Gender	BMI (kg/m²)
1	59	M	30.8	HTN	Unrelated (wife)	52	F	25.7
2	57	M	28.1	DM	Unrelated (wife)	54	F	24.2
3	34	M	23.7	ANCA vasculitis	Related (sister)	30	F	22.1
4	57	M	26.4	DM/HTN	Unrelated (altruistic)	39	M	24.7
5	60	F	28.7	ADPKD	Related (son)	35	M	23.3
6	17	F	16.6	Kearns-Sayre syndrome	Related (mother)	41	F	22.5

BMI – body mass index; ESRD – end-stage renal disease; HTN – hypertension; DM – diabetes mellitus; ANCA – antineutrophil cytoplasmic antibodies; ADPKD – autosomal dominant polycystic kidney disease.

Table 2. Anatomy of the graft.

Recipient	Kidney	MA n	UPA diameter (mm)	UPA detected preoperatively	LPA	LPA diameter (mm)
1	Left	1	1.7	Yes	No	–
2	Right	1	2.2	Yes	No	–
3	Left	1	1.5	Yes	Yes	2
4	Left	2	1.9	No	No	–
5	Left	2	1.5	Yes	No	–
6	Left	1	2	No	Yes	2.5

MA – main artery; UPA – upper pole artery; LPA – lower pole artery.

Table 3. Types of arterial reconstruction.

Recipient	MA reconstruction	Suture	UPA reconstruction	Interposition graft and type	Suture	LPA reconstruction	Suture
1	–	–	End-to-side with hilar branch MA	No	Running Prolene 7-0	–	–
2	–	–	End-to-side with MA	IEA	Running Prolene 8-0	–	–
3	–	–	End-to-side with MA	Donor OV	Running Prolene 8-0	Side-to-side with MA	Running Prolene 8-0
4	Side-to-side	Running Prolene 7-0	End-to-side with MA	No	Running Prolene 8-0	–	–
5	Side-to-side	Running Prolene 7-0	End-to-side with hilar branch MA	No	Running Prolene 8-0	–	–
6	–	–	End-to-side with hilar branch MA	No	Running Prolene 8-0	End-to-side with MA	Running Prolene 8-0

MA – main artery; UPA – upper pole artery; LPA – lower pole artery; IEA – inferior epigastric artery; OV – ovarian vein.

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radionuclide imaging such as Tc-99m MAG_3 scan were performed [21,22].

After discharge, all patients were seen in the posttransplant clinic weekly for 3 months, then monthly throughout the first year posttransplant. Patients were seen in the posttransplant clinic once every 3 months thereafter, with urine analysis, serum BUN and creatinine levels, a complete blood count, and tacrolimus trough level measured at each clinic visit.

Results

Six patients with a single UPA were included in our study, making an incidence of 0.65% among all living donors. In 2 patients, this vessel was not detected preoperatively by CTA. In only 1 case, the right kidney was used because of the presence of a small complex cyst that was resected during preparation. The extemporaneous histologic examination was negative for neoplasm.

The mean (±SD) diameter of the UPA was 1.8 mm (±0.28). **Table 1** lists the demographic characteristics of both donor and recipient together with the etiology of chronic kidney disease, whereas **Tables 2 and 3** describe the anatomy of the graft and the types of arterial reconstruction adopted, respectively.

In these 6 patients who underwent surgical reconstruction of the UPA, we did not observe any vascular or urologic complications and no patient experienced SGF, DGF, or graft failure during a median (range) follow-up of 14.5 (9–49) months. The median (range) creatinine at 5, 14 and 30 days, 3 months, 6 months and 1 year after transplant was 1.7 (3.7–9.9), 1.5 (0.4–2.1), 1.3 (0.6–2.2), 1.1 (0.6–2.0), 1 (0.5–1.9), and 1.3 (0.8–1.7) mg/dL, respectively.

Discussion

We are reporting our experience of reconstructing UPAs during living-donor kidney transplantation. Between 2009 and 2019 there were 6 living-donor kidney transplant recipients that had such reconstruction, 0.65% of all living-donor kidney transplants performed at our center during this 11-year period. Our data show that this surgical approach does not negatively affect the clinical outcomes of these kidney transplants (i.e., no increased risk of arterial or urologic complications) and allows the preservation of integrity of the renal parenchyma.

In the past, the selection criteria of donors for kidney transplantation was very strict, and the presence of grafts with multiple arteries was considered a contraindication to proceed with transplant, particularly in the setting of living-donor kidney transplantation. However, MRA are found in 18% to 43% of potential kidney donors [23], and both kidneys can present MRA in up to 15–20% of donors [6]. Our series refers only to the group of renal allografts with UPAs and not to the entire population of MRA, thus explaining our lower reported incidence of MRA compared with the literature. The use of the Carrel aortic patch that allows graft harvesting with a common ostium can resolve this matter in most cases; obviously, this technique is not applicable in living-donor kidney transplantation.

The use of MRA kidneys has become necessary if the potential benefits of living donation are to be offered to more transplant candidates. The improvement in surgical techniques and the routine use of preoperative CTA with improved resolution that enables detection of thin polar arteries in living-donor kidneys results in better recognition of the vascular anatomy and a safer donor operation, explaining the reasons why MRA grafts are now used without hesitation [8].

Conversely, the use of these grafts is considered a potential risk factor that could impair the outcome of kidney transplant. Even if contradictory results have been reported in the literature [8,14,16,24], the most recent meta-analyses reported a higher incidence of vascular and urologic complications and DGF together with a lower 1-year graft survival when MRA kidneys are transplanted [9,10].

In addition, the strategy of dealing with polar arteries has not yet been clearly addressed, and the optimal thickness and diameter of accessory arteries used for reconstruction to preserve maximal graft function still remain controversial. Indeed, several factors must be considered. Although simple transection can lead to loss of a substantial amount of renal parenchyma perfused by the branch, a longer cold ischemia time for vascular reconstruction may cause acute kidney injury requiring early posttransplant 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. For all of these reasons, several reports empirically have used a 2-mm cutoff value for vascular reconstruction (*vs.* ligation of polar arteries) [11–13].

Concurrently, different approaches have been applied according to the type of polar artery. Whereas numerous studies have recommended the reconstruction of LPA branches to prevent ureteral complications such as leakage and stricture [8,16,24], very few reports have discussed the importance and safety of preserving *vs.* ligating upper pole vessels in living-donor kidney transplantation. In particular, one recent series recommends routinely ligating UPAs [13]. Indeed, though infarction of a small area of the upper pole (<10%) can occur with potential repercussions on the immediate postoperative kidney function of recipients, in the long term, no significant

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differences were observed in estimated glomerular filtration rate or serum creatinine concentration between the 2 groups analyzed: the arterial ligation group and the arterial reconstruction group. However, arterial complications and prolonged total ischemic time were reported in the second group. Although the safety of arterial reconstruction was established, the authors do not provide criteria and indications for arterial reconstruction and optimum techniques for this procedure, stating only that the mean diameter of the 27 UPAs ligated in their study was 1.82 mm [13].

Conversely, older reports describe an association between ligation of a polar artery and the development of late renal artery stenosis, without specifying if the branch was feeding the upper or lower pole [15]. Since no clear indications are given from the literature, our current strategy is to always conserve the UPA in living-donor kidney transplantation, aiming to preserve the entire renal parenchyma and minimize the risk of acute tubular necrosis.

Various techniques are used to revascularize multiple arteries depending on the anatomy or institutional or surgeon preference. At our center, in the presence of a narrow pole artery, this is generally placed on the side of the main artery. If the length of this branch does not allow it to reach the main artery, an interposition graft (recipient IEA or donor gonadal vein) is used, or the artery is directly anastomosed to one of the branches of the main renal artery at the hilum.

Our study presents 6 cases of living-donor kidney transplants during an 11-year period where a thin UPA with a mean diameter of only 1.8 mm was successfully reconstructed. Though the current literature generally poses a cutoff value of 2 mm for arterial reconstruction, suggesting upper pole branch ligation [11–13], in our series arterial reconstruction was carried out in presence of UPA of less than or equal to 2 mm. Preserving upper pole branches avoided the sacrifice of approximately 10% of renal parenchyma without observing subsequent vascular or urologic complications, postoperative hemorrhage requiring surgical re-exploration, arterial thrombosis or stenosis, or ureteral leak or stricture. At the same time, none of these 6 patients experienced SGF, DGF, or graft failure.

According to the literature, the best noninvasive imaging method to detect vascular complications after kidney transplantation is color-Doppler US, the sensitivity and specificity of which in identifying arterial thrombosis approximates 100% [21,22]. Therefore, our routine postoperative management includes serial color-Doppler US and if any doubt on patency of renal artery arises, a CEUS is performed [21]. In the 6 cases reported in our series, because of their complexity, a radionuclide imaging such as Tc-99m MAG_3 scan was always included in the standard postoperative radiologic evaluation and never showed any defect of perfusion.

Of interest, in 2 cases, the preoperative CTA was not able to detect the polar vessel that was identified only during donor surgery, suggesting that accessory vessels of such small caliber can elude the high accuracy of modern radiologic imaging [25,26].

Conclusions

Reconstruction of UPAs even with a cutoff diameter smaller than 2 mm is worth attempting regarding success rate and graft function, particularly with living-donor kidney transplantation.

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