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EARLY OUTCOMES OF LIVING-RELATED DONOR KIDNEY TRANSPLANTATION WITH MULTIPLE RENAL ARTERIES: A RETROSPECTIVE COHORT STUDY WITH AN MSCT-GUIDED ARTERIAL RECONSTRUCTION FRAMEWORK

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ABSTRACT

Multiple renal arteries increase the technical complexity of living-donor kidney transplantation. This retrospective single-center cohort compared fixed-time outcomes in 578 living-related donor kidney transplantations: 471 grafts had one renal artery and 107 had two or more. All donors underwent preoperative multislice computed tomography angiography with three-dimensional reconstruction, and reconstruction was individualized according to vascular anatomy. Because outcome events were sparse, two-sided Fisher exact tests and absolute differences in survival proportions with 95% confidence intervals were used. Multiple-artery grafts accounted for 18.5% of the cohort, and 101 of 107 had two arteries. Six-month graft survival was 97.9% for single-artery grafts and 97.2% for multiple-artery grafts (difference, -0.7 percentage points; 95% CI [-5.9, 1.9]; p = .716). Twelve-month graft survival was 96.2% and 96.3%, respectively (difference, 0.1 percentage points; 95% CI [-5.6, 3.2]; p = 1.000). Recipient survival showed no statistically detectable difference at 6 months (96.8% vs. 96.3%; p = .765) or 12 months (95.5% vs. 94.4%; p = .613). These unadjusted analyses do not establish equivalence or noninferiority. Selected multiple-artery living-donor grafts were feasible in this experienced center, but the proposed MSCT-guided planning framework and area-equivalent ostial diameter remain descriptive tools requiring further validation.

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Introduction

Living-donor kidney transplantation is an established treatment for patients with end-stage kidney disease and offers advantages that include elective planning, reduced waiting time, and favorable graft outcomes. Expansion of the living-donor pool, however, increases the likelihood of evaluating donor kidneys with variant vascular anatomy, including grafts with multiple renal arteries. Multiple renal arteries are common anatomical variants and have historically raised concern because they may require additional bench reconstruction or arterial anastomoses and may increase technical complexity (Lentine et al., 2017; Zorgdrager et al., 2016).

Contemporary evidence suggests that multiple renal arteries should not automatically exclude an otherwise suitable living donor. In a patient-level meta-analysis of 8,400 recipients, Lim et al. (2023) found

no statistically significant difference in overall survival or graft survival between single- and multiple-artery living-donor grafts. Single-center reports have likewise described acceptable outcomes when vascular reconstruction is performed by experienced transplant teams (Garcia et al., 2021; Roth et al., 2024). At the same time, the literature is not uniformly reassuring. A recent systematic review and meta-analysis found slightly lower 1-year graft survival and higher overall and vascular complication rates for multiple-artery grafts, although absolute differences were small and living-donor multiple-artery grafts remained clinically usable (George et al., 2026). These findings underscore the need to distinguish feasibility from formal equivalence and to evaluate vascular complications in addition to survival.

Preoperative vascular imaging is central to this decision process. Computed tomography angiography is widely used to define renal arterial number, origin, diameter, course, branching, and relationships to the renal vein, collecting system, and renal hilum (Aghayev et al., 2019). Such information is particularly important when an accessory or polar artery may supply functionally important renal parenchyma or contribute to ureteral perfusion. Surgical options include separate anastomoses, side-to-side or pantaloon reconstruction, end-to-side reconstruction, and other individualized ex vivo techniques, each selected according to the specific anatomy (Muharia et al., 2025; Roth et al., 2024).

The present study therefore had two related but distinct aims. The primary aim was to compare unadjusted 6- and 12-month graft and recipient survival proportions between living-related donor grafts with one renal artery and grafts with multiple renal arteries. The secondary aim was to describe the center's preoperative MSCT-based anatomical assessment, vascular planning framework, reconstruction patterns, and a geometric area-equivalent ostial diameter calculation used as a technical guide during common-ostium reconstruction. The planning framework and ostial calculation were treated as descriptive tools rather than validated predictors of clinical outcome.

Methods

Study Design and Setting

This retrospective single-center cohort study included 578 living-related kidney transplantations performed at the State Institution "Republican Specialized Scientific and Practical Medical Center of Surgery named after Academician V. Vakhidov." Recipients were divided into a single renal artery group (n = 471) and a multiple renal artery group (n = 107). Primary outcomes were graft and recipient survival at 6 and 12 months.

Ethical Considerations

Donor evaluation and transplantation were performed according to institutional and national requirements. Legal and psychological assessment was completed for all donors.

Donor Evaluation

Donors underwent clinical, laboratory, functional, imaging, legal, and psychological assessment. Selection criteria included adult age, acceptable body mass index, preserved renal function, and absence of diabetes mellitus, uncontrolled hypertension, autoimmune disease, active urinary infection, or other contraindications. Renal assessment included estimated glomerular filtration rate, urinalysis, proteinuria testing, and radionuclide split renal function when indicated (Lentine et al., 2017).

MSCT Angiography

All donors underwent preoperative multislice computed tomography angiography with three-dimensional reconstruction. Assessment included the number and diameter of renal arteries, bifurcation level, arterial length, distance between ostia, polar arteries, segmental perfusion territory, and relationships with the renal vein, ureter, and renal hilum. MSCT findings were used to plan separate anastomoses, common-ostium formation, or individualized ex vivo reconstruction.

Surgical Reconstruction

Bench reconstruction was performed under cold preservation using atraumatic vascular techniques. Separate anastomoses were preferred when arteries were widely separated, whereas side-to-side or

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pantaloon reconstruction was considered for closely positioned arteries. Three- and four-artery grafts were reconstructed using individualized 2+1, 1+1+1, or 2+2 strategies.

For combined arterial reconstruction, the area-equivalent ostial diameter was calculated as:

$D_eq = \sqrt{(d_1^2 + d_2^2)}$

This calculation was used as a morphometric guide rather than as a direct measurement of blood flow.

Descriptive Vascular-Anatomical Planning Framework

A four-level institutional planning framework was used to summarize anticipated technical complexity. Because the present study does not establish that the categories are mutually exclusive or predictive of outcomes, the framework is presented as a descriptive surgical planning aid rather than a validated risk score. Category-specific outcome analysis was not performed.

Table 1

Descriptive Vascular-Anatomical Planning Framework

Category	Arterial anatomy	Minimum diameter	Branching pattern	Planning implication
I	1 artery	>= 4 mm	Bifurcation > 1 cm from hilum	Low expected complexity; standard transplantation
II	2 arteries	2.5-4 mm	Near renal hilum	Moderate complexity; consider bench plasty and experienced vascular technique
III	2-3 arteries	2-3 mm	Intrahilar branching	High complexity; individualized ex vivo reconstruction by a specialized team
IV	>= 3 arteries	< 2 mm	Intrahilar or parenchymal branching	Very high complexity; multidisciplinary review, individualized protocol, consideration of contralateral kidney or nonuse

Note. The framework summarizes the institutional approach to vascular-anatomical planning. It has not been externally validated and should not be interpreted as a prognostic classification.

Surgical Strategy and Bench Reconstruction

The donor nephrectomy approach was selected according to donor anatomy, anticipated technical complexity, and institutional experience. Open retroperitoneal nephrectomy was preferred for the most complex arterial variants. After explantation, the graft was immediately perfused with cold preservation solution. In grafts with multiple arteries, each arterial lumen was perfused to assess patency and segmental perfusion. Bench reconstruction was performed under cold ischemic conditions using atraumatic handling, magnification, fine monofilament polypropylene sutures, and attention to avoiding stenosis, twisting, and tension.

For two arteries located sufficiently close to permit reconstruction without tension, side-to-side or pantaloon reconstruction could be considered; more widely separated arteries could be implanted separately. For three arteries, the center used either a 2+1 approach, in which two arteries were combined and the third implanted separately, or a 1+1+1 approach with three separate arterial anastomoses. For four arteries, the described approach paired upper and lower arterial branches into two reconstructed arterial complexes (2+2). These strategies should be interpreted as anatomy-dependent technical options rather than evidence that one technique is superior to another (Muharia et al., 2025).

Area-Equivalent Ostial Diameter

When two arterial lumens were combined into a common ostium, the reconstructed opening was assessed geometrically. Assuming circular cross-sections, the luminal area of an artery is $S = \pi(d^2)/4$. For two arteries, conservation of total cross-sectional area yields an area-equivalent diameter of $D_eq = \sqrt{(d_1^2 + d_2^2)}$. Thus, arteries measuring 4 mm and 3 mm correspond to an area-equivalent circular diameter of 5 mm. D_eq was treated as a morphometric area-equivalence calculation, not as a validated measure of

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hemodynamic adequacy. Actual flow depends on anastomotic geometry, vessel compliance, downstream resistance, and other factors. Clinical validation would require direct flow, Doppler, angiographic, or stenosis outcome data.

Statistical Analysis

Categorical variables were summarized as counts and percentages. Because the number of graft and recipient deaths or failures was small, two-sided Fisher exact tests were used for comparisons of survival status between the single-artery and multiple-artery groups at 6 and 12 months. Absolute differences in survival proportions were calculated as the multiple-artery proportion minus the single-artery proportion, with 95% confidence intervals estimated using the Newcombe method. Statistical significance was defined as $p < .05$. The analyses were unadjusted. No formal equivalence or noninferiority margin was prespecified; therefore, a nonsignificant result was interpreted only as failure to detect a difference and not as proof of equivalence. Time-to-event analyses were not performed.

Results

Distribution of Renal Arterial Anatomy

Among 578 living-related donor kidney transplantations, 471 grafts (81.5%) had one renal artery and 107 grafts (18.5%) had multiple renal arteries. Within the multiple-artery group, 101 grafts (94.4%) had two arteries, two grafts (1.9%) had three arteries, and four grafts (3.7%) had four arteries. Thus, the evidence from the multiple-artery cohort primarily reflects grafts with two renal arteries, whereas grafts with three or four arteries were uncommon.

Revascularization Patterns

Table 2

Distribution of Multiple-Artery Anatomy and Revascularization Strategies

Arterial anatomy	n/N of MRA (%)	Revascularization pattern	n within anatomy subgroup (%)
2 arteries	101/107 (94.4%)	1+1	101/101 (100.0%)
3 arteries	2/107 (1.9%)	2+1	1/2 (50.0%)
3 arteries	2/107 (1.9%)	1+1+1	1/2 (50.0%)
4 arteries	4/107 (3.7%)	2+2	4/4 (100.0%)

Note. MRA = multiple renal arteries. In the 1+1 and 1+1+1 patterns, arteries were implanted separately. In 2+1, two arteries were combined into a common ostium and the third was implanted separately. In 2+2, four arteries were reconstructed into two paired arterial complexes.

The predominance of 1+1 reconstruction is important for interpretation: 101 of 107 multiple-artery grafts (94.4%) had two arteries and were managed with separate arterial anastomoses. Consequently, the present cohort provides only limited clinical experience with common-ostium reconstruction and does not validate the area-equivalent ostial diameter calculation.

Graft and Recipient Survival Status

At 6 months, graft survival was 461 of 471 (97.9%) in the single-artery group and 104 of 107 (97.2%) in the multiple-artery group. The absolute difference was -0.7 percentage points (95% CI [-5.9, 1.9]), and Fisher's exact test did not detect a statistically significant difference ($p = .716$). At 12 months, graft survival was 453 of 471 (96.2%) and 103 of 107 (96.3%), respectively; the absolute difference was 0.1 percentage points (95% CI [-5.6, 3.2]; $p = 1.000$).

Recipient survival at 6 months was 456 of 471 (96.8%) in the single-artery group and 103 of 107 (96.3%) in the multiple-artery group, corresponding to a difference of -0.6 percentage points (95% CI [-6.2, 2.5]; $p = .765$). At 12 months, recipient survival was 450 of 471 (95.5%) and 101 of 107 (94.4%), respectively, corresponding to a difference of -1.1 percentage points (95% CI [-7.4, 2.6]; $p = .613$).

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Table 3

Unadjusted Fixed-Time Graft and Recipient Survival Outcomes

Outcome	Time	One artery n/N (%)	Multiple arteries n/N (%)	Difference, pp (95% CI)	Fisher p
Graft survival	6 mo	461/471 (97.9)	104/107 (97.2)	-0.7 (-5.9, 1.9)	.716
Graft survival	12 mo	453/471 (96.2)	103/107 (96.3)	0.1 (-5.6, 3.2)	1.000
Recipient survival	6 mo	456/471 (96.8)	103/107 (96.3)	-0.6 (-6.2, 2.5)	.765
Recipient survival	12 mo	450/471 (95.5)	101/107 (94.4)	-1.1 (-7.4, 2.6)	.613

Note. Difference is the multiple-artery survival proportion minus the single-artery survival proportion, expressed in percentage points (pp). Confidence intervals use the Newcombe method. p values are two-sided Fisher exact tests. Nonsignificant p values do not establish equivalence or noninferiority.

Illustrative Complex Reconstructions

Two complex reconstructions illustrate the institutional approach. One three-artery graft was implanted using three separate arterial anastomoses (1+1+1), with adequate early perfusion and no early thrombosis, stenosis, or segmental ischemia reported. One four-artery graft was reconstructed using a 2+2 strategy; cold ischemia time was 30 minutes and warm ischemia time was 42 minutes, with satisfactory early Doppler perfusion. These cases are presented as technical illustrations and do not provide comparative evidence regarding the safety or superiority of the reconstruction strategies.

Discussion

In this retrospective single-center cohort, no statistically detectable difference was observed in unadjusted graft or recipient survival proportions at 6 or 12 months between single-artery and multiple-artery living-related donor kidney grafts. The point estimates were close, but the confidence intervals were sufficiently wide to include clinically meaningful differences in either direction. Accordingly, these findings support feasibility in selected cases but should not be interpreted as proof of equivalence, noninferiority, or absence of an independent effect of arterial anatomy.

The direction of the present findings is broadly consistent with several living-donor studies. Garcia et al. (2021) reported no significant difference in postoperative complications, delayed graft function, renal function, or graft survival in a retrospective comparison of single- and multiple-vessel living-donor grafts. Roth et al. (2024) likewise reported acceptable short- and long-term outcomes after arterial vascular reconstruction in a specialized living-donor program. Most notably, Lim et al. (2023) pooled patient-level survival data from 14 studies and found no significant difference in overall survival or graft survival between single- and multiple-artery living-donor transplantation.

Nevertheless, the broader literature indicates that similar survival does not necessarily mean identical perioperative risk. Zorgdrager et al. (2016) found higher complication and delayed graft function rates and a small reduction in 1-year graft survival among multiple-artery grafts, although longer-term graft and patient survival were similar. George et al. (2026) similarly reported modestly lower 1- and 5-year live-donor graft survival and higher total and vascular complication rates in multiple-artery grafts. These data support a nuanced conclusion: multiple renal arteries are not an automatic contraindication, but they may increase technical and complication burdens that are not captured by survival proportions alone.

This distinction is especially relevant because outcomes in the present study were limited primarily to graft and recipient survival. Systematic comparative data were not available for delayed graft function, postoperative estimated glomerular filtration rate, arterial thrombosis, transplant renal artery stenosis, reintervention, ureteral complications, bleeding, ischemia times across both groups, or length of stay. These outcomes are clinically important in studies of multiple renal arteries. For example, Choudhary et al. (2024) identified ex vivo reconstruction of multiple renal arteries as an independent risk factor for

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clinically significant transplant renal artery stenosis in a matched case-control study, underscoring the value of dedicated vascular follow-up when reconstruction is required.

Preoperative MSCT angiography remains a rational component of donor planning because it characterizes arterial number, caliber, branching, and spatial relationships that determine the feasibility of nephrectomy and implantation (Aghayev et al., 2019). The present study, however, cannot establish the diagnostic accuracy or outcome benefit of MSCT itself because every donor underwent the same imaging pathway and no reference-standard or alternative-imaging comparison was performed. The imaging component should therefore be interpreted as a description of the center's planning process, not as a comparative evaluation of MSCT efficacy.

The four-level vascular-anatomical framework has a similar status. It may help organize anatomical features that increase technical complexity, but the current data do not establish category reliability, calibration, discrimination, or association with complications. The category definitions contain potentially overlapping combinations of arterial number, diameter, and branching level. Future validation should prospectively define mutually exclusive assignment rules, assess interobserver agreement, and correlate categories with operative time, ischemia time, vascular and urological complications, graft function, and long-term outcomes.

The area-equivalent ostial diameter calculation is mathematically sound as a conservation-of-area relationship. For two circular lumens, $D_eq = \sqrt{(d_1^2 + d_2^2)}$ gives the diameter of a circle having the same total cross-sectional area. Its clinical meaning should not be overstated. Hemodynamic performance is also influenced by local geometry, suture configuration, branching angle, vessel compliance, pressure gradient, and downstream resistance. The present cohort offers very limited exposure to common-ostium reconstruction because 94.4% of multiple-artery grafts had two arteries and were implanted as separate anastomoses. The calculation is therefore best considered a hypothesis-generating morphometric aid until linked to Doppler velocities, computed tomography findings, pressure/flow measurements, stenosis, or graft perfusion outcomes.

Accessory polar arteries also require anatomy-specific judgment. Lower-pole arterial branches may contribute to ureteral blood supply and therefore warrant particular caution during donor nephrectomy and implantation, consistent with guideline principles for living-donor evaluation and preservation of clinically important arterial supply (Lentine et al., 2017). The present study does not validate a universal diameter threshold for accessory-artery ligation. Decisions regarding sacrifice or reconstruction should integrate diameter, perfusion territory, location, and the anticipated effect on renal parenchymal and ureteral perfusion.

Limitations

This study has several important limitations. First, its retrospective single-center design limits causal inference and generalizability. Second, the study period and completeness of consecutive case ascertainment were not reported, limiting assessment of temporal context and selection. Third, baseline donor and recipient characteristics were not available for adjusted analysis, and residual confounding therefore cannot be excluded. Fourth, time-to-event analyses were not performed; outcomes were evaluated at fixed 6- and 12-month points. Fifth, the number of grafts with three or four renal arteries was very small, preventing reliable subgroup comparisons of complex reconstruction strategies. Sixth, follow-up was limited to 12 months. Seventh, clinically relevant secondary outcomes—including delayed graft function, renal function, vascular and urological complications, stenosis, and reintervention—were not systematically analyzed. Finally, the proposed planning framework and area-equivalent ostial diameter were not prospectively or externally validated.

Clinical Implications and Future Research

The current data support continued consideration of living-related donor kidneys with multiple renal arteries when donor selection, imaging, and vascular expertise are appropriate. Future work should

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prospectively capture donor and recipient baseline variables, exact arterial measurements, operative and ischemia times, reconstruction technique, serial renal function, Doppler parameters, vascular and urological complications, and time-to-event outcomes. A larger multicenter cohort would allow validation of an anatomy-based planning model and evaluation of whether measured reconstructed ostial area or diameter predicts transplant renal artery stenosis or segmental hypoperfusion.

Conclusion

In this single-center retrospective cohort of 578 living-related donor kidney transplantations, 107 grafts had multiple renal arteries. Unadjusted graft and recipient survival proportions at 6 and 12 months did not show a statistically detectable difference between single- and multiple-artery groups. These findings support the feasibility of selected multiple-artery grafts in an experienced center but do not establish equivalence, noninferiority, or an independent absence of risk. MSCT-based anatomical assessment and individualized reconstruction are clinically plausible components of surgical planning, whereas the proposed vascular-anatomical framework and area-equivalent ostial diameter should be regarded as descriptive tools requiring prospective validation. Future analyses should incorporate baseline covariates, time-to-event methods, graft function, and vascular and urological complications.

Data Availability

The datasets analyzed during the current study are available from the corresponding author upon reasonable request, subject to institutional and ethical requirements.

Author Contributions

Conceptualization: A. S. Suyumov and Z. T. Matkarimov. Surgery and clinical management: A. S. Suyumov, Z. T. Matkarimov, and M. O. Rustamov. Data collection: M. O. Rustamov. Statistical analysis: A. S. Suyumov and Z. T. Matkarimov. Writing - original draft: A. S. Suyumov and Z. T. Matkarimov. Writing - review and editing: all authors. All authors read and approved the final manuscript.

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