Multiple renal artery reconstruction in high-volume living donor kidney transplant centre

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Abstract:

Kidney transplantation (KT) is the most effective treatment for end-stage renal disease; however, certain challenges (e.g. multiple renal arteries) may lower outcomes. We aimed to describe a single-centre experience with reconstruction techniques and outcomes. This retrospective study included 82 patients who underwent KT with multiple renal arteries out of a total of 762 cases between April 2018 and August 2022, with demographic data and renal vessel characteristics collected. The main outcomes were operation time, graft function, complications, and graft survival, and these were compared with a single-artery control group. Most patients had two arteries (82.9%). There were significant differences in warm ischemic time, reconstruction time for arterial anastomosis, and overall operation time compared with the control group ($p<0.05$). One patient (1.2%) developed a pseudoaneurysm requiring reoperation, with no grade 4 or higher complications. Graft function remained stable, and no patients experienced graft failure. The efficacy and safety of KT in patients with multiple renal arteries were acceptable.

Keywords: **kidney transplantation, multiple renal arteries, outcomes, reconstruction.**

Classification numbers: **3.2, 3.6**

1. Introduction

Kidney transplantation has significantly enhanced survival rates and quality of life for patients with end-stage renal disease (ESRD) [1]. The increasing demand for kidney transplants has made living donor KT (LDKT) a favourable solution, particularly prevalent in Asian countries. The advent of minimally invasive living donor nephrectomy has revolutionised this field. Recent data indicate that graft survival rates can reach 90% at five

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years and 70% at ten years post-transplantation [2]. Our centre has performed KT since 2000, with laparoscopic intraperitoneal nephrectomy introduced in 2016. Annually, we conduct 200-250 kidney transplants, with 90% sourced from living donors, classifying us as a high-volume centre [3]. Multiple renal arteries (RAs), present in 18-25% of donors, pose significant challenges due to the need for intricate vascular reconstruction, prolonged warm ischaemic time, and extended operative duration [4, 5]. Inadequate experience may cause thrombosis or stenosis and adversely affect long-term graft survival. Several techniques have been well described in the literature, demonstrating promising short- and long-term graft survival [6-9]. This study aims to delineate our systematic approach to managing up to four RAs, evaluating surgical techniques and immediate post-transplant outcomes.

2. Materials and methods

2.1. Study population

This retrospective study included patients who underwent KT with multiple renal arteries from living donors at Viet Duc University Hospital between April 2018 and August 2022. The study received ethical approval from the Institutional Ethical Review Board (No. 01.2024.NCVĐ).

2.2. Study design

A retrospective cohort study was conducted, recruiting patients who underwent KT with multiple renal arteries (MRA) and comparing their outcomes with those who underwent KT with a single renal artery (control group). The study excluded deceased-donor KT, KT with venous reconstruction, and patients with severe comorbid conditions. The kidney with higher scintigraphy values was preserved for the donor. Data were compared with a control group of single renal artery KT cases performed between January and May 2019 by the same surgeon. All procedures were performed by a single surgeon with ten years of experience in vascular surgery. For HLA matching <3/6, basiliximab was used for induction. Maintenance immunosuppression included prednisolone, mycophenolate mofetil (MMF), and tacrolimus, with target trough levels maintained at 8-10 ng/ml. Colour Doppler ultrasound was routinely performed on postoperative days 2 and 4, and additionally if clinically indicated. If serum creatinine levels increased and ultrasound revealed abnormal findings, corticosteroid bolus therapy or biopsy was considered. Anticoagulation was not routinely applied.

2.3. Data collection, outcomes, and definitions

Baseline characteristics collected included age, gender, haemodialysis status, graft site, and history of previous KT. Technical parameters included vessel characteristics (number, length, and diameter), type of reconstruction in cases with multiple vessels (single common orifice or separate implantation), with the first vessel defined as the largest main artery and subsequent vessels numbered from top to bottom. Warm ischaemic time (from removal from cold storage to reperfusion), vessel reconstruction time, and total operation time were recorded. Complications were documented and graded using the Clavien-Dindo

classification, including ureteric stricture, vascular complications (bleeding, pseudoaneurysm, thrombosis), and medical complications (acute allograft rejection, slow graft function, delayed graft function). Postoperative outcomes, including length of hospital stay, postoperative kidney function, and graft survival, were also documented.

2.4. Surgical technique

The management algorithm for multiple renal arteries is detailed in Fig. 1. During bench surgery, the perfusion zone of each artery was assessed, and the diameter and length of each vessel were measured. Side-to-side reconstruction was preferred when arterial diameters and lengths were comparable (Fig. 1). For small-diameter arteries, even after post-dilatation, the inter-arterial distance was evaluated; reconstruction was performed if the distance permitted safe anastomosis, otherwise separate anastomoses were performed. In rare instances, when the upper pole artery diameter was minimal, and its perfusion area was less than 10%, ligation was undertaken (Fig. 2). Anastomoses were performed using continuous 6/0 or 7/0 Prolene sutures under 2.5× magnification surgical loupes to ensure precision.

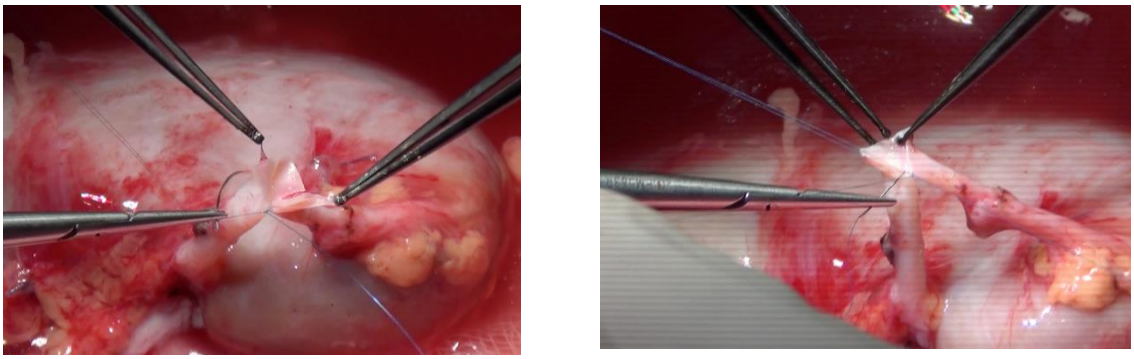

Fig. 1. Reconstruction technique in benchwork.

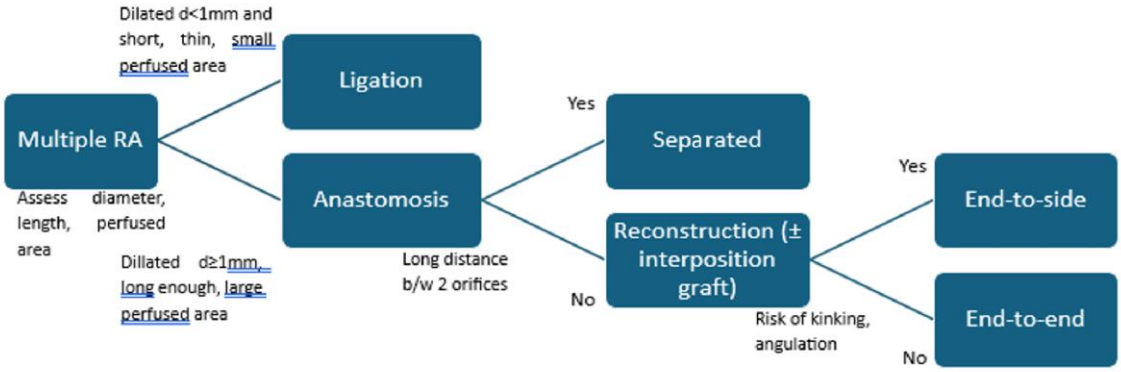

Fig. 2. Management algorithm for multiple renal arteries.

2.5. Data analysis

The data were collected and analysed using IBM SPSS version 20.0 software. Percentages were used for categorical variables and mean±SD for continuous variables. A two-tailed p-value<0.05 was considered statistically significant. Graft survival was analysed using the Cox regression model.

3. Results

Of the 762 kidney transplantations (KTs) performed, 95 patients (12.5%) with multiple renal arteries (MRAs) underwent KT, with 82 patients providing comprehensive data for analysis. The mean follow-up duration was 58±33.9 months, with no graft loss observed. A total of 75.6% of patients were in the 18-50 age group, with a male-to-female ratio of 1.93:1. In addition, 82.9% of patients were on haemodialysis prior to transplantation, with no cases of retransplantation; there was no significant difference compared with the control group (Table 1).

Table 1. Baseline characteristics.

Characteristics	MRA (n=82)	Control (n=59)	p-value
Age			
- <18	1 (1.2)	1 (1.7)	0.034
- 18-50	62 (75.6)	54 (91.5)	
- ≥50	19 (23.2)	4 (6.8)	
Sex			
- Male	54 (65.9)	42 (71.2)	0.50
- Female	28 (34.1)	17 (28.8)	
Haemodialysis (%)	68 (82.9)	49 (83.1)	0.98
Retransplant (%)	0 (0)	0 (0)	-
Donor graft site			
- Right kidney	57 (69.5)	33 (55.9)	0.1
- Left kidney	25 (30.5)	26 (44.1)	

Regarding graft vessels, most patients (82.9%) had a single renal vein, with a smaller subset presenting two (15.9%) or more veins (1.2%). There was no significant difference in the mean lengths and diameters of the first renal vein (2.43 and 1.27 cm vs 2.17 and 1.17 cm) or the second renal vein (1.77 and 0.89 cm vs 1.5 and 1.0 cm), respectively (p>0.05). For cases with two arteries, a single reconstructed orifice was preferred, while for three arteries, one reconstructed and one separate orifice was more common (Fig. 2, Table 2). Two patients had four arteries, in whom reconstruction was performed using two anastomoses. (Fig. 3).

Table 2. Operation characteristics, complications, and long-term graft survival.

Characteristics	MRA (n=82)	Control (n=59)	p-value
No. of renal vein			
- 1 vein	68 (82.9)	57 (96.6)	
- 2 veins	13 (15.9)	2 (3.4)	-
- >2 veins	1 (1.2)	0 (0)	
Renal vein length (mean±SD) (cm)			
- 1st RV	2.43±0.98	2.17±0.65	0.08
- 2nd RV	1.77±0.67	1.50±0.0	0.59
- 3rd RV	4.0±0.0	-	-
Renal vein diameter (mean±SD) (cm)			
- 1st RV	1.27±0.34	1.17±0.20	0.06
- 2nd RV	0.89±0.40	1.0±0.0	0.80
- 3rd RV	0.4±0.0	-	-
Renal artery length (mean±SD) (cm)			
- 1st RA	3.10±0.61	3.61±0.66	<0.001
- 2nd RA	3.10±0.79	-	-
- 3rd RA	2.75±1.03	-	-
- 4th RA	3.75±0.25	-	-
Renal artery diameter (mean±SD) (cm)			
- 1st RA	0.44±0.10	0.44±0.09	0.71
- 2nd RA	0.25±0.10	-	-
- 3rd RA	0.29±0.22	-	-
- 4th RA	0.20±0.10	-	-
No. of renal arteries and reconstruction (%)			
- Two arteries (n=68)	42 (61.8)	-	-
o Common orifice	26 (38.2)		
o Separated			
- Three arteries (n=12)	2 (16.7)		

o Common orifice o One common orifice, one separated - Four arteries in two common orifices (n=2)	10 (83.3) 2 (100)		
Iliac atherosclerosis	1 (1.2)	0 (0)	-
Inverted KT	18 (21.95)	0 (0)	-
Warm ischemic time (mins)	42.76±10.01	30.93± 7.27	<0.001
Arterial reconstruction time (mean±SD) (mins)	28.84±10.05	25.2±8.87	0.04
Total reconstruction time (mean±SD) (mins)	34.25±7.74	26.72±6.34	<0.001
Operation time (mins)	201.22±48.38	171.10±34.94	<0.001
Complications (%)			
- Slow graft function	13 (15.8)	9 (15.3)	-
- Delayed graft function	0 (0)	0 (0)	
- Acute rejection	2 (2.4)	2 (3.4)	
- Graft loss	0 (0)	0 (0)	
- Pseudoaneurysm, requiring reoperation	1 (1.2)	0 (0)	
- RA stenosis	0 (0)	0 (0)	
- Surgical site infection	1 (1.2)	0 (0)	
Clavien-Dindo classification			
- Grade 1, 2	3 (3.7)	2 (3.4)	
- Grade 3	1 (1.2)	0 (0)	-
- Grade 4, 5	0 (0)	0 (0)	
Post-op creatinine (µmol/l) (median (IQR))			
- Day 1	600 (400)	568.3 (333)	0.69
- Day 3	147.4 (115)	122.8 (81)	0.013
- Day 5	120.2 (56)	110.4 (55)	0.30
- Day 7	113 (47)	108 (51)	0.64
Hospital stays (days)	16.06±8.69	19.85±14.80	0.06
Graft survival	82 (100)	59 (100)	-

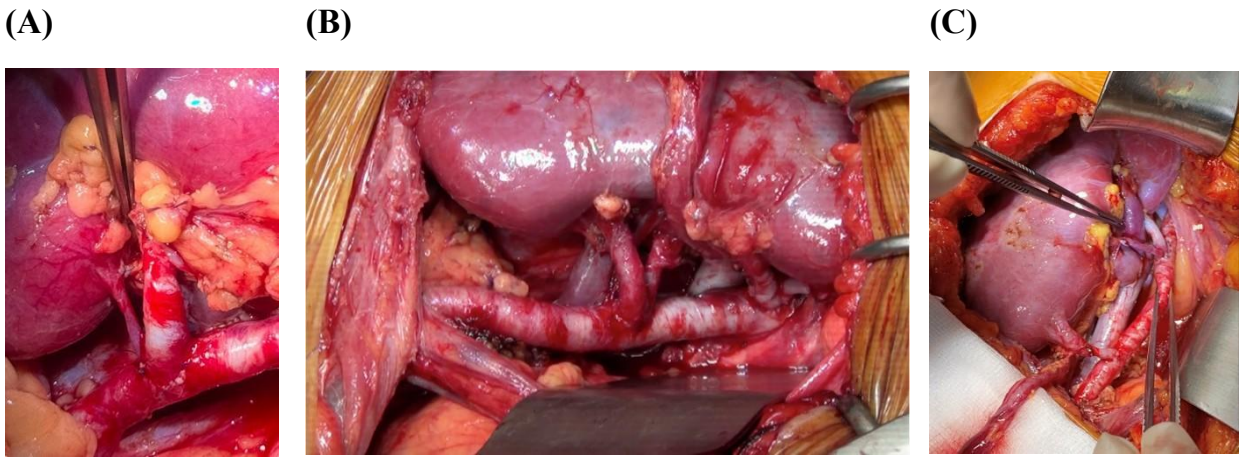

Fig. 3. Reconstruction for multiple renal arteries. (A) Two arteries, **(B)** Three arteries, **(C)** four arteries.

The mean warm ischaemic time was 42.76±10.01 minutes, and the mean operation time was 201.22±48.38 minutes, ensuring graft viability, although both were significantly higher than in the control group (30.93±7.27 and 171.1±34.94 minutes, respectively). Reconstruction times for arterial anastomoses were also longer (28.84±10.05 vs 25.2±8.87 minutes, $p<0.05$).

Complication rates were low, with no delayed graft function or graft loss reported. Acute rejection (treated with bolus corticosteroids, without biopsy confirmation) occurred in 2.4% of cases, while pseudoaneurysm requiring reoperation and surgical site infection were each observed in 1.2% of patients. A total of 3.7% of patients experienced Grade I-II complications, with no severe complications documented. Postoperative serum creatinine levels showed a significant decrease over the first week, although improvement was slower on day 3 compared with the single-artery group, and remained stable thereafter. There was no difference in postoperative creatinine levels between the separate and common orifice groups (Table 3). The average postoperative hospital stay was 16.06±8.69 days. No graft failure occurred during outpatient follow-up.

Table 3. Renal function classified by reconstruction techniques.

Post-op creatinine (μmol/l) (median (IQR))	**Two arteries**		**Three arteries**		**Four arteries**
	Common	***Separated***	***Common***	***Common + Separated***	
Day 1	630.8 (509)	600 (266)	843.5	463.1 (735)	281.9
Day 3	156.4 (118)	138.3 (85)	553.5	136 (266)	140.7
Day 5	125.8 (50)	119.3 (48)	411.5	114.4 (107)	83.8
Day 7	120 (53)	110.5 (35)	231.5	107.9 (77)	83.9

*$p>0.05$

4. Discussion

Historically, MRAs were considered a relative contraindication for KT due to technical complexities. Recent studies have elucidated strategies to address these challenges, demonstrating favourable outcomes. We provide insight into the efficacy of these surgical techniques and their implications for graft survival. The observed graft survival rates suggest that, with meticulous surgical planning, the presence of multiple arteries does not compromise short- or long-term success. However, the risk of vascular complications highlights the need for ongoing advancements in surgical techniques and postoperative care protocols. These findings emphasise the importance of individualised patient assessment and tailored surgical approaches to optimise outcomes. The exact benchwork time was not fully collected; however, in the case involving four arteries, the time reached 45 minutes. We favour bench reconstruction over separate anastomoses when vessel anatomy permits. However, there are no data demonstrating the superiority of one technique over another [10, 11]. In cases of significant vessel calibre disparity, separate anastomoses were preferred, aligning with practices reported by other centres. The complication rate was slightly lower compared with other studies, and our data also showed comparable outcomes relative to conventional KT. Owing to the renal blood supply, ligation of an artery may cause ischaemia in the corresponding region. Therefore, this was performed only when the artery was very small (<1 mm), of insufficient length for reconstruction, and supplied less than 10% of the renal parenchyma [12].

Because of the segmental nature of the renal blood supply, ligation of small accessory arteries may risk segmental ischaemia in the corresponding renal parenchyma. There is concern that ligation of an inferior artery could cause infarction or urinary leakage due to inadequate ureteral blood supply; however, this has rarely been reported in the literature [13]. Comprehensive preoperative imaging and preservation of peri-ureteric tissue are critical to minimising risks such as urinary leakage [14]. Although no arteries required ligation in our study, this approach was considered only when the artery was too small (<1 mm) after dilatation, had insufficient length for reconstruction, and the affected area was minimal. Doppler ultrasound and serial postoperative creatinine monitoring were employed to assess graft perfusion, despite our hospital stay (16.06±8.69 days) exceeding global benchmarks due to extended rehabilitation and follow-up protocols.

In our study, no cases of transplant renal artery stenosis (TRAS) were observed, whereas D. Choudhary, et al. (2024) [9] reported an overall TRAS incidence of 1.14% in cases where *ex vivo* vascular reconstruction was performed. Vascular complications were minimal in our cohort (1.2% pseudoaneurysm, no thrombosis), lower than the 5.6% partial arterial thrombosis reported in end-to-side reconstructions [15]. Mechanisms contributing to higher risks in prior studies include intimal hyperplasia in reconstructed vessels, as well as thrombus propagation leading to chronic ischemia and fibrosis in end-to-side approaches [9].

There may be concern that prolonged operation time and warm ischaemic time could adversely affect outcomes; however, advances in vascular techniques have largely mitigated these effects, resulting in comparable outcomes. A meta-analysis of MRA KT revealed that, although MRA grafts are associated with higher complication rates and delayed graft function compared with single renal artery (SRA) grafts, long-term graft and patient survival are comparable. Specifically, MRA grafts demonstrated a 13.8% complication rate, compared with 11% for SRA grafts, and a delayed graft function rate of 10.3%, compared with 8.2% in the single-artery group. Despite these challenges, 5-year graft survival rates were similar, underscoring the importance of advanced surgical techniques and individualised patient care in achieving successful outcomes [8, 16]. Nevertheless, MRA grafts should not be routinely preferred owing to longer nephrectomy, benchwork, and surgical times.

Our study proposes a management algorithm for KT involving multiple renal arteries. Although many studies have been published, most focus on individual techniques rather than a comprehensive algorithm for these scenarios [7, 17-19]. These findings support the broader adoption of MRA grafts in clinical practice, potentially improving the quality of life for patients with end-stage renal disease. Limitations of this study include its retrospective design, which may introduce bias, and the modest sample size (n=82), limiting generalisability. Future prospective studies with larger cohorts and randomised controlled trials are warranted to validate these findings and further elucidate factors influencing outcomes in MRA transplantation.

5. Conclusions

Multiple renal artery grafts, when managed with meticulous bench reconstruction by experienced surgeons in specialised centres, can provide acceptable short-term outcomes. The efficacy and safety of KT in patients with multiple renal arteries were satisfactory. Although the procedure can be successfully performed, it should be undertaken in specialised centres. Long-term outcomes, particularly regarding the incidence of TRAS and rejection, require ongoing surveillance and reporting.

CRediT author statement

Khai Ninh Viet: Conceptualisation, Study design, Writing - Original draft preparation, Follow-up; Dang Do Hai: Data collection, Writing - Original draft preparation, Follow-up; Tuan Hoang: Surgical assistance, Data collection, Formal analysis, Writing - Reviewing and Editing; Trung Nguyen Duc: Formal analysis, Writing - Reviewing and Editing; Hung Duong Duc: Surgical procedure, Conceptualisation, Methodology, Writing - Reviewing and Editing.

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This study was approved by the Institutional Ethical Review Board (No. 01.2024.NCVĐ).

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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