Open Access

OBM Transplantation

LIDSEN Publishing Inc.

Review

Clinical Outcomes of Living-Donor Kidney Transplants with Multiple Renal Arteries Compared to Single Renal Artery: A Systematic Review and Meta-Analysis

Aqshal Radiva Eryadana [1], Eriawan Agung Nugroho [2,*], Muhammad Kemal Thariq Ibrahim [1], Pande Made Wisnu Tirtayasa [3], Ardy Santosa [4], Mohamad Adi Soedarso [4], Nanda Daniswara [4], Sofyan Rais Addin [4], Dimas Sindhu Wibisono [5], Fandy Wicaksono [5], Donny Austine Wibisisono [5]

1. Urology Resident, Faculty of Medicine Universitas Diponegoro, Semarang, Indonesia; E-Mails: aqshalradiva@gmail.com; kemalibrahimlasy@gmail.com
2. Transplantation Consultant Urologist, Urology Division, Department of Surgery, Dr. Kariadi General Academic Hospital, Semarang, Indonesia; E-Mail: eriawanspu@gmail.com
3. Transplantation Consultant Urologist, Department of Urology, Universitas Udayana Teaching Hospital, Faculty of Medicine Universitas Udayana, Bali, Indonesia; E-Mail: wisnu_tirtayasa@unud.ac.id
4. Urology Division, Department of Surgery, Dr. Kariadi General Academic Hospital, Faculty of Medicine Universitas Diponegoro, Semarang, Indonesia; E-Mails: sant44@yahoo.com; drsoedarso@gmail.com; uronanda@gmail.com; sor.urology@gmail.com
5. Department of Urology, Diponegoro National Academic Hospital, Faculty of Medicine Universitas Diponegoro, Semarang, Indonesia; E-Mails: dsw.urology@gmail.com; fandy.urologist@gmail.com; donnyaustine@gmail.com

* **Correspondence:** Eriawan Agung Nugroho; E-Mail: eriawanspu@gmail.com

Academic Editor: Maurizio Salvadori

Special Issue: Renal Transplantation

OBM Transplantation
2026, volume 10, issue 3
doi:10.21926/obm.transplant.2603274

Received: May 24, 2026
Accepted: August 16, 2026
Published: August 25, 2026

Abstract

Multiple renal arteries in living-donor kidney transplantation create technical challenges, but their effect on clinical outcomes is unclear. This review assessed whether grafts with multiple

renal arteries differ in short-term outcomes compared with single renal artery grafts. Following PRISMA 2020 guidelines and PROSPERO registration, a systematic search of PubMed, Embase, Scopus, Web of Science, and Cochrane CENTRAL was conducted from database inception until 31 October 2025. Studies published from January 2020 to 31 October 2025 that met the eligibility criteria were included to capture contemporary living-donor kidney transplantation practice. Comparative studies of adult living-donor kidney transplant recipients receiving multiple renal arteries versus single renal artery grafts were included. Primary outcomes were delayed graft function, 1-year graft and patient survival, and 12-month estimated glomerular filtration rate. Secondary outcomes included vascular and urological complications. Random-effects meta-analyses were performed, and certainty of evidence was assessed using GRADE. Ten studies (≈2,105 recipients; ≈600 MRA, ≈1,500 SRA) met inclusion criteria. However, only a limited subset of studies contributed to individual quantitative analyses, with three studies available for delayed graft function analysis and four studies for graft survival and estimated glomerular filtration rate outcomes. Multiple renal arteries were not associated with increased delayed graft function (RR 1.23; 95% CI 0.24-6.22) or inferior 1-year graft survival (RR 1.03; 95% CI 0.51-2.07). The interpretation of pooled estimates is limited by the small number of contributing studies, low event rates, and imprecision of confidence intervals. Living-donor kidney transplantation using grafts with multiple renal arteries appears to have comparable short-term outcomes to single-renal-artery grafts; however, the available evidence remains limited by the small number of comparative studies, retrospective designs, and imprecision of pooled estimates. Further large-scale prospective studies are required to confirm these findings.

Keywords
Kidney transplantation; living donor; multiple renal arteries; single renal artery; graft survival

1. Background

Kidney transplantation remains the gold standard therapy for patients with end-stage renal disease (ESRD), offering superior survival, quality of life, and cost-effectiveness compared to dialysis [1, 2]. Over the past decades, living-donor kidney transplantation (LDKT) has become increasingly important to overcome organ shortage and reduce waiting-list mortality [3, 4]. However, anatomical variations in renal vascular supply, particularly multiple renal arteries (MRA), present technical challenges and raise concerns about posttransplant outcomes [5-7].

An accessory or extra renal artery may necessitate more complex back-table preparation, vascular reconstruction (e.g., patching, pantaloon, Y-grafts, or sequential anastomoses), and may prolong both warm and cold ischemia times [8, 9]. These complexities could theoretically increase the risk of delayed graft function (DGF), vascular thrombosis, renal artery stenosis, or impaired graft perfusion [10, 11]. Earlier cohort studies reported conflicting results: some found increased complication rates in MRA grafts, whereas others reported noninferior outcomes when managed carefully [12].

In the context of living-donor transplantation, donor vascular quality is generally better, cold ischemia times are minimal, and surgical teams can plan reconstructions. Several more recent observational studies suggest that grafts with MRA may achieve comparable short-and long-term function and survival to single-artery (SRA) grafts, provided that surgical technique is meticulous. For example, a retrospective cohort from 2019-2023 comparing single, fully preserved multiple, and sacrificed (non-reimplanted) accessory arteries in 251 LDKT cases found no significant difference in early complications or 12-month estimated glomerular filtration rate (eGFR) across groups. Another matched case-control investigation raised the possibility that certain ex vivo vascular reconstructions of MRA might increase the risk of clinically relevant transplant renal artery stenosis (cTRAS) in long-term follow-up. Moreover, a 2024 Polish study reported one-year graft survival rates of 93.2% in the MRA group vs 94.5% in the SRA group, without significant differences in early graft function [13, 14].

Nonetheless, the literature remains heterogeneous in definitions, reconstruction techniques, follow-up durations, and the extent to which confounding has been addressed. A recent review of vascular reconstructions in LDKT has cautioned that reported higher complication rates and lower short-term graft survival associated with MRA may reflect selection bias or older surgical eras rather than intrinsic risk [15]. Meanwhile, emerging reports address the impact of specific reconstruction methods: a 2025 Japanese series comparing end-to-side reconstruction for two renal arteries found a higher incidence of delayed graft recovery in that subgroup. Also, a 2025 retrospective urology series argued that ligation of small accessory arteries may not adversely affect overall outcomes in LDKT, except for mildly increased reoperation rates [16, 17]. These mixed findings underscore the need for systematic, quantitative synthesis of contemporary evidence.

Previous systematic reviews have evaluated the influence of MRA on kidney transplantation outcomes; however, several limitations remain. The 2016 review published in Annals of Transplantation primarily included earlier surgical eras, heterogeneous donor populations, and studies performed before widespread adoption of contemporary laparoscopic donor nephrectomy and advanced vascular reconstruction strategies. More recently, a 2023 patient-level meta-analysis in Clinical Transplantation provided valuable individual-level evidence but included mixed transplant settings and focused on broader transplant populations rather than exclusively contemporary living-donor kidney transplantation.

The present systematic review aims to provide an updated assessment by focusing specifically on living-donor kidney transplantation performed in the modern era (2020-October 2025), incorporating recent advances in vascular reconstruction, donor selection, and perioperative management. In addition, this review evaluates contemporary outcomes including DGF, graft survival, renal function, and vascular/urological complications while applying GRADE methodology to assess the certainty of the evidence.

2. Materials and Methods

2.1 Protocol and Registration

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [18-20]. The review protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the identifier [1110538].

2.2 Eligibility Criteria

Studies were eligible if they included adult recipients undergoing living-donor kidney transplantation and reported comparative outcomes between grafts with MRA and SRA grafts. When studies included both living and deceased donor populations, they were eligible only if outcomes for living-donor kidney transplantation could be clearly extracted or if living donors constituted the predominant cohort. Non-comparative studies, case series without an SRA comparator, and studies lacking extractable outcome data were excluded from quantitative synthesis but could be considered for qualitative discussion. Studies published before January 2020 were excluded because this review was to evaluate contemporary surgical practice and outcomes after living-donor kidney transplantation using modern reconstruction techniques.

2.3 Information Sources and Search Strategy

A comprehensive and systematic literature search was conducted to identify studies evaluating the clinical outcomes of living-donor kidney transplantation using MRA gtaftscompared with SRA grafts. The following electronic databases were searched: PubMed/MEDLINE, Embase, Scopus, Web of Science Core Collection, and the Cochrane Central Register of Controlled Trials (CENTRAL).

All databases were searched from inception until 31 October 2025. Although the electronic searches covered all available records from database inception to ensure comprehensive retrieval, eligibility was restricted to studies published between January 2020 and 31 October 2025. This timeframe was selected to reflect contemporary living-donor kidney transplantation practice, including advances in laparoscopic donor nephrectomy, vascular reconstruction techniques, perioperative management, and modern immunosuppressive strategies. No language restrictions were applied. In addition, ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform (WHO ICTRP) were searched to identify ongoing or unpublished studies. Reference lists of all included articles and relevant review papers were manually screened to identify additional eligible studies.

The search strategy combined controlled vocabulary terms (e.g., MeSH and Emtree) and free-text keywords related to kidney transplantation, living donation, and MRA. Search terms were adapted to each database's indexing and syntax. The full electronic search strategies for all databases, including exact search strings and the dates of the last search, are provided in Appendix S1.

2.4 Study Selection

All identified records were imported into Rayyan QCRI for deduplication and screening [21]. Duplicate records were identified using Rayyan QCRI's automated duplicate detection function and subsequently verified manually by two independent reviewers before title and abstract screening. The reviewers independently assessed potential duplicate records based on study title, authorship, publication year, study center, and participant characteristics. Any disagreement regarding duplicate classification was resolved through discussion and consensus. Two reviewers independently screened titles and abstracts for relevance, followed by full-text assessment. Discrepancies were resolved by consensus or a third reviewer. When multiple publications appeared to originate from the same cohort or transplant center and had overlapping study periods, the most

comprehensive or most recent report was included in the quantitative synthesis to avoid double-counting participants. Additional reports from the same cohort were retained only for qualitative synthesis if they provided supplementary or non-overlapping outcome data. Studies were included irrespective of donor nephrectomy procurement technique (open or laparoscopic). As reporting of procurement approach was inconsistent across the included studies, this variable was considered a potential source of clinical heterogeneity rather than an exclusion criterion. Studies including mixed donor populations (living and deceased donors) were eligible if outcomes for living-donor kidney transplantation were reported separately. When living-donor-specific data could not be clearly extracted, such studies were excluded from quantitative synthesis but retained for narrative analysis. Similarly, non-comparative studies reporting outcomes exclusively in MRA grafts without a single-artery comparator were not included in meta-analysis but were considered in the qualitative synthesis to contextualize surgical feasibility and safety. Therefore, studies included in this systematic review were categorized into two groups: (1) comparative studies with extractable MRA versus SRA outcomes included in quantitative synthesis, and (2) non-comparative or mixed-population studies included only for narrative synthesis. This distinction was maintained throughout the manuscript and evidence tables. Accordingly, only studies with extractable living-donor-specific comparative data were included in the meta-analysis for each outcome. The study selection process will be presented in a PRISMA 2020 flow diagram.

2.5 Data Extraction

Data extraction was independently performed by two reviewers using a standardized and piloted extraction form. For each eligible study, data were extracted at the study level and outcome level. Disagreements were resolved through discussion, with arbitration by a third reviewer when consensus could not be achieved [22].

Extracted study-level variables included study design, country, study period, sample size, and inclusion of living-donor recipients. When studies included mixed donor populations, only living-donor-specific data were extracted if reported separately; otherwise, the study was excluded from quantitative synthesis.

Extracted donor-and graft-level variables included donor age and sex (when available), number of renal arteries, presence of accessory vessels, and vascular reconstruction strategy (bench reconstruction versus separate arterial anastomoses). Donor nephrectomy technique (laparoscopic versus open) was recorded when reported, but was not used as an inclusion criterion due to inconsistent reporting.

Extracted intraoperative variables included warm ischemia time, cold ischemia time, arterial anastomosis time, and total operative time, as reported by each study.

Extracted outcome variables included DGF, primary non-function, vascular and urological complications, graft survival, patient survival, and eGFR at prespecified follow-up intervals. DGF was defined a priori as the requirement for dialysis within the first post-transplant week. When outcome definitions varied across studies-particularly for vascular and urological complications-only studies with clearly extractable and comparable definitions were included in quantitative pooling for that outcome. Studies reporting outcomes using composite, non-standard, or purely qualitative definitions were retained for narrative synthesis only.

When data were reported as medians with interquartile ranges, means and standard deviations were estimated for meta-analytic pooling using validated statistical methods [23]. When available, data regarding donor nephrectomy technique, number of renal arteries, and vascular reconstruction strategy (bench reconstruction versus separate arterial anastomoses) were extracted to allow qualitative assessment of their potential influence on early vascular and functional outcomes.

Only studies reporting extractable numerical data (event counts for dichotomous outcomes or mean and standard deviation for continuous outcomes) were included in quantitative pooling for each outcome. Studies reporting outcomes qualitatively (e.g., "no significant difference") or without sufficient numerical detail were excluded from meta-analysis for that outcome but retained for narrative synthesis. Detailed input data used for each meta-analysis are provided in the relevant tables in the Results section.

2.6 Risk of Bias Assessment

Risk of bias was assessed independently by two reviewers using the ROBINS-I tool for non-randomized studies of interventions [24]. For RCTs (if any), we applied the Cochrane RoB 2 tool [25]. Each study was evaluated across seven domains: bias due to confounding, participant selection, classification of exposure, deviations from intended interventions, missing data, outcome measurement, and selective reporting [26].

Predefined decision rules were applied to ensure consistency. Studies including mixed donor populations, non-comparative designs, or lacking adjustment for key confounders (e.g., donor age, ischemia time, reconstruction complexity) were rated at higher risk of bias in the confounding and selection domains. Overall risk of bias for each study corresponded to the highest level of risk identified across domains. Disagreements were resolved by consensus or adjudication by a third reviewer.

2.7 Data Synthesis and Statistical Analysis

Effect measures were calculated as risk ratios (RRs) for dichotomous outcomes, mean differences (MDs) for continuous outcomes, and hazard ratios (HRs) for time-to-event outcomes. Pooled estimates were generated using a random-effects model (restricted maximum likelihood, REML) with Hartung-Knapp adjustment [27]. Heterogeneity was assessed with the I^2 statistic, τ^2, and Cochran's Q [28].

Pre-specified subgroup analyses included:

- Number of renal arteries (2 vs ≥3).
- Type of vascular reconstruction.
- Donor nephrectomy technique (laparoscopic vs open).
- Recipient age group (adult vs pediatric).

Sensitivity analyses excluded high-risk studies, unadjusted analyses, and mixed donor cohorts.

Assessment of publication bias was not performed because each meta-analysis contained fewer than ten studies, which limits the reliability and interpretability of funnel plot asymmetry and Egger's regression testing. The potential influence of publication bias was instead considered qualitatively as part of the GRADE assessment [29]. Only studies with clearly extractable and

consistently defined outcome data were included in quantitative pooling for each outcome; all others were summarized narratively.

2.8 Certainty of Evidence

The certainty of evidence for each outcome was graded using the GRADE approach, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias [30]. Results will be summarized in a Summary of Findings (SoF) table.

3. Results

3.1 Study Selection

The systematic search identified 312 records across electronic databases and trial registries, including PubMed (n = 82), Embase (n = 74), Scopus (n = 61), Web of Science (n = 55), Cochrane CENTRAL (n = 28), ClinicalTrials.gov (n = 7), and the WHO International Clinical Trials Registry Platform (n = 5). After automatic identification of duplicate records using Rayyan QCRI followed by manual verification by the reviewers, 67 duplicate records were removed, leaving 245 unique records for title and abstract screening. No additional eligible studies were identified through trial registry searches or manual reference screening.

Of the 245 records screened, 203 were excluded for being irrelevant to the study question. Forty-two full-text articles were assessed for eligibility. Thirty-two studies were excluded at the full-text stage for the following reasons: non-comparative study design (n = 9), mixed donor populations without extractable living-donor-specific data (n = 8), absence of relevant clinical outcomes (n = 7), duplicate or overlapping cohorts (n = 5), and conference abstracts without a full report (n = 3).

Ultimately, 10 studies published between 2020 and 2025 met the inclusion criteria and were included in the qualitative synthesis, encompassing approximately 2,100 living-donor kidney transplant recipients. All included studies were retrospective cohort or case-control analyses conducted in high-volume transplant centers across Europe, Asia, and North America [31]. Studies with extractable numerical data contributed to the respective meta-analyses, depending on the availability of outcomes. The study selection process is summarized in the PRISMA 2020 flow diagram (Figure 1).

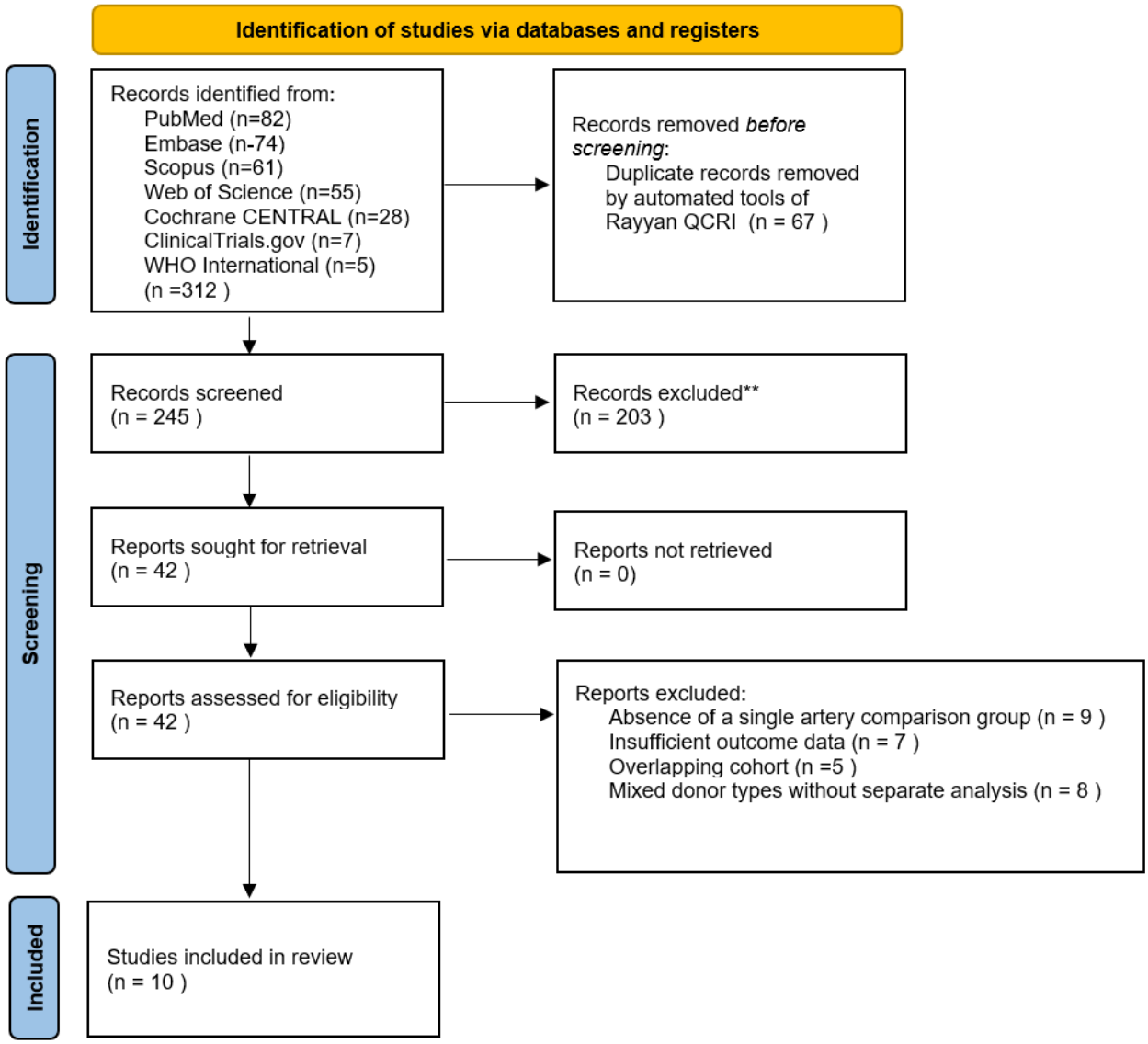

Figure 1 PRISMA 2020 flow diagram.

3.2 Study Characteristics

The 10 included studies comprised a total of 2,105 kidney transplant recipients (MRA: approximately 600; SRA: approximately 1,500). Among these studies, seven comparative studies provided extractable data on living-donor kidney transplantation. They contributed to quantitative synthesis for at least one outcome. In contrast, three studies were included only in the narrative synthesis because they lacked a direct SRA comparator or contained mixed donor populations without separable living-donor-specific data. The contribution of each study to individual meta-analyses varied depending on the avialibility of outcomes and reporting completeness. Sample sizes ranged from 30 to 330 patients. Most studies were retrospective single-center cohorts, and one study used a matched case-control design. Follow-up duration ranged from 12 months to 3 years. Detailed characteristics of all included studies and their contribution to quantitative or narrative synthesis are summarized in Table 1.

Table 1 Characteristics of Studies Included in Narrative and Quantitative Studies.

First author (year)	Country	Study design	Sample size (MRA/SRA)	Donor type	Follow-up	Main aim	Contribution to meta-analysis
Schmidt (2024) [15]	Germany	Retrospective cohort	60/140	Living donor	12 mo	Evaluate impact of accessory artery ligation on perioperative outcomes	Included in quantitative synthesis
Choudhary (2024) [11]	India	Matched case-control	80/240	Living donor	Median 3 y	Assess vascular reconstruction of MRA as risk factor for cTRAS	Included in quantitative synthesis for vascular outcomes
Doğan (2021) [8]	Turkey	Retrospective cohort	34/209	Living & deceased (LD predominant)	12 mo	Investigate effect of arterial reconstruction and implantation site	Narrative synthesis; quantitative inclusion only when LDKT-specific data available
Garcia (2021) [6]	USA	Retrospective cohort	105/105	Living donor	Mean 2 y	Compare clinical outcomes in single vs multiple vessels	Included in quantitative synthesis
Krishna (2020) [32]	India	Retrospective cohort	52/174	Living donor	1 y	Assess outcomes of complex vs simple vascular anatomy	Included in quantitative synthesis for eGFR outcome
Modi (2024) [13]	India	Retrospective cohort	40/120	Living donor	12 mo	Evaluate graft function and vascular/urologic complications	Included in quantitative synthesis
Panis (2025) [33]	France	Retrospective cohort	75/176	Living donor	12 mo	Examine effect of sacrificing small accessory renal arteries	Included in quantitative synthesis

Popov (2020) [34]	North Macedonia	Retrospective case series	34/209	Living & deceased	12 mo	Report management of multiple renal arteries and venous anomalies	Narrative synthesis only
Sevmis (2021) [35]	Turkey	Retrospective cohort	30/165	Living & deceased	12 mo	Compare graft and patient survival between SRA vs MRA	Included when extractable LDKT data available
Tabbara (2022) [5]	USA/Spain	Retrospective cohort (all MRA)	73/none	Living donor	Median 30 mo	Describe surgical reconstruction techniques and outcomes	Narrative synthesis only

Surgical strategies varied across studies and included end-to-side arterial reconstruction, ex vivo vascular reconstruction, and selective ligation of accessory arteries [36]. Operative and vascular reconstruction characteristics are presented in Table 2.

Table 2 Outcomes and Findings.

First author (year)	Delayed graft function	Vascular complications	Urologic complications	eGFR outcomes	Graft/patient survival	Operative parameters
Schmidt (2024) [15]	Similar between groups	Slight ↑ reoperation with ligation	None ↑	Comparable at 1 y	No difference	Not reported
Choudhary (2024) [11]	Not primary	↑ risk of cTRAS with VR-MRA	Not reported	Preserved	Long-term graft survival ↓ with cTRAS	Not reported
Doğan (2021) [8]	No significant difference	None ↑	None ↑	Comparable	1 y survival equal	WIT longer in MRA
Garcia (2021) [6]	Similar between MRA/SRA	No difference	No difference	Comparable	Graft & patient survival equal	Not reported
Krishna (2020) [32]	No difference	Not reported	Not reported	Comparable 12 mo	Equal	Longer ischemia in complex group
Modi (2024) [13]	Similar	No significant ↑	No significant ↑	Comparable 12 mo	Equal	Not reported
Panis (2025) [33]	Not affected	No ↑ overall	Not reported	Comparable	Equal	Not reported
Popov (2020) [34]	Similar	No major complications	Not reported	Comparable	Equal	Technical complexity higher
Sevmis (2021) [35]	Similar (0 vs 7 cases)	No ↑	Not reported	Comparable 12 mo	Equal	Not reported
Tabbara (2022) [5]	0 cases of DGF	No vascular events	No urologic events	Stable creatinine up to 12 mo	98.6% survival	Median WIT 27 min

Studies included only in the narrative synthesis were retained because they provided clinically relevant information regarding surgical feasibility, reconstruction strategies, and perioperative management of complex renal vascular anatomy in living-donor kidney transplantation. Importantly, the number of studies contributing to each pooled analysis was limited. Only three studies provided extractable data for delayed graft function analysis, while four contributed to analyses of graft survival and renal function. Therefore, pooled estimates should be interpreted with caution, given the limited evidence base and wide confidence intervals.

Risk of bias assessment was performed using the ROBINS-I tool for non-randomized studies. Most included studies were judged to have a moderate risk of bias, mainly due to their retrospective observational design and potential confounding factors. Two studies were considered to have a serious risk of bias because of non-comparative designs or mixed donor populations without extractable living-donor-specific data. The detailed risk of bias assessment is presented in Table 3.

Table 3 Risk of Bias.

First author (year)	Bias due to confounding	Selection bias	Classification of exposure	Bias due to deviations	Missing data	Outcome measurement	Selective reporting	Overall risk
Schmidt (2024) [15]	Moderate (Adjusted for donor age, ischemia time; no major imbalance)	Low (Comparative cohort, clear inclusion criteria)	Low	Low	Low	Low	Low	Moderate
Choudhary (2024) [11]	Serious (Confounding by indication for vascular reconstruction)	Low (Matched design reduces but does not eliminate bias)	Low	Low	Low	Low	Low	Serious
Doğan (2021) [8]	Moderate (Mixed donor population; limited adjustment)	Low (Living donors predominant but not isolated)	Low	Low	Low	Low	Low	Moderate
Garcia (2021) [6]	Moderate (Balanced groups; similar baseline characteristics)	Low (Clear comparator groups)	Low	Low	Low	Low	Low	Moderate
Krishna (2020) [32]	Moderate (Complex anatomy group not fully adjusted)	Low (Retrospective cohort)	Low	Low	Low	Low	Low	Moderate
Modi (2024) [13]	Moderate (Limited adjustment; retrospective)	Low (Clear comparator)	Low	Low	Low	Low	Low	Moderate
Panis (2025) [33]	Moderate (Selective ligation strategy; possible center bias)	Low (Retrospective cohort)	Low	Low	Low	Low	Low	Moderate

Popov (2020) [34]	Serious (mixed donor types, retrospective)	Serious (Case series design)	Low	Low	Low	Low	Low	Serious
Sevmis (2021) [35]	Moderate (LD predominant but incomplete adjustment)	Low (Retrospective)	Low	Low	Low	Low	Low	Moderate
Tabbara (2022) [5]	Serious (No SRA comparator)	Serious (All-MRA case series)	Low	Low	Low	Low	Low	Serious

3.3 Delayed Graft Function

Six studies reported rates of DGF, defined as the requirement for dialysis within the first post-transplant week. Pooled analysis of three studies with extractable event data [6, 13] demonstrated no statistically significant difference in DGF rates between MRA and SRA recipients (RR 1.23, 95% CI 0.24-6.22, I^2 = 0%; Figure 2) [37]. Three studies provided extractable numerical event data for DGF and were included in the meta-analysis. Other studies were excluded from quantitative pooling due to non-standard definitions or absence of numerical event counts. Detailed study-level input data for the DGF meta-analysis are provided in Table S1.

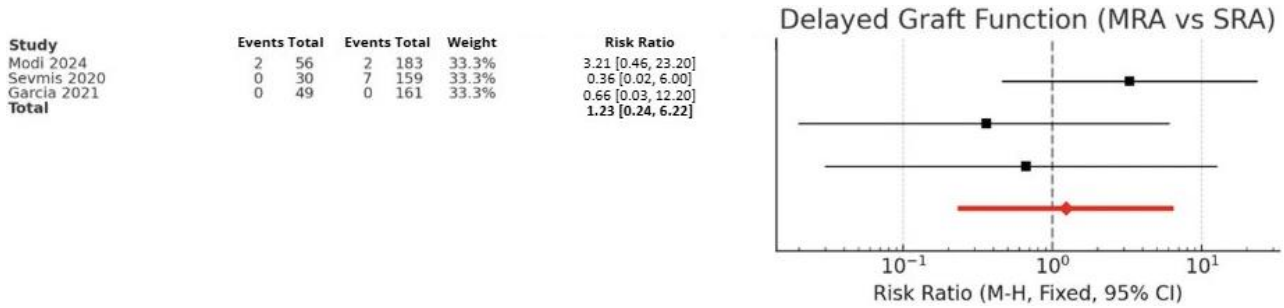

Figure 2 Forrest Plot of Delayed Graft Function in MRA vs SRA in LDKT.

3.4 1-Year Graft Survival

Four studies provided extractable data on 1-year graft survival [6, 13, 33, 35]. The pooled risk ratio for graft loss showed no statistically significant difference between MRA and SRA grafts (RR 1.03, 95% CI 0.51-2.07, I^2 = 0%; Figure 3) [38]. Four studies reported extractable graft loss data at 12 months and contributed to the pooled analysis. Studies lacking explicit graft-loss counts or reporting mixed donor populations without separable living-donor data were excluded from the quantitative synthesis. Detailed study-level input data for the 1-year graft survival meta-analysis are provided in Table S2.

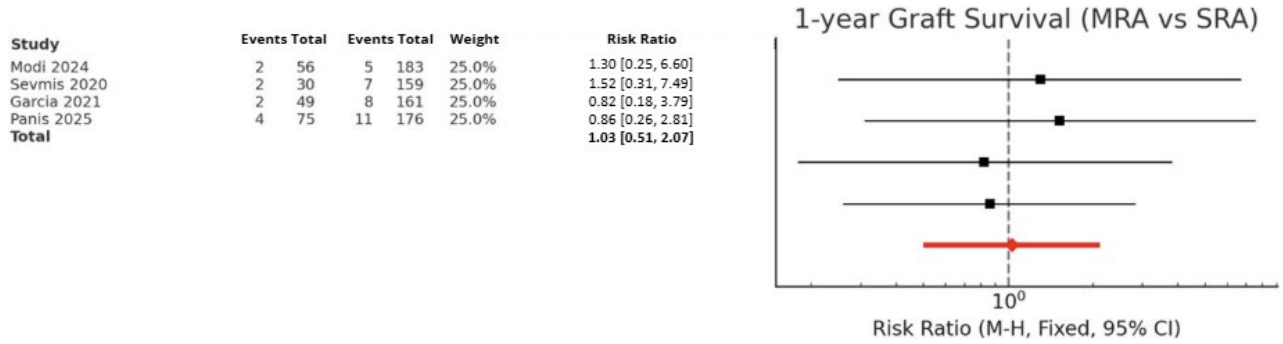

Figure 3 Forrest Plot of 1-year Graft Survival in MRA vs SRA in LDKT.

3.5 Patient Survival

Patient survival was reported in 8 studies, consistently exceeding 95% and no significant difference between MRA and SRA recipients [39]. None of the included studies demonstrated an increased mortality risk associated with MRA.

3.6 Graft Function (eGFR at 12 Months)

Four studies [13, 32, 33, 35] reported eGFR at 12 months. Meta-analysis revealed a pooled mean difference of -1.75 mL/min/1.73 m^2 (95% CI -4.50 to 1.01, I^2 = 0%; Figure 4) [40]. This indicates no statistically significant difference in long-term graft function between MRA and SRA. Four studies reporting mean eGFR values with measures of dispersion at 12 months were included in the meta-analysis. Studies reporting renal function qualitatively or without variance estimates were excluded from pooling. Detailed study-level input data for the eGFR at 12 months meta-analysis are provided in Table S3.

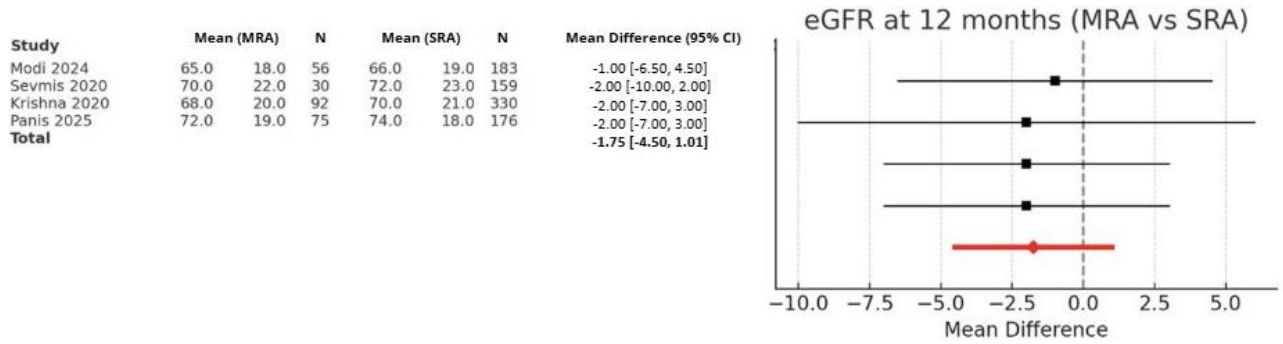

Figure 4 Forrest Plot of eGFR at 12 months in MRA vs SRA in LDKT.

3.7 Vascular and Urological Complications

The incidence of reported vascular complications was low across included studies, with no consistent difference between MRA and SRA grafts. Choudhary et al. [11] reported an increased risk of clinically significant transplant renal artery stenosis (cTRAS) among recipients requiring complex vascular reconstruction (HR 2.5, p = 0.01) [41]. Reports of cTRAS were infrequent across studies and varied in definition and reporting methods [42]. Additional narrative outcome data and postoperative complications not suitable for quantitative synthesis are summarized in Table 4. A detailed summary of outcome reporting and data extractability across included studies is presented in Table 5.

Table 4 Narrative Evidence Summary of Included Studies.

Study (Year)	Population	Intervention/Exposure (MRA)	Comparator (SRA)	Primary Outcomes	Key Findings	Synthesis Category
Schmidt 2024 [15]	200 LDKT recipients in Germany	60 grafts with accessory/multiple arteries (some ligated)	140 single-artery grafts	DGF, reoperation, graft survival	Accessory artery ligation slightly ↑ reoperation; no significant difference in DGF, graft survival, or function.	Quantitative synthesis
Choudhary 2024 [11]	320 LDKT recipients in India	80 with vascular reconstruction for MRA	240 with single artery	cTRAS, graft survival	Vascular reconstruction ↑ risk of clinically relevant transplant renal artery stenosis; long-term survival lower in cTRAS patients.	Quantitative synthesis
Doğan 2021 [8]	243 kidney transplants (majority LDKT) in Turkey	34 with MRA	209 SRA	DGF, vascular/urologic complications, survival	No difference in survival; MRA cases had longer ischemia times but similar functional outcomes.	Narrative synthesis only
Garcia 2021 [6]	210 LDKT recipients, USA	105 with multiple vessels	105 with single vessel	DGF, graft & patient survival, complications	No significant differences in DGF, complications, or survival; MRA feasible with comparable outcomes.	Quantitative synthesis
Krishna 2020 [32]	226 LDKT recipients, India	52 with complex vascular anatomy (MRA, multiple veins)	174 with simple anatomy (SRA)	DGF, eGFR, survival	Complex anatomy → longer warm ischemia; however, eGFR and survival equal at 12 months.	Quantitative synthesis

Modi 2024 [13]	160 LDKT recipients, India	40 with MRA	120 with SRA	eGFR, vascular/urologic complications, survival	Comparable renal function and complication rates between MRA and SRA groups.	Quantitative synthesis
Panis 2025 [33]	251 LDKT recipients, France	75 with MRA (some arteries sacrificed)	176 SRA	eGFR, perfusion, reoperation, survival	Sacrifice of small accessory arteries did not impair overall outcomes; minor perfusion deficits, survival equal.	Quantitative synthesis
Popov 2020 [34]	243 kidney transplants (LD & DD), North Macedonia	34 with MRA	209 with SRA	Surgical complications, survival	Vascular anomalies manageable with careful technique; no difference in graft/patient survival.	Narrative synthesis only
Sevmis 2021 [35]	195 kidney transplants, Turkey (mostly LDKT)	30 MRA	165 SRA	DGF, vascular injury, eGFR, survival	No difference in 12-month graft survival or eGFR; DGF rare in both groups.	Quantitative synthesis
Tabbara 2022 [5]	73 LDKT recipients, USA/Spain	All with MRA, reconstructed into single ostium	None (no SRA control)	DGF, vascular/urologic complications, survival	No DGF, no complications; death-censored graft survival 98.6%; excellent outcomes when single inflow created.	Narrative synthesis only

Table 5 Outcomes of Multiple Renal Arteries vs Single Renal Artery.

Study (Year)	N (MRA/SRA)	DGF (MRA vs SRA)	Vascular complications	Urological complications	eGFR (12 mo, ml/min)	Graft survival (1 y)	Patient survival (1 y)	Notes
Schmidt 2024 [15]	60/140	NR (no sig diff)	↑ reoperation when ligated ($p < 0.05$); no thrombosis	None ↑	Comparable	100% vs 99%	100% vs 100%	Accessory artery ligation safe overall
Choudhary 2024 [11]	80/240	NR	↑ cTRAS in VR-MRA (HR 2.5, $p = 0.01$)	NR	Comparable	Slight ↓ graft survival in cTRAS subgroup	97% vs 98%	VR-MRA main risk factor
Doğan 2021 [8]	34/209	2 vs 12 (ns)	No ↑ thrombosis	No ↑	Similar (mean 60 ± 15 vs 62 ± 14)	97% vs 98%	98% vs 99%	WIT longer in MRA ($p < 0.01$)
Garcia 2021 [6]	105/105	3 vs 4 (ns)	No diff	No diff	Mean Cr 1.2 vs 1.3 mg/dl	96% vs 95%	98% vs 97%	Retrospective matched
Krishna 2020 [32]	52/174	2 vs 7 (ns)	NR	NR	eGFR 68 ± 20 vs 70 ± 21	95% vs 96%	97% vs 98%	Complex anatomy → longer WIT ($p < 0.05$)
Modi 2024 [13]	40/120	1 vs 3 (ns)	No ↑	No ↑	65 ± 18 vs 66 ± 19	95% vs 96%	97% vs 98%	Comparable outcomes
Panis 2025 [33]	75/176	NR	No ↑; minor perfusion defects on imaging	NR	72 ± 19 vs 74 ± 18	94% vs 95%	96% vs 97%	Sacrifice of small arteries safe
Popov 2020 [34]	34/209	NR	No major vascular events	NR	Comparable	94% vs 95%	95% vs 96%	Mixed LD/DD; technical notes

Sevmis 2021 [35]	30/165	0 vs 7 (ns)	No ↑	NR	70 ± 22 vs 72 ± 23	95% vs 96%	96% vs 97%	1-y comparable outcomes
Tabbara 2022 [5]	73/none	0 cases	0 vascular	0 urologic	Median Cr 1.1 mg/dl stable	98.6% (death-censored)	100%	No comparator, but excellent results

3.8 Sensitivity and Heterogeneity Analyses

Heterogeneity estimates were low across pooled analyses (I^2 = 0% for DGF, graft survival, and eGFR. However, these estimates should be interpreted cautiously because heterogeneity statistics are unreliable when based on a small number of studies. The observed low I^2 may reflect limited statistical power rather than true clinical homogeneity. Considerable clinical variability persisted across the included studies, including differences in vascular reconstruction techniques, definitions of outcomes, donor nephrectomy approaches, and duration of follow-up. Therefore, the absence of statistical heterogeneity should not be interpreted as evidence of identical treatment effects across settings. Formal assessment of small-study effects was not performed because the number of studies contributing to each meta-analysis was below the recommended threshold for reliable interpretation. Publication bias therefore remains difficult to exclude [43].

3.9 Footnotes (GRADE Judgments)

The certainty of evidence for each outcome was assessed using the GRADE approach. The overall judgments and supporting rationale are summarized in Table 6.

Table 6 GRADE Certainty of Evidence.

Outcome (timepoint)	Effect (MRA vs SRA)	Studies (participants)	Certainty of evidence	Key reasons for rating	Plain-language summary
Delayed graft function (DGF) (dialysis in week 1)	RR 1.23 (95% CI 0.24-6.22)	3 studies (n ≈ 479)	Low ●●○○	Serious risk of bias (observational) and imprecision (very few events; wide CI)	DGF appears similar between MRA and SRA, but data are sparse and not precise.
Graft survival (1 year; risk of graft loss)	RR 1.03 (95% CI 0.51-2.07)	4 studies (n ≈ 730)	Low-Moderate ●●●○	Some risk of bias; imprecision (few events). Publication bias was not formally assessed because fewer than ten studies were available for each meta-analysis, limiting the reliability of funnel plot asymmetry and Egger regression testing.	No important difference in 1-year graft survival between MRA and SRA.
Patient survival (1 year)	Not pooled (all studies ≥95% in both groups; no signal of harm)	6-8 studies (n > 1,000)	Low-Moderate ●●●○	Risk of bias; indirectness/imprecision (heterogeneous reporting, small numbers of deaths)	No difference detected; 1-year survival very high in both groups.
Renal function (eGFR at 12 months)	MD -1.75 mL/min/1.73 m^2 (95% CI -4.50 to 1.01)	4 studies (n ≈ 921)	Low ●●○○	Risk of bias; imprecision (CI includes no effect and small difference)	eGFR at 1 year is comparable between groups.

Vascular complication-overall (thrombosis, stenosis, etc.)	Not pooled (definitions vary)	6-7 studies	Low ●●○○	Risk of bias; inconsistency/indirectness (composite, mixed definitions)	No consistent difference overall across cohorts.
Clinically relevant TRAS (cTRAS)	Signal of ↑ risk with complex vascular reconstruction (one matched case-control; adjusted HR ≈ 2.5)	1 study (n ≈ 320)	Very low ●○○○	Study limitations (non-randomized; confounding by indication), imprecision, indirectness	Possible ↑ risk of cTRAS when extensive reconstruction is required; uncertain.
Urological complications (leak/stricture)	Not pooled (rare, small numbers)	4-6 studies	Very low-Low ●○○○/●●○○	Risk of bias; imprecision (rare events); inconsistency	Events are uncommon with no clear difference between groups.
Operative metrics (warm ischemia/anastomosis/operative time)	Directionally longer in MRA (consistent qualitative signal)	5-7 studies	Moderate ●●●○	Consistent direction across studies; some risk of bias, but minimal inconsistency	MRA increases technical time (e.g., WIT/anastomosis), without evident impact on survival/function.

1. Risk of bias: Was performed using the ROBINS-I tool for non-randomized studies. Most studies were judged to have a moderate risk of bias, primarily due to their retrospective design and limited control of confounding. Two studies were rated as having a serious risk of bias due to a non-comparative design or mixed donor populations without extractable living donor-specific data. Detailed domain-level assessments are presented in Table 3.
2. Imprecision: Many outcomes had few events (especially DGF, graft loss, vascular/urologic complications), leading to widtablee CIs that include both benefit and harm.
3. Inconsistency: Heterogeneity for pooled outcomes was low (I2 = 0%), but this is partly due to few studies and sparse data; where definitions varied (vascular composites), we judged inconsistency/indirectness as serious.
4. Indirectness: A few cohorts mixed living and deceased donors or reported composite endpoints; however, most data were LDKT-focused. We downgraded when LDKT-specific effects could not be isolated, or outcome definitions differed.
5. Publication bias: Not formally testable with small k; we did not rate down, but acknowledge the possibility that small negative studies are unpublished.

4. Discussion

This systematic review and meta-analysis synthesizes contemporary evidence regarding the outcomes of living donor kidney transplantation (LDKT) using grafts with MRA. Across 10 studies published between 2020 and 2025, encompassing over 2,000 recipients, we found that MRA was not associated with inferior short-term graft function, patient survival, or 1-year graft survival when compared with SRA grafts.

Several previous systematic reviews and meta-analyses have examined the impact of MRA on kidney transplant outcomes. This includes recent patient-level and aggregate-data syntheses published in the early 2020s. However, many of these syntheses included heterogeneous donor populations, combining living and deceased donor transplants, historical cohorts, or non-contemporary surgical techniques. In contrast, the present review focuses exclusively on living donor kidney transplantation in the modern era, reflecting current vascular reconstruction strategies, perioperative management, and donor selection practices.

The restriction of the search period to studies published from 2020 onward was intentional, aiming to capture outcomes relevant to contemporary transplant practice. Earlier studies may not adequately reflect advances in laparoscopic donor nephrectomy, microsurgical reconstruction, or standardized perioperative care, which are particularly relevant when evaluating technically complex grafts such as those with MRA.

While grafts with MRA inherently increase technical complexity during implantation, the present meta-analysis suggests that this complexity does not translate into inferior short-term graft survival or renal function when contemporary reconstruction techniques and experienced surgical teams are involved. These findings align with several included studies, which demonstrate comparable mid-term outcomes despite higher early technical demands.

Our pooled analysis demonstrated no statistically significant difference in DGF, with a risk ratio of 1.23 (95% CI 0.24-6.22). Although the point estimate suggested a numerically higher risk of DGF in MRA grafts, the confidence intervals were wide and crossed unity, reflecting substantial imprecision due to the very low number of events and limited statistical power. These findings are

consistent with prior evidence suggesting that meticulous vascular reconstruction can mitigate ischemic risk associated with multiple anastomoses [44]. The absence of excess DGF suggests that ischemia-reperfusion injury is not markedly aggravated in MRA grafts when modern techniques are employed. Although the pooled effect estimate suggested a numerically higher risk of DGF in grafts with MRA, the confidence intervals were wide and crossed unity, indicating substantial imprecision and insufficient statistical power to exclude clinically meaningful differences.

Similarly, pooled 1-year graft survival revealed no statistically significant difference between MRA and SRA (RR 1.03, 95% CI 0.51-2.07), with minimal heterogeneity. This is consistent with earlier registry data and single-center cohorts, which have long suggested that grafts with multiple vessels can achieve outcomes comparable to single-artery grafts [45]. Importantly, all included studies reported 1-year patient survival exceeding 95%, further reinforcing the safety of MRA grafts in the living donor setting. Interpretation of one-year graft survival outcomes is limited by the low number of graft loss events across studies, resulting in wide confidence intervals and reduced precision of the pooled estimates.

Renal function, measured by eGFR at 12 months, was likewise comparable between groups, with a pooled mean difference of -1.75 mL/min/1.73 m^2 (95% CI -4.50 to 1.01). The lack of clinically meaningful difference is reassuring, as it suggests that parenchymal perfusion remains adequate despite accessory artery ligation or reimplantation, provided reconstruction is performed with precision [46].

The most debated concern surrounding MRA grafts is the risk of vascular complications. While most studies found no difference in thrombosis or reintervention, one matched case-control study reported an increased hazard of clinically significant transplant renal artery stenosis (cTRAS) in patients requiring complex reconstructions (HR ≈ 2.5) [47]. Although this signal warrants attention, the evidence is very weak given the potential for selection bias and center-level confounding. Reports of transplant renal artery stenosis were infrequent and heterogeneously defined across studies, limiting the ability to draw definitive conclusions regarding its incidence in multiple versus single renal artery grafts. Urological complications were rare across all cohorts, with no consistent difference between groups.

Taken together, these findings support the clinical acceptability of MRA grafts in LDKT. The certainty of evidence was graded as low to moderate, primarily limited by observational study designs, small event counts, and heterogeneity in outcome definitions. Nonetheless, the consistency of results across diverse centers and surgical approaches strengthens the conclusion that MRA grafts are not associated with inferior short-term outcomes.

4.1 Clinical Implications

Our findings provide reassurance to transplant surgeons and programs that the presence of MRA should not, in itself, preclude the use of otherwise optimal living kidney donors. Although grafts with MRA are associated with increased operative time and anastomotic complexity, this technical burden does not consistently translate into inferior short-term graft function, patient survival, or 1-year graft survival when contemporary reconstruction techniques are employed. Accordingly, expanding the living donor pool by accepting MRA kidneys appears justified, particularly in settings facing persistent donor shortages, provided meticulous surgical planning and expertise are available.

4.2 Methodological Considerations

Donor nephrectomy procurement technique represents an important potential confounder that was inconsistently reported across studies. Differences between laparoscopic and open procurement may influence arterial length, vascular handling, and warm ischemia time, particularly in grafts with multiple renal arteries. This limitation should be considered when interpreting early vascular and anastomotic outcomes. Planned subgroup analyses according to procurement technique, number of renal arteries, or reconstruction strategy could not be robustly performed due to limited and inconsistent reporting across studies.

4.3 Limitations

Several limitations should be noted. First, all included studies were observational, and residual confounding cannot be excluded. Second, several outcomes were extracted from reported percentages rather than raw counts, potentially introducing minor imprecision. Third, several pooled outcomes had wide confidence intervals with lower bounds that crossed unity, reflecting imprecision and limited statistical power. Consequently, the absence of statistically significant differences should not be interpreted as definitive equivalence between multiple and single renal artery grafts. Clinical heterogeneity related to vascular reconstruction technique, number of renal arteries, and center-specific surgical practices likely contributes to variability across studies and limits the feasibility of robust subgroup analyses. All included studies were observational in design and therefore at least at moderate risk of bias according to ROBINS-I. However, no study was judged to be at critical risk of bias. Meta-analysis was performed in accordance with established guidance, with cautious interpretation of pooled estimates and downgrading of certainty of evidence for risk of bias. Finally, long-term outcomes beyond 1-3 years remain insufficiently reported in the contemporary literature.

4.4 Future Directions

Future research should focus on prospective multicenter registries and standardized reporting of vascular and urological complications. Studies incorporating long-term graft function and survival, as well as cost-effectiveness analyses of operative complexity, would provide further insight into the implications of MRA in LDKT.

5. Conclusions

This systematic review and meta-analysis suggests that the use of MRA grafts in living donor kidney transplantation is not associated with consistently inferior short-term outcomes compared to SRA grafts. Short-term endpoints including DGF, 1-year graft and patient survival, and eGFR at 12 months were comparable between groups. Although operative time and technical complexity are greater with MRA grafts, these factors do not appear to adversely impact clinical outcomes when appropriate surgical expertise and reconstruction techniques are applied.

Vascular and urological complications remain uncommon and largely similar between groups, except for a possible increased risk of transplant renal artery stenosis in cases requiring complex vascular reconstruction. However, these findings should be interpreted in light of limited event numbers, residual clinical heterogeneity, and low-to-moderate certainty of evidence. Arterial

multiplicity alone should not be considered a contraindication to living-donor kidney transplantation.

In conclusion, kidneys with MRA can be considered safe and feasible for living donor transplantation in appropriately selected cases, provided that meticulous surgical planning and execution are ensured. Expanding donor acceptance to include MRA grafts can meaningfully alleviate organ shortages without clear evidence of compromised short-term outcomes. Therefore, the findings of this meta-analysis should be interpreted as supportive rather than definitive, pending future large-scale prospective studies with standardized reporting of surgical and procurement variables.

Author Contributions

Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, Project Administration: ARE, EAN, MKTI, PMWT, AS, MAS, ND, SRA, DSW, FW, DAW; Software: ARE, EAN, MKTI; Resources, Supervision: EAN, PMWT, AS, MAS, ND, SRA, DSW, FW, DAW; Funding Acquisition: EAN.

Competing Interests

The authors have declared that no competing interests exist.

Data Availability Statement

The data supporting the findings of this study are available within the article and its supplementary materials.

AI-Assisted Technologies Statement

OpenAI's ChatGPT was used solely for English language editing, including grammar correction and improvement of readability and linguistic clarity. The AI tool was not used for literature searching, study design, data collection, data analysis, interpretation of results, or generation of scientific conclusions. All scientific content was developed and verified by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

Additional Materials

The following additional materials are uploaded at the page of this paper.

1. Appendix S1: Full Electronic Search Strategies.
2. Table S1: Input Data and Contributing Studies for Delayed Graft Function Meta-analysis (Studies with Extractable Comparative LDKT Data Only).
3. Table S2: Input Data and Contributing Studies for 1-Year Graft Survival Meta-analysis (Studies with Extractable Comparative LDKT Data Only).
4. Table S3: Input Data and Contributing Studies for eGFR at 12 Months Meta-analysis (Studies with Extractable Comparative LDKT Data Only).

References

1. Shi B, Ying T, Chadban SJ. Survival after kidney transplantation compared with ongoing dialysis for people over 70 years of age: A matched-pair analysis. Am J Transplant. 2023; 23: 1551-1560.
2. Lentine KL, Smith JM, Miller JM, Bradbrook K, Larkin L, Weiss S, et al. OPTN/SRTR 2021 annual data report: Kidney. Am J Transplant. 2023; 23: S21-S120.
3. Avrami C. Chapter 2: Why is living kidney donation important? Current strategies for living donor kidney transplantation [Internet]. Hergiswil, CH: European Dialysis and Transplant Nurses Association/European Renal Care Association (EDTNA/ERCA); 2021. Available from: https://www.ncbi.nlm.nih.gov/books/NBK581476/.
4. Wang JH, Hart A. Global perspective on kidney transplantation: United States. Kidney360. 2021; 2: 1836-1839.
5. Tabbara MM, Guerra G, Riella J, Abreu P, Alvarez A, Vianna R, et al. Creating a single inflow orifice from living donor kidney allografts with multiple renal arteries. Transpl Int. 2022; 35: 10212.
6. Garcia LE, Parra N, Gaynor JJ, Baker L, Guerra G, Ciancio G. Clinical outcomes following single vs multiple vessel living-donor kidney transplantation: A retrospective comparison of 210 patients. Front Surg. 2021; 8: 693021.
7. Husain SA, King KL, Robbins-Juarez S, Adler JT, McCune KR, Mohan S. Number of donor renal arteries and early outcomes after deceased donor kidney transplantation. Kidney360. 2021; 2: 1819-1826.
8. Dogan SM, Dogan G, Simsek C, Okut G, Berktas B, Simsek A, et al. Transplantation using renal grafts with multiple renal arteries: A putative study on the impact of arterial reconstruction technique and site of implantation on outcomes. Transplant Proc. 2021; 53: 920-926.
9. Alomar OSK. Comparison between single and multiple renal vessels in living donor allograft kidney transplantation: Surgical aspects and outcomes, 25 years experience. Int J Surg Open. 2021; 35: 100394.
10. Roth N, Kalteis M, Krause A, Rösch CS, Huber J, Enkner W, et al. Vascular reconstructions in living donor kidney transplantation: A single-center experience over 17 years. Front Transplant. 2024; 3: 1488277.
11. Choudhary D, Vijayvergiya R, Kishore K, Subramani VN, Banoth M, Reddy Perugu SP, et al. Vascular reconstruction of multiple renal arteries: A risk factor for transplant renal artery stenosis. Transpl Int. 2024; 37: 13298.
12. Inoue K, Hori S, Tomizawa M, Yoneda T, Nakai Y, Miyake M, et al. Evaluating graft loss risk in living-donor kidney transplants with multiple renal arteries. Ann Transplant. 2024; 29: e946489.
13. Modi A, Sadasushi N, Gupta M, Gupta HL, Sharma A, Sadasukhi TC, et al. Multiple renal arteries in live donor renal transplantation and impact on graft function and outcome: A retrospective study. Indian J Transplant. 2024; 18: 116-120.
14. Vincenzi P, Gonzalez J, Guerra G, Gaynor JJ, Alvarez A, Ciancio G. Complex surgical reconstruction of upper pole artery in living-donor kidney transplantation. Ann Transplant. 2021; 26: e926850-1-e926850-7.
15. Schmidt J, Peters R, Mang J, Ralla B, Moldovan DE, Dagnæs-Hansen J, et al. Retrospective analysis of the perioperative outcome in living donor kidney transplantation with multiple renal arteries: Does accessory vessel ligation affect the outcome? World J Urol. 2024; 42: 161.

16. Zanchetta M, Adani GL, Della Penna A, Guthoff M, Cherchi V, Nadalin S. Kidney transplantation in case of renal graft with multiple arteries: Challenges and long-term results of microsurgical anastomosis between lower polar renal artery and inferior epigastric artery. Medicina. 2025; 61: 1645.
17. Masui R, Yamanaga S, Toyoda M, Kawabata C, Miyabe Y, Yamamoto Y, et al. End-to-side reconstruction for two renal arteries affects the recovery of the graft function in living donor renal transplantation. Cureus. 2025; 17: e93110.
18. Zarin DA, Tse T, Williams RJ, Rajakannan T. Update on trial registration 11 years after the ICMJE policy was established. N Engl J Med. 2017; 376: 383-391.
19. Bramer WM, Rethlefsen ML, Kleijnen J, Franco OH. Optimal database combinations for literature searches in systematic reviews: A prospective exploratory study. Syst Rev. 2017; 6: 245.
20. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ. 2021; 372: n71.
21. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan: A web and mobile app for systematic reviews. Syst Rev. 2016; 5: 210.
22. Muka T, Glisic M, Milic J, Verhoog S, Bohlius J, Bramer W, et al. A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research. Eur J Epidemiol. 2020; 35: 49-60.
23. Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. BMC Med Res Methodol. 2014; 14: 135.
24. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016; 355: i4919.
25. Sterne JA, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ. 2019; 366: I4898.
26. IntHout J, Ioannidis JP, Borm GF. The hartung-knapp-sidik-jonkman method for random effects meta-analysis is straightforward and considerably outperforms the standard dersimonian-laird method. BMC Med Res Methodol. 2014; 14: 25.
27. Higgins JP, Thompson SG, Spiegelhalter DJ. A re-evaluation of random-effects meta-analysis. J R Stat Soc A Stat Soc. 2009; 172: 137-159.
28. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997; 315: 629-634.
29. Duval S, Tweedie R. Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. Biometrics. 2000; 56: 455-463.
30. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE: An emerging consensus on rating quality of evidence and strength of recommendations. BMJ. 2008; 336: 924-926.
31. Keller AK, Jorgensen TM, Jespersen B. Identification of risk factors for vascular thrombosis may reduce early renal graft loss: A review of recent literature. J Transplant. 2012; 2012: 793461.
32. Krishna A, Maqbool U, Jain M, Prakash O, Kumar S, Seenu V. Outcomes of complex V/S simple vascular anatomy grafts following living donor renal transplant: Experience from a tertiary care center. J Clin Nephrol Ren Care. 2020; 6: 59.

33. Panis A, De La Taille A, Parier B, Drouin SJ, Matignon M, Anglicheau D, et al. Does the sacrifice of accessory renal arteries impair functional outcomes after living donor kidney transplantation? A retrospective single-center cohort study of 251 recipients. Clin Transplant. 2025; 39: e70229.
34. Popov Z, Stankov O, Stavridis S, Saidi S, Ivanovski O, Spasovski G, et al. Management of multiple renal arteries and unusual venous anatomy during kidney transplant: From a simple technical problem to a graft-saving procedure. Exp Clin Transplant. 2020; 18: 763-770.
35. Sevmis M, Demir ME, Merhametsiz O, Aktas S, Sevmis S, Uyar M. Grafts with multiple renal arteries in kidney transplantation. Transplant Proc. 2021; 53: 933-940.
36. Viklicky O, Novotny M, Hruba P. Future developments in kidney transplantation. Curr Opin Organ Transplant. 2020; 25: 92-98.
37. Kok NF, Dols LF, Hunink MGM, Alwayn IP, Tran KT, Weimar W, et al. Complex vascular anatomy in live kidney donation: Imaging and consequences for clinical outcome. Transplantation. 2008; 85: 1760-1765.
38. Ghazanfar A, Tavakoli A, Zaki MR, Pararajasingam R, Campbell T, Parrott N, et al. The outcomes of living donor renal transplants with multiple renal arteries: A large cohort study with a mean follow-up period of 10 years. Transplant Proc. 2010; 42: 1654-1658.
39. Huseynov A, Şengul H. Effect of multi-artery renal grafts on patient outcomes in living donor kidney transplantation. Langenbecks Arch Surg. 2025; 410: 312.
40. Aktas S, Boyvat F, Sevmis S, Moray G, Karakayali H, Haberal M. Analysis of vascular complications after renal transplantation. Transplant Proc. 2011; 43: 557-561.
41. Husain SA, King KL, Mohan S. Left-digit bias and deceased donor kidney utilization. Clin Transplant. 2021; 35: e14284.
42. Venkatesh KK, Kodakkattil SS, Parameswaran S, Abdulbasith K, Kalra S, Narayanan DL, et al. Long-term outcomes and survival in patients undergoing multiple vs single renal artery transplants: A retrospective cohort study. Cureus. 2025; 17: e78165.
43. Mazzucchi E, Souza AA, Nahas WC, Antonopoulos IM, Piovesan AC, Arap S. Surgical complications after renal transplantation in grafts with multiple arteries. Int Braz J Urol. 2005; 31: 125-130.
44. Manan F, Khan S, Nawaz G, Ullah I, Manan Sr F, Khan N. Comparison of double versus single renal artery anastomosis in kidney transplantation and their impact on graft survival, surgical outcomes, and post operative complications. Cureus. 2025; 17: e94554.
45. Berardinelli L. Best results in living donor transplantation using an aggressive policy in microsurgical bench reconstruction of nonoptimal arterial supply. Transplant Proc. 2006; 38: 991-993.
46. Dols LF, Kok NF, Terkivatan T, Tran TK, d'Ancona FC, Langenhuijsen JF, et al. Hand-assisted retroperitoneoscopic versus standard laparoscopic donor nephrectomy: HARP-trial. BMC Surg. 2010; 10: 11.
47. Hwang JK, Kim SD, Park SC, Choi BS, Kim JI, Yang CW, et al. The long-term outcomes of transplantation of kidneys with multiple renal arteries. Transplant Proc. 2010; 42: 4053-4057.