Ilomata International Journal of Social Science

OPEN ACCESS

RECEIVED 1 April 2026
ACCEPTED 6 July 2026
PUBLISHED 31 July 2026

CITATION
Fadil MR, Sutrisno FG, Lestari JY, Iskandar AF, (2026). A Systematic Review of Clinical Outcomes in Laparoscopic versus Robotic Donor Nephrectomy. Ilomata International Journal of Social Science. 7 (3), 986-994.
doi: 10.61194/ijss.v7i3.2344

TYPE Original Research
PUBLISHED 31 July 2026
DOI 10.61194/ijss.v7i3.2344
VOL 7 Issue 3 July 2026

A Systematic Review of Clinical Outcomes in Laparoscopic versus Robotic Donor Nephrectomy

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Abstract

Living donor kidney transplantation remains the preferred treatment for end-stage renal disease because it provides superior long-term outcomes compared with dialysis. The increasing use of minimally invasive techniques, particularly Laparoscopic Donor Nephrectomy (LDN) and Robotic Donor Nephrectomy (RDN), has prompted comparisons of their perioperative performance and donor outcomes. This study systematically reviewed evidence comparing postoperative renal function, hospital length of stay, perioperative parameters, and postoperative complications between LDN and RDN. A systematic review following PRISMA guidelines searched PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar for comparative studies published between 2010 and 2025. Methodological quality was assessed using the Newcastle–Ottawa Scale and the JBI Critical Appraisal Checklist. Ten studies met the inclusion criteria and were synthesized qualitatively. The evidence indicates that RDN and LDN produce comparable postoperative renal function, including stable estimated glomerular filtration rate (eGFR) and serum creatinine levels. Several studies reported shorter hospital stays, lower early postoperative pain scores, and faster recovery with RDN, although robotic procedures required longer operative times during early implementation. Complication rates were generally low and similar between techniques. Overall, both LDN and RDN are feasible and safe minimally invasive approaches for living donor nephrectomy. However, variations in study design, institutional experience, and outcome reporting limit definitive conclusions regarding the superiority of either technique, highlighting the need for standardized high-quality comparative studies.

KEYWORDS

complications, hospital stay, laparoscopic donor nephrectomy, renal function, robotic donor nephrectomy.

Introduction

Kidney transplantation represents the definitive therapeutic intervention for individuals with end-stage renal disease (ESRD), demonstrating superior long-term survival and quality-of-life outcomes compared with dialysis modalities (Matas & Rule, 2022; Ortiz et al., 2025). The success of living donor kidney transplantation, however, depends not only on recipient graft outcomes but also on the preservation of donor safety and postoperative well-being during nephrectomy procedures (Chan et al., 2025; Napoli et al., 2024). Consequently, surgical techniques for donor nephrectomy continue to evolve toward minimally invasive approaches that reduce periopersative morbidity while maintaining graft integrity and functional outcomes (Plage et al., 2020).

Since its introduction in the 1990s, laparoscopic donor nephrectomy (LDN) has become the standard minimally invasive approach for living kidney procurement because of its association with reduced postoperative pain, shorter hospitalization, improved cosmetic outcomes, and faster recovery compared with open surgery, without compromising graft function (Wang et al., 2020). The technique also demonstrates acceptable intraoperative safety profiles characterized by low conversion rates and limited transfusion requirements (Zaytoun et al., 2021). Nevertheless, conventional laparoscopy remains technically demanding, particularly in complex donor anatomy and prolonged procedures, due to limitations in instrument dexterity, ergonomics, and depth perception.

Technological advancements in minimally invasive surgery have subsequently facilitated the development of robotic donor nephrectomy (RDN), which incorporates three-dimensional visualization, articulated instrumentation, enhanced precision, and improved operator ergonomics (Munoz Abraham et al., 2025; Serni et al., 2021). These features potentially reduce surgeon fatigue and improve technical performance during donor kidney procurement. Previous studies have suggested that robotic systems may contribute to more stable perioperative performance and facilitate the learning process in experienced transplant centers (Khajeh et al., 2023; Pham et al., 2026). Furthermore, robotic assistance has been associated with favorable donor safety profiles and satisfactory recipient graft outcomes, supporting its growing adoption in modern transplantation programs (Kędzierska-Kapuza et al., 2024).

Despite increasing clinical utilization of RDN, comparative evidence between robotic and laparoscopic donor nephrectomy remains heterogeneous. Several studies have reported shorter hospitalization and lower postoperative pain scores with robotic approaches, whereas operative duration, warm ischemia time, and perioperative efficiency outcomes remain inconsistent across institutions and surgeon experience levels (Khajeh et al., 2023; Musquera et al., 2025). In addition, substantial economic and operational considerations continue to influence the broader implementation of robotic surgery, including acquisition costs, maintenance expenses, specialized infrastructure, and workforce training requirements (Boyar et al., 2021; Hinojosa-Gonzalez et al., 2023; Serni et al., 2021). Although some reports suggest that shorter recovery periods and reduced morbidity may partially offset these expenditures, the overall clinical value of RDN relative to LDN remains incompletely established.

Several comparative reviews and meta-analyses have previously evaluated minimally invasive donor nephrectomy techniques, primarily focusing on technical and perioperative variables such as operative time, blood loss, and conversion rates (Khajeh et al., 2023; Kourounis et al., 2024). However, important limitations remain within the existing literature. First, many prior syntheses included relatively limited evidence windows or predominantly early-generation robotic studies, thereby reducing applicability to current robotic platforms and contemporary transplant practice. Second, donor-centered clinical outcomes including postoperative renal function preservation, hospital length of stay as a recovery indicator, and standardized postoperative complication profiles have often been discussed only secondarily within broader technical comparisons. Third, substantial variability persists in the reporting of perioperative outcomes and institutional experiences across geographic settings, limiting the consistency of evidence interpretation.

Previous systematic reviews on minimally invasive approaches to living donor nephrectomy have largely concentrated on operative technical details, thereby leaving notable gaps in the comprehensive assessment of donor-centered outcomes, including postoperative renal function, hospital length of stay, and perioperative as well as postoperative complications between LDN and RDN (Hinojosa-Gonzalez et al., 2023). The present systematic review seeks to address these deficiencies through a focused, donor-centered comparative synthesis of evidence published between 2010 and 2025, incorporating data from diverse transplantation centers (Dagnæs-Hansen et al., 2022). Furthermore, this review integrates contemporary evidence regarding the implementation of robotic surgical systems and associated operational considerations within modern transplant programs (Munoz Abraham et al., 2025). By emphasizing clinically relevant donor outcomes in conjunction with these procedural developments, the synthesis aims to deliver an updated and practically oriented evidence base for clinicians and healthcare institutions involved in living donor kidney transplantation (Dagnæs-Hansen et al., 2025).

Therefore, this study aims to systematically review and comparatively synthesize the available literature evaluating laparoscopic donor nephrectomy (LDN) and robotic donor nephrectomy (RDN), with particular emphasis on postoperative renal function, hospital length of stay, and perioperative and postoperative complications. The review further seeks to clarify the current evidentiary position of robotic donor nephrectomy within modern minimally invasive transplantation practice while identifying areas requiring further standardized and high-quality comparative research.

Methods

Study Design

This study employed a systematic review design to comparatively evaluate clinical outcomes between laparoscopic donor nephrectomy (LDN) and robotic donor nephrectomy (RDN) in living kidney donors. The review focused on donor-centered outcomes, including postoperative renal function, length of hospital stay, and perioperative as well as postoperative complications, in order to synthesize current evidence regarding the safety and clinical feasibility of both minimally invasive techniques (Hinojosa-Gonzalez et al., 2023; Khajeh et al., 2023). The review methodology was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological transparency, reproducibility, and systematic evidence identification and synthesis (Kourounis et al., 2024; Munoz Abraham et al., 2025).

Considering the substantial heterogeneity across included studies in terms of study design, outcome definitions, institutional protocols, and reporting formats, the present review primarily adopted a structured narrative synthesis approach rather than formal quantitative meta-analysis. Accordingly, no pooled effect estimates or forest plot analyses were generated, and findings were synthesized descriptively to identify consistent comparative patterns between LDN and RDN.

Literature Search Strategy

A comprehensive literature search was conducted across five electronic databases: PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. The search process was performed between January and March 2025, with the final database search completed on March 28, 2025. These databases were selected to maximize coverage of peer-reviewed literature related to minimally invasive donor nephrectomy and transplant surgery (Hinojosa-Gonzalez et al., 2023).

The search strategy utilized combinations of Medical Subject Headings (MeSH) terms and free-text keywords combined using Boolean operators (AND, OR), including:

1. "Laparoscopic donor nephrectomy" OR "LDN" OR "laparoscopic live donor nephrectomy";
2. "Robotic donor nephrectomy" OR "RDN" OR "robot-assisted donor nephrectomy";
3. "Renal function" OR "serum creatinine" OR "estimated glomerular filtration rate (eGFR)" OR "GFR";
4. "Hospital stay" OR "length of stay" OR "postoperative recovery";
5. "Complications" OR "perioperative complications" OR "postoperative complications" OR "Clavien-Dindo classification";

6. "Comparative study" OR "cohort study" OR "observational study".

Only studies published between 2010 and 2025 were considered eligible to ensure inclusion of evidence reflecting contemporary robotic surgical systems, perioperative management strategies, and modern transplantation practices (Calpin et al., 2025). To maintain feasibility and relevance during Google Scholar screening, only the first 200 records sorted by relevance were reviewed, consistent with common practice in systematic review methodology. Duplicate records across databases were identified and removed prior to screening.

Study Selection and Eligibility Criteria

Study selection was conducted independently by two reviewers through a multi-stage screening process consisting of title screening, abstract assessment, and full-text evaluation according to predefined eligibility criteria (Hinojosa-Gonzalez et al., 2023). Any disagreements between reviewers were resolved through discussion, and unresolved discrepancies were adjudicated by a third reviewer.

The inclusion criteria were as follows:

1. Original comparative studies directly evaluating laparoscopic donor nephrectomy (LDN) and robotic donor nephrectomy (RDN) in living kidney donors;
2. Studies reporting at least one donor-centered clinical outcome, including postoperative renal function (e.g., serum creatinine or eGFR), hospital length of stay, or perioperative/postoperative complications;
3. Prospective or retrospective cohort studies and comparative observational studies published in peer-reviewed journals;
4. Articles published in English between 2010 and 2025.

The exclusion criteria included:

1. Non-comparative studies, case reports, conference abstracts, editorials, narrative reviews, and systematic reviews without original patient-level comparative data;
2. Studies involving pediatric donors or non-living donor nephrectomy procedures;
3. Studies lacking sufficient outcome reporting relevant to the review objectives;
4. Duplicate publications or overlapping datasets.

Review-level publications identified during screening were used solely for background contextualization and citation tracking and were not included in the final evidence synthesis. Similarly, non-comparative robotic case series were excluded from the analytical dataset to maintain consistency with the predefined comparative review framework.

Data Extraction

Data extraction was performed independently by two reviewers using a standardized extraction form developed prior to study assessment. The extracted variables included:

1. Author(s), publication year, and country of study;
2. Study design and sample size for LDN and RDN groups;
3. Donor demographic characteristics, including age, sex distribution, and body mass index;
4. Surgical parameters, including operative time, estimated blood loss, and warm ischemia time;
5. Postoperative renal function indicators, including serum creatinine levels and estimated glomerular filtration rate (eGFR);
6. Length of hospital stay;
7. Reported perioperative and postoperative complications, including Clavien-Dindo classification where available;
8. Main findings and reported clinical implications.

Data extraction discrepancies were resolved through reviewer discussion and cross-verification against the original full-text articles.

Quality Appraisal

Methodological quality assessment of the included studies was conducted independently by two reviewers using the Newcastle–Ottawa Scale (NOS) for cohort and observational comparative studies and the Joanna Briggs Institute (JBI) Critical Appraisal Checklist where appropriate. The appraisal evaluated participant selection, comparability between study groups, outcome assessment, and adequacy of follow-up procedures. Any differences in quality scoring were resolved through consensus discussion to improve assessment reliability.

Data Synthesis and Analysis

Given the heterogeneity in study populations, perioperative protocols, outcome definitions, and reporting methods, the included studies were synthesized using a structured narrative approach rather than statistical meta-analysis. The synthesis focused on identifying recurring comparative trends between LDN and RDN across three principal analytical domains:

1. Postoperative renal function outcomes as indicators of donor safety and early renal adaptation;
2. Length of hospital stay as an indicator of postoperative recovery and healthcare utilization;
3. Perioperative and postoperative complications as indicators of surgical safety and procedural feasibility.

Findings from individual studies were systematically compared and summarized using descriptive tables and thematic interpretation to facilitate cross-study evaluation of similarities, differences, and emerging patterns in donor outcomes between laparoscopic and robotic donor nephrectomy.

Result and Discussion

Search Strategy and Study Selection

A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar to identify studies comparing laparoscopic donor nephrectomy (LDN) and robotic donor nephrectomy (RDN) in living kidney donors. The search covered studies published between 2010 and March 2025 using combinations of predefined keywords related to donor nephrectomy, renal function, hospital stay, and perioperative complications (Hinojosa-Gonzalez et al., 2023; Khajeh et al., 2023).

The initial database search identified 400 records. After removal of duplicate articles and records excluded through preliminary screening procedures, 320 studies remained for title and abstract screening. Following this stage, 200 records were excluded because they did not meet the predefined inclusion criteria, including studies unrelated to donor nephrectomy, non-comparative surgical reports, conference abstracts, editorials, and review articles without original comparative data. A total of 120 full-text articles were subsequently assessed for eligibility. During full-text evaluation, 110 articles were excluded for reasons including non-comparative study design, insufficient donor outcome reporting, overlapping datasets, or lack of direct comparison between LDN and RDN. Ultimately, 10 studies fulfilled all eligibility criteria and were included in the final qualitative

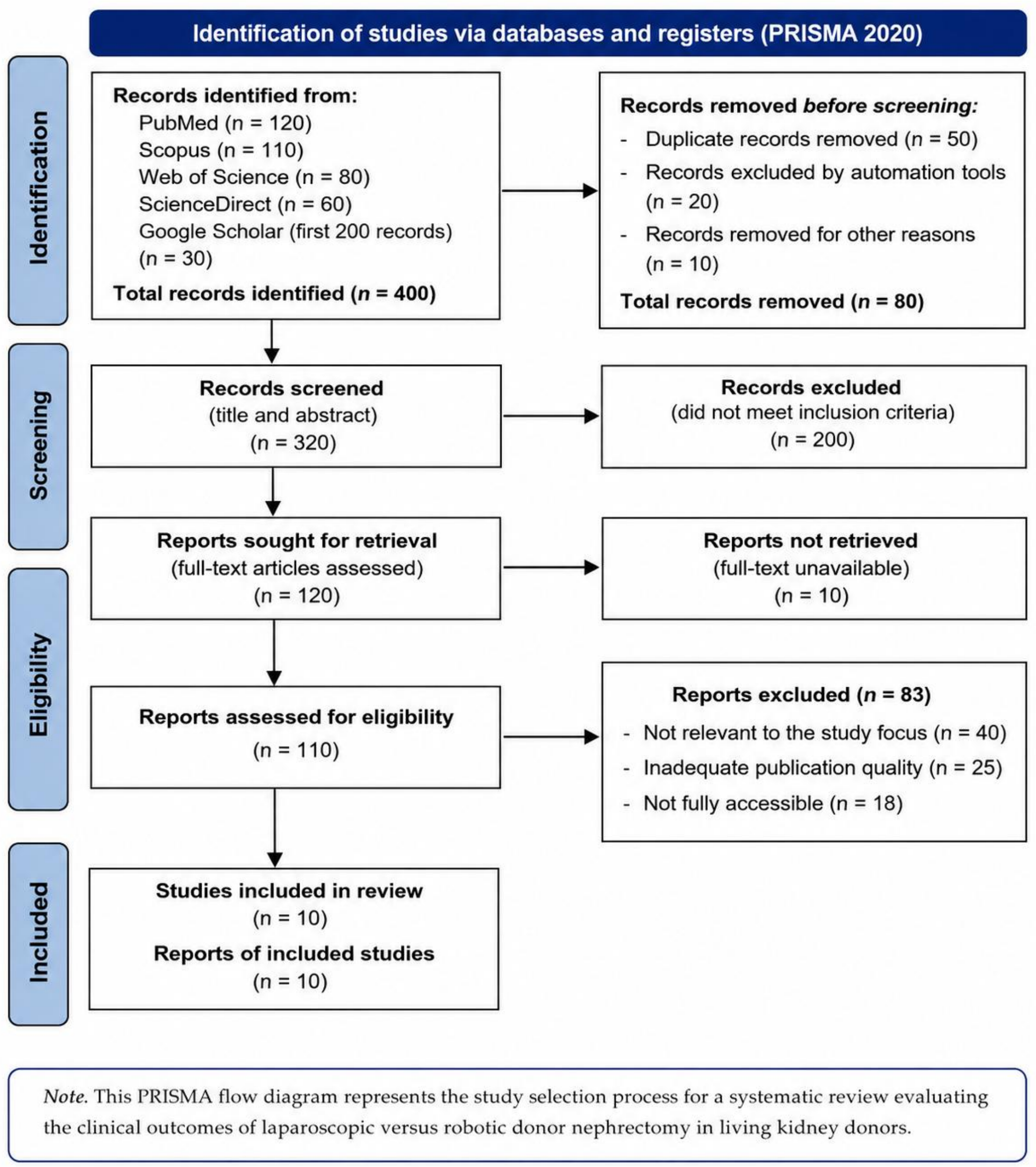

Figure 1. PRISMA 2020 Flow Diagram of Study Selection for the Systematic Review of Laparoscopic versus Robotic Donor Nephrectomy in Living Kidney Donors

synthesis.

The selection process was conducted in accordance with PRISMA guidelines to ensure methodological transparency and reproducibility. Because of substantial heterogeneity in study design, outcome definitions, and reporting approaches across the included studies, the final synthesis was performed narratively rather than through formal quantitative meta-analysis.

PRISMA Flow Diagram

The PRISMA flow diagram demonstrates a rigorous and transparent study selection process undertaken to identify relevant evidence comparing laparoscopic donor nephrectomy (LDN) and robotic donor nephrectomy (RDN) in living kidney donors (see Figure 1). From an initial retrieval of 400 records across five electronic databases, 80 records were removed prior to screening, resulting in 320 studies undergoing title and abstract assessment, of which 200 were excluded for failing to meet the predefined eligibility criteria. Subsequently, 120 full-text articles were sought for retrieval, with 10 reports unavailable, leaving 110 studies for detailed eligibility assessment; among these, 83 articles were excluded due to irrelevance to the study objectives (n = 40), inadequate publication quality (n = 25), or limited accessibility (n = 18). Ultimately, 10 studies satisfied all inclusion criteria and were incorporated into the final qualitative synthesis, providing the evidence base for evaluating comparative donor outcomes, including postoperative renal function, length of hospital stay, and perioperative or postoperative complications associated with LDN and RDN.

Quality Assessment and Risk of Bias

Methodological quality assessment was performed independently by two reviewers using the Newcastle–Ottawa Scale (NOS) for cohort studies and the Joanna Briggs Institute (JBI) Critical Appraisal Checklist where appropriate. The evaluated domains included participant selection, comparability between study groups, adequacy of outcome assessment, and completeness of follow-up. Overall, most included studies demonstrated moderate methodological quality with relatively low risk of bias in outcome reporting (Xun et al., 2023). However, several methodological limitations were

Table 1. Characteristics of Included Studies in the Systematic Review and Meta-Analysis

Author (Year)	Country	Study Design	Population	Intervention	Findings
(Zeuschner et al., 2020)	Germany	Retrospective cohort	Living kidney donors	RDN vs LDN	RDN showed comparable perioperative safety and renal function preservation to LDN; operative times were similar after accounting for learning curve; complication rates remained low and equivalent between groups. Overall, both techniques demonstrated excellent donor outcomes with no significant long-term differences in graft function.
(Windisch et al., 2022)	Belgium	Retrospective comparative	Adult living donors	RDN vs HLDN (hand-assisted LDN)	RDN exhibited longer operative time but similar warm ischemia time; hospital stay was significantly shorter; renal function showed minor persistent creatinine elevation at 1 month but remained clinically acceptable. RDN proved safe and efficient relative to established minimally invasive standards.
(Khajeh et al., 2023)	Netherlands	Retrospective cohort	Living kidney donors	Robot-assisted DN vs LDN	Robot-assisted donor nephrectomy was safely implemented by experienced laparoscopic surgeons without inferior outcomes. Perioperative parameters including complications and renal function were equivalent or non-inferior to laparoscopic approach. The transition showed efficient adoption with maintained donor safety and graft quality.
(Van de Geijn et al., 2024)	Italy	Retrospective bicentric	Living kidney donors	RDN vs LDN	RDN facilitated faster learning curve and better multi-vessel handling; postoperative complications were infrequent; perioperative outcomes were comparable or favored RDN in high-volume settings. Both approaches ensured high safety for donors.
(Hinojosa-Gonzalez et al., 2023)	Mexico/International	Systematic review with meta (but primary studies pooled)	Living donors	RDN vs LDN	Operative time and bleeding were similar; warm ischemia time slightly longer in RDN but LOS and pain reduced; complications and conversions equivalent. Robotic technique offers a comparable alternative with potential donor recovery advantages.
(Munoz Abraham et al., 2025)	International	Review/update (includes comparative)	Living donors	RDN focus	RDN consistently showed low complication rates and reliable perioperative outcomes; advantages in ergonomics and precision noted; donor and recipient safety maintained. RDN has emerged as a safe, effective minimally invasive option globally.
(Centonze et al., 2023)	Italy	Retrospective bicentric cohort	Living kidney donors	RDN vs LDN	RDN demonstrated a faster learning curve and better handling of multiple vessels compared to LDN; postoperative complications were low and comparable between groups; perioperative outcomes were equivalent or favored RDN in high-volume centers. Both techniques ensured high donor safety with no significant differences in major adverse events. RDN demonstrated a faster learning curve and better handling of multiple vessels compared to LDN; postoperative complications were low and comparable between groups; perioperative outcomes were equivalent or favored RDN in high-volume centers. Both techniques ensured high donor safety with no significant differences in major adverse events. .
(Pham et al., 2026)	Vietnam	Retrospective observational	Living donors	Right robotic-assisted laparoscopic	Mean operative time was ~172 min with minimal blood loss (~56 mL). There were no intraoperative complications or open

Author (Year)	Country	Study Design	Population	Intervention	Findings
				donor nephrectomy	conversions. Donors and recipients showed satisfactory early renal function outcomes.
(Kourounis et al., 2024)	International	Cochrane review (RCTs pooled, but includes RDN data)	Live kidney donors	RDN vs LDN/ODN	RDN comparable to LDN in pain and complications; longer procedure but potential advantages in select outcomes; evidence supports minimally invasive equivalence. High-certainty data affirm donor safety across techniques.
(Bhattu et al., 2015)	India	Prospective randomized comparative	Living donors	Robotic vs Standard LDN	RDN had lower pain scores and analgesic requirements than LDN at 6-48 hrs. Hospital stay was shorter in RDN, but total operative time and warm ischemia time were longer. Donor complications and graft outcomes were similar across both techniques.

identified. Most studies employed retrospective observational designs and single-center datasets, potentially introducing selection bias and limiting external generalizability (Drukker et al., 2021). In addition, variations in surgeon expertise, institutional learning curves, and perioperative management protocols contributed to clinical heterogeneity across studies (Mamikutty et al., 2021). These limitations were considered during narrative interpretation of the comparative findings.

Characteristics of Included Studies

Table 1 presents the characteristics of studies included in this systematic review and meta-analysis comparing robotic-assisted donor nephrectomy (RDN) with laparoscopic donor nephrectomy (LDN) and its variants in living kidney donors. It summarizes the country, study design, population, intervention, and key findings of each included study.

Synthesis and Interpretation of Findings

The present systematic review demonstrates that both robotic donor nephrectomy (RDN) and laparoscopic donor nephrectomy (LDN) provide generally comparable donor-centered clinical outcomes, particularly regarding postoperative renal function preservation and perioperative safety. Across the included studies, postoperative estimated glomerular filtration rate (eGFR) and serum creatinine levels remained clinically acceptable following both procedures, suggesting that minimally invasive donor nephrectomy can preserve donor renal adaptation effectively regardless of surgical platform (Khajeh et al., 2023; Kourounis et al., 2024; Zeuschner et al., 2020). Likewise, major perioperative complications, conversion rates, and adverse donor events were consistently reported as infrequent across both approaches.

However, the interpretation of these findings requires careful contextualization. Although several studies reported shorter hospitalization periods and lower early postoperative pain scores in robotic cohorts, these advantages were generally modest and were not uniformly observed across all institutions (Bhattu et al., 2015; Hinojosa-Gonzalez et al., 2023). Furthermore, operative duration frequently remained longer in RDN, particularly during initial implementation phases, reflecting the influence of robotic setup requirements and institutional learning curves (Van de Geijn et al., 2024; Windisch et al., 2022). Therefore, the apparent perioperative advantages associated with robotic surgery should not be interpreted as definitive evidence of overall clinical superiority.

Compared with previous comparative reviews and meta-analytic syntheses, the present review contributes a more updated donor-centered evidence perspective by emphasizing studies published between 2010 and 2025 and prioritizing postoperative renal function, hospital length of stay, and complication profiles as the principal analytical outcomes. Earlier reviews frequently focused on operative technical variables such as blood loss, warm ischemia time, and operative duration (Khajeh et al., 2023; Kourounis et al., 2024). In contrast, the present synthesis specifically integrates more recent institutional experiences and contemporary robotic implementation data while maintaining emphasis on donor recovery and safety outcomes. Although the overall conclusions remain broadly consistent with prior evidence, the inclusion of newer comparative studies allows a more current interpretation of robotic donor nephrectomy within evolving transplant practice.

Critical Evaluation of Evidence Quality and Heterogeneity

The overall consistency of donor safety findings across studies strengthens confidence that both RDN and LDN are clinically feasible minimally invasive approaches when performed in experienced transplant centers. Nevertheless, the quality of the evidence base remains an important limitation. Most included studies employed retrospective cohort designs with non-randomized patient allocation, thereby increasing susceptibility to selection bias, confounding variables, and institutional practice effects (Khajeh et al., 2023; Zeuschner et al., 2020). Only limited prospective randomized evidence was available, and sample sizes varied substantially between studies.

Importantly, the observed heterogeneity across studies appears to be influenced not merely by methodological variation but also by contextual surgical factors. Differences in operative time, perioperative efficiency, and complication rates were frequently associated with surgeon experience, institutional robotic volume, and procedural standardization. High-volume transplant centers with established robotic programs generally reported shorter learning curves, more stable perioperative outcomes, and greater technical advantages in handling complex vascular anatomy (Centonze et al., 2023). In contrast, centers during early robotic adoption phases more commonly reported prolonged operative duration and workflow inefficiencies. Accordingly, variability in outcomes may reflect differences in institutional maturity and training infrastructure rather than intrinsic superiority of one surgical modality over another.

This interpretation is particularly important because learning-curve effects can substantially influence comparative outcome reporting. Several robotic cohorts included procedures performed after substantial laparoscopic experience had already been established, potentially biasing comparisons in favor of robotic implementation under optimized conditions (Khajeh et al., 2023). Therefore, caution is necessary when generalizing findings from highly specialized centers to broader transplant settings with varying levels of robotic expertise and resource availability.

Table 2. Summary of Key Research Findings

No	Category of Findings	Key Research Outcomes	References
1	Renal Function Preservation	Comparable postoperative eGFR and serum creatinine outcomes between RDN and LDN	(Grigoriou et al., 2025; Hinojosa-Gonzalez et al., 2023; Theodorakis & Nikolaou, 2025; Khajeh et al., 2023; Kourounis et al., 2024; Zeuschner et al., 2020)
2	Operative Time and Learning Curve	RDN frequently demonstrated longer operative duration during early implementation phases	(Van de Geijn et al., 2024; Windisch et al., 2022)
3	Hospital Stay and Recovery	Several studies reported shorter hospitalization and lower postoperative pain in RDN cohorts	(Bhattu et al., 2015; Hinojosa-Gonzalez et al., 2023)
4	Complication Rates	Low and generally comparable complication and conversion rates across both techniques	(Centonze et al., 2023; Pham et al., 2026)
5	Technical and Institutional Factors	Outcomes were influenced by surgeon experience, institutional volume, and robotic learning-curve maturity	(Khajeh et al., 2023; Van de Geijn et al., 2024)
6	Management and Resource Implications	Robotic implementation requires consideration of cost, infrastructure, training, and institutional sustainability	(Munoz Abraham et al., 2025; Musquera et al., 2025; Serni et al., 2021; Shen et al., 2020)

Comparative Perspectives Across Geographic and Institutional Settings

The included studies represented transplant centers from Europe, Asia, and Latin America, thereby providing a relatively broad international perspective on minimally invasive donor nephrectomy. Despite geographic diversity, most studies consistently reported comparable postoperative renal outcomes and low complication rates between RDN and LDN (Coco & Leanza, 2025; Napoli et al., 2024). This consistency suggests that both techniques can achieve acceptable donor safety outcomes across different healthcare systems when appropriate expertise is available.

Nevertheless, regional differences in access to robotic technology likely influence both implementation feasibility and reported outcomes. Studies originating from high-volume European and international referral centers frequently described greater procedural standardization, structured robotic training pathways, and access to advanced robotic platforms. In contrast, institutions in resource-constrained settings may encounter limitations related to acquisition costs, maintenance expenses, specialized workforce requirements, and limited robotic case volumes. These structural differences may affect operative efficiency, learning-curve progression, and long-term sustainability of robotic donor nephrectomy programs.

Consequently, the broader adoption of robotic donor nephrectomy should not be viewed solely as a technical surgical transition but also as a healthcare management and resource-allocation issue. Decisions regarding implementation require consideration of institutional capacity, surgical training infrastructure, case volume sustainability, and economic feasibility in addition to short-term perioperative outcomes.

Management and Social Implications

The findings of this review also carry implications for healthcare management and donor-centered surgical care. Although robotic donor nephrectomy may offer ergonomic benefits for surgeons and potentially improved early postoperative recovery for donors, the current evidence remains insufficient to support universal implementation of robotic systems across all transplantation programs. Existing evidence regarding cost-effectiveness remains limited, and most included studies did not perform formal economic analyses comparing robotic and laparoscopic approaches (Zaytoun et al., 2021).

Accordingly, claims regarding improved healthcare efficiency associated with robotic surgery should be interpreted cautiously. Shorter hospitalization and reduced analgesic requirements reported in several studies may contribute to incremental improvements in postoperative recovery pathways; however, these benefits must be balanced against substantial acquisition costs, maintenance expenditures, and the need for specialized personnel and training programs (Boyar et al., 2021). Furthermore, the potential benefits of robotic surgery may be most achievable in high-volume institutions capable of sustaining procedural proficiency and operational efficiency over time.

From a social perspective, unequal access to robotic surgical technology may also contribute to disparities between transplantation centers and healthcare systems. Institutions with limited financial and technological resources may be unable to adopt robotic programs despite increasing global technological standardization. Consequently, future evaluation of robotic donor nephrectomy should incorporate broader healthcare accessibility, institutional equity, and sustainability considerations in addition to perioperative clinical outcomes alone.

Limitations and Future Research Directions

Several limitations should be acknowledged in interpreting the findings of this review. First, the predominance of retrospective observational studies limits causal inference and increases vulnerability to reporting and selection bias. Second, outcome definitions and perioperative protocols varied across institutions, restricting direct comparability between studies. Third, follow-up durations were frequently short, limiting evaluation of long-term donor renal function and graft-related outcomes.

In addition, the present review employed narrative synthesis rather than formal quantitative meta-analysis because of substantial heterogeneity in study design and outcome reporting. Although this approach improved interpretive consistency, it limits the ability to generate pooled effect estimates or quantify statistical heterogeneity directly. Furthermore, evidence regarding cost-effectiveness, donor quality of life, and long-term healthcare utilization remains insufficiently developed within the existing literature.

Future research should prioritize multicenter prospective comparative studies with standardized outcome definitions and longer follow-up durations. Greater emphasis should also be placed on donor-centered recovery outcomes, quality-of-life assessment, institutional learning-curve evaluation, and comprehensive health economic analysis. Such evidence will be essential to determine whether robotic donor nephrectomy provides clinically meaningful advantages beyond technical refinement in selected high-volume settings.

Summary of Key Findings

Overall, the present review supports the interpretation that both RDN and LDN are safe and clinically effective minimally invasive techniques for living donor nephrectomy. The most consistently supported findings involve preservation of donor renal function and low complication rates across experienced centers (see Table 2). Potential robotic advantages in recovery and ergonomics appear incremental rather than transformative and remain strongly influenced by institutional expertise and resource capacity. Consequently, current evidence supports cautious and context-dependent integration of robotic donor nephrectomy rather than definitive replacement of established laparoscopic approaches.

Conclusion

This systematic review indicates that Robotic Donor Nephrectomy (RDN) and Laparoscopic Donor Nephrectomy (LDN) demonstrate generally comparable donor-centered clinical outcomes, particularly regarding postoperative renal function preservation and perioperative safety. Across the included studies, both techniques were associated with stable postoperative estimated glomerular filtration rate (eGFR), clinically acceptable serum creatinine levels, and low major complication rates, supporting the overall safety of minimally invasive donor nephrectomy in contemporary transplantation practice. Although several studies reported modest reductions in hospital length of stay and early postoperative pain among robotic cohorts, these advantages were not uniformly observed across all settings and should therefore be interpreted cautiously. The review further suggests that operative duration in RDN is strongly influenced by institutional learning-curve effects and surgeon experience. Several high-volume centers reported progressive improvement in operative efficiency after approximately 20–40 robotic donor nephrectomy cases, indicating that procedural familiarity and structured training pathways substantially affect perioperative performance. Consequently, differences in operative outcomes between RDN and LDN appear to reflect institutional expertise and implementation maturity rather than definitive procedural superiority.

Compared with earlier comparative reviews that predominantly emphasized technical surgical parameters, the present synthesis contributes a more updated donor-centered perspective by integrating evidence published between 2010 and 2025 and prioritizing postoperative renal function, hospital stay, and complication outcomes. The findings support the interpretation that both RDN and LDN can contribute to value-based transplantation care when implemented appropriately within experienced surgical programs. However, the current evidence base remains dominated by retrospective observational studies, with limited randomized comparative data, limited long-term follow-up, and insufficient cost-effectiveness evaluation. Accordingly, recommendations regarding broader robotic adoption should remain proportional to the present strength of evidence. Decisions concerning implementation of robotic donor nephrectomy should be guided by institutional case volume, surgeon proficiency, availability of robotic infrastructure, economic sustainability, and learning-curve capacity rather than assumptions of universal clinical superiority. While robotic systems may offer incremental advantages in surgical ergonomics and perioperative recovery in selected high-volume centers, existing evidence does not yet establish clear long-term superiority over established laparoscopic approaches.

Future research should prioritize multicenter prospective and randomized comparative studies using standardized outcome reporting frameworks, longer follow-up durations, and consistent complication grading systems. In addition, comprehensive cost-effectiveness and cost–utility analyses are required to determine whether the potential perioperative benefits of robotic donor nephrectomy justify the substantial resource investment required for implementation across diverse healthcare systems. Extended evaluation of donor quality of life, functional recovery trajectories, and long-term graft outcomes will be essential to strengthen the evidentiary basis for clinical and healthcare management decision-making in minimally invasive living donor nephrectomy.

Author contributions

The authors explicitly outline their individual contributions to ensure transparency. Muhammad Rizki Fadil, as the corresponding author, led the entire research process by conceptualizing the study, developing the systematic review protocol, conducting comprehensive literature searches across multiple databases, extracting and analyzing data, and drafting the original manuscript through to final revisions. Fabian Gamal Sutrisno actively participated in title and abstract screening, quality appraisal of studies using the Newcastle Ottawa Scale and JBI Checklist, and provided critical input on the methods and results sections. Jeremia Yusak Lestari contributed to quantitative data extraction, preparation of tables summarizing study characteristics and key findings, and interpretation of meta-analytic results concerning renal function and hospital stay. Archie Fontana Iskandar supported the critical analysis of evidence, writing of the discussion and managerial implications, and ensured narrative consistency from a healthcare service perspective. All authors have read, revised, and approved the final version of the manuscript prior to submission.

Acknowledgements

The authors, who serve as active staff and employees at Rumah Sakit Umum Daerah (RSUD) Cimacan, Cianjur Regency, West Java, Indonesia, wish to express their sincere and profound gratitude to the Director and the entire hospital management. The provision of time, opportunity, and guidance has been invaluable throughout the preparation of this systematic review article. As clinical staff with daily patient care responsibilities, the authors deeply appreciate the institutional flexibility and encouragement that enabled them to complete this research without compromising service delivery. Special thanks are also extended to colleagues in the Department of Surgery and the kidney transplant service team for their clinical insights, moral support, and collaborative spirit during the data analysis and manuscript writing phases.

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