International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

ARTICLE TITLE	OPEN VERSUS LAPAROSCOPIC NEPHRECTOMY FOR RENAL TUMORS: A SYSTEMATIC REVIEW AND META-ANALYSIS OF PERIOPERATIVE, FUNCTIONAL AND ONCOLOGIC OUTCOMES
DOI	https://doi.org/10.31435/ijitss.1(49).2026.4766
RECEIVED	22 November 2025
ACCEPTED	07 January 2026
PUBLISHED	21 January 2026
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

OPEN VERSUS LAPAROSCOPIC NEPHRECTOMY FOR RENAL TUMORS: A SYSTEMATIC REVIEW AND META-ANALYSIS OF PERIOPERATIVE, FUNCTIONAL AND ONCOLOGIC OUTCOMES

Paweł Jan Babiński *(Corresponding Author, Email: pbabinski1@wp.pl)*
St. Vincent de Paul Municipal Hospital, Gdynia, Poland
ORCID ID: 0009-0000-8597-8910

Magdalena Wiśniewska
St. Vincent de Paul Municipal Hospital, Gdynia, Poland
ORCID ID: 0009-0008-2420-7117

Zuzanna Karolina Jędrzejczak
Polish Red Cross Maritime Hospital, Gdynia, Poland
ORCID ID: 0009-0006-8158-6032

Andrzej Józef Horabik
Polish Red Cross Maritime Hospital, Gdynia, Poland
ORCID ID: 0009-0008-3693-7360

Małgorzata Dmochowska
St. Vincent de Paul Municipal Hospital, Gdynia, Poland
ORCID ID: 0009-0009-5021-1838

Julia Hertmanowska
University Clinical Centre, Gdańsk, Poland
ORCID ID: 0009-0003-0918-3624

Marta Piotrowska
St. Vincent de Paul Municipal Hospital, Gdynia, Poland
ORCID ID: 0009-0002-3733-1754

Krzysztof Chmura
St. Vincent de Paul Municipal Hospital, Gdynia, Poland
ORCID ID: 0009-0008-6145-9110

Adrianna Alicja Piekarska
University Clinical Centre, Gdańsk, Poland
ORCID ID: 0009-0004-9781-1770

Gabriela Kryger
University Clinical Centre, Gdańsk, Poland
ORCID ID: 0009-0005-5096-4849

ABSTRACT

Background: Renal tumors are increasingly detected early due to widespread imaging. For localized tumors, particularly stage T1, partial nephrectomy (PN) is the standard of care, offering oncological efficacy while preservingrenal function. Laparoscopic partial nephrectomy (LPN) has been increasingly adopted, yet comparative outcomes with open partial nephrectomy (OPN) remain actively evaluated.
Aim: To systematically review perioperative, functional, and oncological outcomes of LPN versus OPN in patients with localized renal tumors, including the impact of tumor anatomical complexity.
Materials and Methods: A systematic literature search of PubMed identified comparative studies of LPN versus OPN for T1–T1b renal tumors. Extracted data included operative time, estimated blood loss, complications, renalfunction, oncological outcomes, and tumor complexity assessed by nephrometry scores.
Results: LPN showed perioperative advantages, including reduced blood loss and shorter hospital stay, with operative time generally comparable to OPN in experienced centers. Early and long-term renal function, measured by estimated glomerular filtration rate, was similar between approaches. Oncological outcomes, including positive surgical margins, recurrence-free survival, cancer-specific survival, and overall survival, were equivalent. In anatomically complex or selected T1b tumors, LPN achieved acceptable perioperative and oncological outcomes when performed in experienced centers.
Conclusions: Laparoscopic partial nephrectomy is a safe and effective alternative to open surgery for localized renal tumors, offering perioperative benefits without compromising renal function or oncological control. Tumor complexity and patient characteristics are more influential determinants of outcomes than surgical approach. LPN should be considered a standard option in centers with expertise in minimally invasive nephron-sparing surgery.

KEYWORDS

Renal Tumors, Partial Nephrectomy, Laparoscopic Surgery, Open Surgery, Nephron-Sparing Surgery, Oncological Outcomes

CITATION

Paweł Jan Babiński, Magdalena Wiśniewska, Zuzanna Karolina Jędrzejczak, Andrzej Józef Horabik, Małgorzata Dmochowska, Julia Hertmanowska, Marta Piotrowska, Krzysztof Chmura, Adrianna Alicja Piekarska, Gabriela Kryger (2026) Open Versus Laparoscopic Nephrectomy for Renal Tumors: A Systematic Review and Meta-Analysis of Perioperative, Functional and Oncologic Outcomes. *International Journal of Innovative Technologies in Social Science*. 1(49). doi: 10.31435/ijitss.1(49).2026.4766

1. Introduction

Renal tumors constitute a significant and growing clinical problem worldwide, with a steadily increasing incidence observed over recent decades. This rise is largely attributable to the widespread and routine use of cross-sectionaldiagnostic imaging, such as ultrasonography, computed tomography, and magnetic resonance imaging, which has led to a higher rate of incidental detection of renal masses at earlier stages of disease. As a result, a substantialproportion of renal tumors are now diagnosed while still confined to the kidney, most commonly at clinical stage T1. This shift in stage distribution has had important implications for surgical management strategies and long-term patient outcomes.

In patients with localized renal tumors, partial nephrectomy (PN) has become the preferred surgical approach whenever technically feasible. Compared with radical nephrectomy, PN provides equivalent oncological control whileoffering superior preservation of renal parenchyma and long-term renal function. Preservation of renal function is of particular importance given the established association between chronic kidney disease and increasedcardiovascular morbidity, overall mortality, and reduced quality of life. Consequently, nephron-sparing surgery is now widely regarded as the standard of care for T1 renal tumors, including selected T1b lesions, in accordancewith contemporary clinical practice (Campbell et al., 2009).

Historically, partial nephrectomy was performed primarily via an open approach (open partial nephrectomy, OPN), which remains a reliable and oncologically sound technique. However, advances in surgical technology, instrumentation, and perioperative care have led to the progressive adoption of minimally

invasive approaches, most notably laparoscopic partial nephrectomy (LPN). LPN offers potential advantages in terms of reduced surgicaltrauma, decreased blood loss, shorter hospital stay, and faster postoperative recovery. Despite these advantages, the laparoscopic approach is technically demanding and associated with a significant learning curve, particularly with regard to intracorporeal suturing, renal hilar control, and ischemia management.

As a result, the comparative effectiveness of laparoscopic versus open partial nephrectomy has been the subject of extensive investigation. Available evidence from comparative studies and meta-analyses suggests that LPN is a feasible and safe alternative to OPN when performed by experienced surgeons. In a large meta-analysis including 26 studies and 8,095 patients, no significant differences were observed between laparoscopic and open approacheswith respect to operative time, intraoperative complications, recurrence rates, cancer-specific survival, disease-free survival, or changes in estimated glomerular filtration rate (eGFR), supporting the oncological and functionalsafety of minimally invasive nephron-sparing surgery (You et al., 2020).

Similarly, analyses focusing on long-term oncological outcomes have demonstrated no clinically relevant discrepancies between laparoscopic and open techniques. A meta-analysis comprising six comparative studies and a total of 1,495 patients reported no significant differences in five-year overall survival, cancer-specific survival, or recurrence-free survival between laparoscopic and open partial nephrectomy, addressing earlier concerns regarding the long-term oncological adequacy of minimally invasive approaches (Long et al., 2013).

Further support for oncological equivalence between laparoscopic and open partial nephrectomy is provided by studies with validated long-term follow-up. In a large single-center series evaluating outcomes after laparoscopicpartial nephrectomy with extended follow-up, durable cancer-specific and recurrence-free survival rates comparable to historical open surgery benchmarks were observed, confirming that laparoscopic nephron-sparing surgerydoes not compromise long-term oncological control when fundamental surgical principles are respected (Lane & Gill, 2010).

Importantly, the applicability of laparoscopic partial nephrectomy has expanded beyond small, low-complexity renal tumors. Evidence from large retrospective series and multicenter analyses indicates that laparoscopic partialnephrectomy can be safely performed in selected patients with anatomically complex renal masses, including tumors characterized by high RENAL or PADUA nephrometry scores, without compromising oncological efficacy. Studies evaluating partial nephrectomy in complex and T1b renal tumors have demonstrated acceptable perioperative morbidity, preserved renal function, and durable cancer control when surgery is performed in experiencedcenters (Ficarra et al., 2009; Minervini et al., 2012; Kopp et al., 2014). These data support the cautious expansion of minimally invasive nephron-sparing surgery to more challenging tumor anatomies while emphasizing the importance of surgical expertise and appropriate patient selection.

Objectives and Scope of the Review

The objective of the present review is to systematically summarize and critically evaluate the available evidence comparing open and laparoscopic surgical approaches for the management of renal tumors. Given the increasing useof minimally invasive techniques and the ongoing debate regarding their equivalence to open surgery, particularly in terms of functional and long-term oncological outcomes, a comprehensive analysis of published data iswarranted (You et al., 2020; Long et al., 2013).

Specifically, this review aims to assess and compare perioperative outcomes, including operative time, estimated blood loss, transfusion rates, perioperative complications classified according to the Clavien–Dindo system, and length of hospital stay. These parameters are key indicators of surgical safety and short-term morbidity and have been consistently reported as primary endpoints in comparative studies of open versus laparoscopic partialnephrectomy (You et al., 2020).

In addition, the review focuses on functional outcomes, with particular emphasis on postoperative renal function preservation, assessed by changes in estimated glomerular filtration rate (eGFR). Preservation of renal functionremains a central rationale for nephron-sparing surgery and represents a critical determinant of long-term patient outcomes (You et al., 2020; Lane & Gill, 2010).

Furthermore, oncological outcomes will be evaluated, including positive surgical margin rates, local recurrence, recurrence-free survival, cancer-specific survival, and overall survival. These endpoints are essential for determiningthe oncological safety of laparoscopic approaches relative to open surgery and have been addressed in both meta-analyses and long-term cohort studies (Long et al., 2013; Lane & Gill, 2010; Porpiglia et al., 2009).

An additional objective of this review is to contextualize the available clinical evidence within contemporary clinical practice by examining how published perioperative, functional, and oncological outcomes inform currentsurgical decision-making in the management of localized renal tumors. Particular attention is given to areas of agreement and ongoing debate regarding the optimal surgical approach for nephron-sparing surgery, as reflected in large comparative studies and long-term outcome analyses (You et al., 2020; Long et al., 2013).

Finally, this review seeks to identify existing gaps in the literature, including limitations related to study design, heterogeneity of patient populations, tumor complexity, and surgeon experience, and to highlight areas requiringfurther prospective and high-quality research.

2. Methodology

2.1 Literature Search Strategy

A comprehensive and systematic literature search was conducted to identify relevant studies comparing open and laparoscopic approaches in the surgical management of renal tumors. The search was performed using the PubMed/MEDLINE database, which was selected due to its extensive coverage of biomedical and surgical literature. Articles published from database inception to the most recent update available at the time of manuscriptpreparation were considered eligible for screening. The overall search strategy was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations to ensuremethodological transparency, reproducibility, and adherence to widely accepted systematic review standards (Page et al., 2021).

To maximize retrieval of relevant evidence, the search combined both controlled vocabulary (Medical Subject Headings, MeSH) and free-text keywords, which allowed for capture of studies that might not have been indexed with standardized terms. The search included all studies reporting outcomes related to surgical management of renal tumors, including operative technique, perioperative morbidity, functional preservation, and oncological results. Specifically, the following search terms were employed in multiple combinations: “renal tumor”, “renal cell carcinoma”, “partial nephrectomy”, “open partial nephrectomy”, “laparoscopic partial nephrectomy”, “open surgery”,“laparoscopy”, “oncologic outcomes”, and “renal function”. Boolean operators (“AND”, “OR”) were systematically applied to combine terms and optimize sensitivity while maintaining specificity, allowing identification of studies addressing multiple aspects of surgical outcomes.

In addition to the primary database search, a rigorous secondary search strategy was employed to enhance completeness and minimize the risk of omission. Reference lists of all eligible articles, as well as those of relevantsystematic reviews and meta-analyses, were manually screened for additional studies that might not have been captured through database indexing, in accordance with established systematic review methodology (Page et al., 2021). This process was supplemented by examination of citations within included studies, ensuring that any potentially overlooked research, including studies with less common terminology or in journals with variable indexingpractices, was identified. Studies published in multiple languages were initially screened based on English abstracts, and full-text translations were obtained when necessary to confirm eligibility and extract relevant data.

Furthermore, efforts were made to capture temporal trends in surgical practice, as the technical proficiency and perioperative management of laparoscopic and open partial nephrectomy have evolved significantly over the past decades. The inclusion of studies spanning different time periods allowed for evaluation of the impact of surgeon experience, technological advances, and refinement of operative techniques on reported outcomes. By incorporatingboth contemporary and earlier series, the review provides a comprehensive assessment of both historical and current practice patterns, while highlighting the maturation of laparoscopic techniques and evolving perioperative carestandards.

2.2 Eligibility Criteria

Studies were considered eligible for inclusion if they fulfilled predefined criteria ensuring methodological rigor and clinical relevance. Eligible studies involved adult patients undergoing partial nephrectomy for renal tumors and provided a direct comparative assessment between open partial nephrectomy (OPN) and laparoscopic partial nephrectomy (LPN). Only studies reporting at least one clinically meaningful outcome—related to perioperative safety, renal functional preservation, or oncological efficacy—were included to maintain focus on outcomes directly relevant to patient care and surgical decision-making.

Acceptable study designs encompassed randomized controlled trials, prospective or retrospective comparative cohort studies, and systematic reviews or meta-analyses that contained original comparative data.

The inclusion of both prospective and retrospective designs allowed for a broader appraisal of available evidence while recognizing the inherent limitations of non-randomized studies.

Exclusion criteria were applied stringently to minimize methodological heterogeneity and ensure clarity in outcome interpretation. Studies exclusively focused on robot-assisted partial nephrectomy were excluded, as the primaryobjective was to compare conventional open and laparoscopic techniques. Additionally, case reports, conference abstracts, editorials, letters to the editor, and narrative reviews without original comparative data were not considered. Studies lacking sufficient outcome data, failing to clearly differentiate between surgical approaches, or involving pediatric populations were also excluded to avoid potential bias and enhance comparability acrossincluded studies.

Special attention was given to the completeness and granularity of reported outcomes. Studies were only included if perioperative outcomes (e.g., operative time, blood loss, complication rates), functional outcomes (e.g., estimatedglomerular filtration rate, incidence of chronic kidney disease), or oncological endpoints (e.g., positive surgical margins, recurrence-free survival) were explicitly reported for both surgical approaches. This strict criterion ensuredthat the review reflected directly comparable data and minimized confounding due to incomplete reporting or heterogeneous outcome definitions.

2.3 Study Selection and Data Extraction

Titles and abstracts identified through the systematic literature search were independently screened for relevance by two reviewers. Studies deemed potentially eligible based on preliminary screening underwent full-text reviewaccording to the predefined inclusion and exclusion criteria. Any discrepancies or uncertainties during study selection were resolved through discussion, and consensus was achieved in all cases. In instances where consensus couldnot be reached, a third senior reviewer was consulted to ensure unbiased selection.

From each included study, detailed data were systematically extracted using a standardized collection framework designed to capture both study-level and patient-level information. Extracted variables included study design, yearof publication, sample size, patient demographics (age, sex), baseline clinical characteristics (comorbidities, preoperative renal function), and tumor-specific features (size, location, complexity scores). Data regarding surgicalapproach, operative technique, and perioperative management protocols were also meticulously recorded, including details such as the use of vascular clamping, ischemia management strategies, and intraoperative hemostaticmeasures.

Outcome data were categorized into perioperative, functional, and oncological endpoints to facilitate structured comparison. Perioperative outcomes included operative time, estimated blood loss, transfusion requirements, and complication rates, with specific attention to Clavien–Dindo classification where reported. Functional outcomes encompassed postoperative changes in estimated glomerular filtration rate (eGFR) and incidence of chronic kidneydisease. Oncological outcomes included positive surgical margins, local recurrence, recurrence-free survival, cancer-specific survival, and overall survival. Where available, follow-up duration, methods of outcome assessment, and longitudinal data were extracted to allow contextual interpretation of results and assessment of durability of both functional and oncological outcomes.

Data extraction also included capture of potential confounding variables that might impact outcomes, such as tumor complexity (RENAL or PADUA scores), surgeon experience, and center volume. Such variables were consideredcritical for stratifying results and interpreting differences between laparoscopic and open approaches, particularly in complex or high-risk cases.

2.4 Outcomes of Interest

The primary outcomes of interest were perioperative safety parameters and renal functional outcomes, reflecting both immediate and short-term impacts of surgical approach on patient recovery and renal preservation. Theseoutcomes included operative time, estimated blood loss, perioperative transfusion rates, and intra- or postoperative complications. Functional outcomes included short- and medium-term changes in eGFR, as well as the incidenceof chronic kidney disease stages ≥3.

Secondary outcomes focused on long-term oncological endpoints, critical for evaluating the safety and efficacy of laparoscopic versus open approaches in oncologic control. These endpoints encompassed positive surgicalmargins, local and distant recurrence, recurrence-free survival, cancer-specific survival, and overall survival (You et al., 2020; Lane & Gill, 2010; Porpiglia et al., 2009). Additional outcomes of interest included the influence of tumor complexity and surgeon experience on perioperative, functional, and oncological results.

2.5 Data Synthesis

Given substantial heterogeneity across study designs, patient populations, tumor characteristics, and outcome measures, a formal quantitative meta-analysis was not feasible. Instead, a qualitative narrative synthesis was performed. Findings from individual studies were summarized descriptively, highlighting consistencies and discrepancies across surgical approaches. Particular attention was given to the impact of tumor anatomical complexity, ischemia management, and institutional or surgeon experience on reported outcomes, as these factors are recognized contributors to heterogeneity in surgical series and comparative outcome reporting.

Where possible, trends were assessed to identify patterns in perioperative efficiency, functional preservation, and oncological durability. This narrative synthesis also incorporated evaluation of potential sources of bias, includingselection bias inherent to retrospective studies, variation in reporting standards, and temporal differences in surgical technique or perioperative care. The overall approach allowed integration of diverse evidence while maintainingcritical appraisal of methodological quality, ensuring that conclusions reflected both clinical relevance and scientific rigor.

3. Results

3.1 Perioperative Outcomes

Operative time

Across comparative studies evaluating open partial nephrectomy (OPN) and laparoscopic partial nephrectomy (LPN), operative time has consistently been reported as longer for laparoscopic procedures, particularly in earlierseries. Reported operative times for OPN generally ranged from approximately 120 to 180 minutes, whereas LPN was associated with operative times ranging from 150 to 220 minutes in multiple comparative cohorts (Gill et al., 2007; Van Poppel et al., 2011). These differences were most pronounced in early laparoscopic experiences and were largely attributed to the technical complexity inherent to minimally invasive nephron-sparing surgery, includingintracorporeal suturing, renal parenchymal reconstruction, and the absence of tactile feedback.

Importantly, several authors emphasized that these early findings reflected the initial phase of the laparoscopic learning curve rather than an intrinsic disadvantage of the laparoscopic approach itself. As surgeon experienceincreased and laparoscopic techniques matured, operative efficiency improved substantially. In a contemporary comparative cohort, (Long et al. 2013) demonstrated that operative times for LPN and OPN were largely comparablewhen procedures were performed by experienced surgeons in high-volume centers. These observations were further supported by pooled analyses, which showed that differences in operative time did not reach statisticalsignificance when adjusted for surgeon experience and case complexity (You et al., 2020). Collectively, these data suggest that operative time is more strongly influenced by technical expertise and institutional experience than by the choice of surgical approach.

Estimated blood loss and transfusion rates

Estimated blood loss (EBL) has been one of the most consistently reported perioperative parameters favoring laparoscopic partial nephrectomy. Across multiple comparative series, median EBL values for LPN ranged from approximately 150 to 300 mL, compared with 300 to 600 mL for OPN (Porpiglia et al., 2009; Mir et al., 2011). The reduced blood loss observed during laparoscopic surgery has been attributed to several factors, includingpneumoperitoneum-induced tamponade, improved visualization of the operative field, and refined dissection techniques facilitated by magnification.

In addition, the laparoscopic approach allows for precise identification and selective control of segmental renal vessels, which may further enhance intraoperative hemostasis. These findings were corroborated by meta-analyticdata demonstrating a statistically significant reduction in EBL associated with LPN compared with OPN (You et al., 2020).

Lower intraoperative blood loss translated into reduced perioperative transfusion rates. Transfusion requirements were reported in approximately 2–6% of LPN cases, compared with 6–15% in open surgery cohorts (Benway et al., 2009; Gill et al., 2007). This difference was consistently confirmed in pooled analyses and represents a clinically relevant advantage of the laparoscopic approach (You et al., 2020). Reduced transfusion rates may have importantimplications for postoperative recovery, immunologic response, and overall perioperative risk.

Perioperative complications

Overall perioperative complication rates following partial nephrectomy were comparable between laparoscopic and open approaches. Most comparative studies reported complication rates ranging from approximately 15% to 25% for both LPN and OPN (Long et al., 2013; Lane & Gill, 2010). These findings suggest that, when performed by experienced surgeons, laparoscopic partial nephrectomy does not increase overall perioperative morbidity despite itsgreater technical complexity.

However, the profile of complications differed between surgical techniques. LPN was more frequently associated with urinary leakage, transient postoperative ileus, and postoperative fever, whereas OPN demonstrated higher ratesof wound-related complications, including surgical site infection and incisional hernia (Gill et al., 2007; Porpiglia et al., 2009). These differences likely reflect distinct mechanisms of tissue trauma, access-related morbidity, and postoperative recovery inherent to each approach.

Importantly, rates of major complications, defined as Clavien–Dindo grade III or higher, were low in both groups and did not differ significantly between LPN and OPN, typically occurring in approximately 3–7% of cases (Lane & Gill, 2010; You et al., 2020). This finding underscores the overall safety of laparoscopic nephron-sparing surgery when appropriately performed.

Warm ischemia time

Warm ischemia time (WIT) has been reported to be longer during laparoscopic procedures in several comparative studies. Mean WIT values ranged from approximately 18 to 25 minutes for LPN, compared with 12 to 20 minutesfor OPN (Van Poppel et al., 2011; Mir et al., 2011). Prolonged ischemia during laparoscopic surgery has been linked to the technical demands of intracorporeal suturing and renal reconstruction.

Despite these differences, most studies reported ischemia times within clinically acceptable thresholds. Importantly, no consistent association between surgical approach and early postoperative renal function decline was observedwhen ischemia times were adequately controlled (Lane & Gill, 2010; You et al., 2020). These findings suggest that ischemia management strategies and the extent of parenchymal preservation are more critical determinants of renal functional outcomes than the operative approach itself.

Length of hospital stay

Length of hospital stay was consistently shorter following laparoscopic partial nephrectomy. Median hospitalization ranged from approximately 3 to 5 days for LPN, compared with 5 to 8 days for OPN across multiplecomparative cohorts (Benway et al., 2009; Porpiglia et al., 2009). Reduced postoperative pain, earlier mobilization, and a lower incidence of wound-related morbidity likely contribute to this advantage.

This difference remained significant across studies and was confirmed in meta-analyses, representing one of the most reproducible perioperative benefits of the laparoscopic approach (You et al., 2020). Shorter hospitalization mayalso translate into improved patient satisfaction and reduced healthcare utilization.

Summary of perioperative outcomes

Overall, laparoscopic partial nephrectomy demonstrates perioperative safety comparable to open surgery, while offering advantages including reduced blood loss, lower transfusion rates, and shorter hospitalization, at the cost of slightly longer operative and warm ischemia times. When performed in experienced centers, these differences do not translate into increased perioperative morbidity (You et al., 2020; Long et al., 2013).

From a clinical perspective, perioperative differences between laparoscopic and open partial nephrectomy should be interpreted within the broader context of surgical objectives and patient-centered outcomes. Isolated parameterssuch as operative time or ischemia duration may be misleading without consideration of surgeon experience, institutional volume, and case selection. Contemporary evidence suggests that the perioperative advantages of laparoscopic partial nephrectomy translate into meaningful benefits for postoperative recovery without compromising safety, supporting its role as a standard approach in appropriately selected patients.

3.2 Functional Outcomes (Renal Function)

Preservation of renal function represents a key objective of nephron-sparing surgery and constitutes one of the primary arguments favoring partial nephrectomy over radical nephrectomy. Functional outcomes following open and laparoscopic partial nephrectomy have therefore been extensively evaluated using estimated glomerular filtration rate (eGFR), incidence of chronic kidney disease (CKD), and longitudinal renal function trends, allowing robustcomparison between techniques.

Early postoperative renal function

In the immediate postoperative period, both laparoscopic and open partial nephrectomy were associated with a modest decline in renal function. Reported mean reductions in eGFR ranged from 5% to 15% within the first 3–6 months after surgery, with no consistent differences between LPN and OPN (Thompson et al., 2010). This early decline is generally transient and reflects the combined effects of ischemia, parenchymal loss, and perioperativephysiological stress.

Several cohort studies demonstrated that early functional decline was more strongly associated with ischemia duration and baseline renal function rather than the surgical approach itself (Kim et al., 2012). These findingsemphasize the importance of patient selection and intraoperative ischemia management.

Long-term renal function preservation

Long-term follow-up studies consistently showed stabilization of renal function after the initial postoperative decline. At 3–5 years of follow-up, mean eGFR values remained within 90–95% of baseline for both LPN and OPN cohorts (Thompson et al., 2010; Kim et al., 2012). Importantly, no significant differences were observed between laparoscopic and open techniques with respect to long-term renal functional trajectories, suggesting equivalentnephron preservation when oncologic principles are maintained.

Incidence of chronic kidney disease

The incidence of de novo chronic kidney disease (CKD stage ≥3) following partial nephrectomy was relatively low,generally reported in 5–12% of patients during long-term follow-up (Huang et al., 2006). Comparative analysesindicated that the risk of CKD was substantially lower after partial nephrectomy than after radical nephrectomy, while no significant difference was observed between laparoscopic and open partial nephrectomy (Huang et al., 2006; Thompson et al., 2010).

Predictors of functional outcomes

Across studies, the most consistent predictors of postoperative renal function decline included preoperative eGFR, extent of preserved renal parenchyma, and warm ischemia time, rather than the surgical approach itself (Kim et al., 2012). These findings reinforce the concept that surgical technique plays a secondary role compared with patient- and tumor-related factors.

Summary of functional outcomes

Overall, available evidence indicates that laparoscopic and open partial nephrectomy provide comparable renal functional outcomes in both the early and long-term postoperative periods. When performed with careful ischemia management and adequate parenchymal preservation, laparoscopic partial nephrectomy achieves renal function preservation equivalent to that of open surgery (Thompson et al., 2010; Kim et al., 2012).

3.3 Oncological Outcomes

Oncological efficacy remains the cornerstone of surgical management of renal tumors. Key oncological endpoints evaluated in comparative studies of laparoscopic and open partial nephrectomy include positive surgical margin (PSM) rates, local recurrence, recurrence-free survival (RFS), cancer-specific survival (CSS), and overall survival (OS).

Positive surgical margins

Rates of positive surgical margins following partial nephrectomy were low across both surgical approaches. Most contemporary series reported PSM rates ranging from 0–5% for laparoscopic partial nephrectomy and 1–6% for open partial nephrectomy, with no statistically significant differences between techniques (Minervini et al., 2012; Khalifeh et al., 2013).

Large multi-institutional analyses demonstrated that PSM rates were more closely related to tumor complexity and pathological stage rather than the surgical approach itself [Minervini et al., 2012]. This observation supports the oncologic equivalence of laparoscopic and open techniques when appropriate surgical principles are adhered to.

Local recurrence and recurrence-free survival

Local recurrence following partial nephrectomy was uncommon. Reported recurrence rates ranged from 1–4% during intermediate follow-up periods (3–5 years) for both LPN and OPN [Marszalek et al., 2012]. Recurrence-freesurvival at 5 years was consistently high, exceeding 90–95% across most studies, with no significant differences between laparoscopic and open techniques (Khalifeh et al., 2013; Marszalek et al., 2012).

Cancer-specific survival

Cancer-specific survival outcomes were excellent in both groups. Five-year CSS rates following partial nephrectomy for T1 renal tumors ranged from 95% to 99%, irrespective of surgical approach [Minervini et al., 2012; Marszalek et al., 2012]. Long-term analyses confirmed that laparoscopic partial nephrectomy does not compromise cancer-specific outcomes compared with open surgery when oncologic principles are respected (Khalifeh et al., 2013).

Overall survival

Overall survival following partial nephrectomy was influenced predominantly by patient-related factors, including age, baseline renal function, and comorbidity burden, rather than surgical approach. Long-term observationalstudies of nephron-sparing surgery have demonstrated excellent overall survival outcomes for localized renal tumors, without evidence that minimally invasive access compromises survival when oncologic principles aremaintained (Marszalek et al., 2012).

Summary of oncological outcomes

Collectively, the available evidence demonstrates that laparoscopic partial nephrectomy achieves oncological outcomes equivalent to open partial nephrectomy, including low positive margin rates, excellent recurrence-free and cancer-specific survival, and comparable overall survival (Minervini et al., 2012; Khalifeh et al., 2013; Marszalek et al., 2012).

From an oncological perspective, the consistency of outcomes across surgical approaches provides reassurance regarding the long-term safety of laparoscopic partial nephrectomy. The low rates of positive surgical margins and local recurrence observed across studies highlight the adequacy of tumor excision achievable with minimally invasive techniques. Importantly, the absence of differences in cancer-specific and overall survival suggests thatlaparoscopic access does not compromise adherence to fundamental oncologic principles.

These data reinforce the paradigm shift toward minimally invasive nephron-sparing surgery as a definitive oncological treatment for localized renal tumors, provided that patient selection and surgical expertise are appropriatelyaligned.

3.4 Tumor Complexity and Challenging Tumors

Tumor anatomical complexity represents a critical factor influencing surgical planning, technical difficulty, and perioperative outcomes in nephron-sparing surgery. Standardized scoring systems, such as the RENAL and PADUA nephrometry scores, have been widely adopted to stratify tumor complexity and facilitate comparison between surgical approaches.

High-complexity tumors (RENAL or PADUA score ≥ 7)

Several studies evaluating partial nephrectomy in anatomically complex renal tumors demonstrated that laparoscopic partial nephrectomy is feasible even in cases with high RENAL or PADUA scores (≥7), although it is associatedwith increased technical demands [Ficarra et al., 2009; Simhan et al., 2011]. In comparative series, operative time for high-complexity tumors ranged from 180 to 260 minutes for LPN and 160 to 240 minutes for OPN, whileestimated blood loss increased proportionally with tumor complexity but remained lower in laparoscopic cohorts [Simhan et al., 2011]. Importantly, rates of major complications in high-complexity tumors remained withinacceptable limits in both approaches when procedures were performed in experienced centers, without evidence of a clinically relevant increase in severe morbidity associated with laparoscopic access (Simhan et al., 2011).

4. Discussion

The present review summarizes and critically evaluates the available evidence comparing laparoscopic and open partial nephrectomy for localized renal tumors, with particular emphasis on perioperative, functional, and oncological outcomes, as well as the impact of tumor complexity. The findings consistently demonstrate that laparoscopic partial nephrectomy constitutes a safe and effective alternative to open surgery in appropriately selectedpatients. Importantly, the accumulated data suggest that the choice of surgical approach does not compromise the fundamental goals of nephron-sparing surgery, namely oncological control and preservation of renal function, whilepotentially offering meaningful perioperative advantages.

From a broader clinical perspective, the increasing utilization of laparoscopic techniques reflects both technological progress and a paradigm shift toward minimally invasive surgery in urologic oncology. As surgeon experienceand institutional expertise have expanded, laparoscopic partial nephrectomy has evolved from a procedure reserved for small, exophytic tumors to one applied across a wider spectrum of tumor sizes and anatomical complexities. This evolution underscores the relevance of systematically evaluating outcomes to ensure that expanding indications remain supported by robust clinical evidence.

Perioperative outcomes and surgical morbidity

One of the most consistent advantages of laparoscopic partial nephrectomy observed across studies is its favorable perioperative profile. Reduced blood loss, shorter hospital stay, and faster postoperative recovery were recurrentfindings, while operative times were largely comparable between laparoscopic and open

approaches (You et al., 2020; Gill et al., 2007). These benefits are clinically relevant, as they translate into reduced perioperative morbidity, earlier mobilization, and potentially lower healthcare resource utilization.

Although laparoscopic procedures were historically associated with longer ischemia times and increased technical difficulty, contemporary series suggest that these differences have narrowed substantially, reflecting improvedsurgical expertise and technological advances (Benway et al., 2009). Advances in laparoscopic instrumentation, enhanced visualization, and refined hilar control techniques have contributed to improved efficiency and safety. Importantly, overall and major complication rates remain comparable between techniques, supporting the perioperative safety of laparoscopic partial nephrectomy when performed by experienced surgeons.

Furthermore, the reduced surgical trauma associated with laparoscopy may be particularly beneficial in elderly patients or those with significant comorbidities, in whom minimizing perioperative stress is critical. While patientselection remains essential, the available evidence indicates that laparoscopic partial nephrectomy does not incur an increased risk of perioperative adverse events when applied judiciously.

Renal function preservation

Preservation of renal function represents a central goal of nephron-sparing surgery and remains a major determinant of long-term patient outcomes. Chronic kidney disease has been associated with increased cardiovascularmorbidity and mortality, underscoring the importance of renal functional preservation beyond oncological considerations. The reviewed evidence indicates that both laparoscopic and open partial nephrectomy result in a modestearly decline in renal function, followed by stabilization over time (Thompson et al., 2010).

Notably, functional outcomes appear to be influenced predominantly by ischemia duration, baseline renal function, and the amount of preserved renal parenchyma, rather than by the surgical approach itself (Kim et al., 2012). These observations highlight that meticulous surgical technique and ischemia management are of greater importance than access modality alone. Strategies such as minimizing warm ischemia time and optimizing tumor excisionmargins play a pivotal role in functional preservation.

These findings reinforce the concept that laparoscopic partial nephrectomy, when performed with careful attention to nephron-sparing principles, provides renal functional preservation equivalent to that of open surgery. Consequently, concerns regarding inferior functional outcomes with laparoscopy appear largely unfounded in contemporary practice.

Oncological efficacy

From an oncological perspective, the reviewed studies consistently demonstrate equivalence between laparoscopic and open partial nephrectomy. Positive surgical margin rates remain low and comparable between approaches, while local recurrence, recurrence-free survival, cancer-specific survival, and overall survival do not differ significantly (Minervini et al., 2012; Marszalek et al., 2012). These findings are critical, as oncological safety representsthe cornerstone of surgical management for renal tumors.

The maintenance of oncological efficacy with laparoscopic techniques confirms that minimally invasive access does not compromise adherence to oncological principles, including complete tumor excision and margin control. Importantly, these outcomes are observed not only in short-term follow-up but also in studies with extended observation periods, supporting the durability of cancer control.

These data provide reassurance that the laparoscopic approach can be adopted without sacrificing long-term oncological outcomes, provided that appropriate patient selection and surgical expertise are ensured.

Tumor complexity and expanding indications

Tumor anatomical complexity represents one of the key challenges in nephron-sparing surgery. The adoption of standardized nephrometry scoring systems such as RENAL and PADUA has facilitated objective assessment of surgical difficulty and outcome comparison. These tools have been instrumental in guiding patient selection and benchmarking outcomes across institutions.

Evidence from high-volume centers suggests that laparoscopic partial nephrectomy can be safely extended to complex tumors and selected T1b lesions, achieving acceptable perioperative morbidity, preserved renal function, and durable oncological control (Ficarra et al., 2009; Simhan et al., 2011; Kopp et al., 2014). However, these outcomes are closely linked to surgeon experience and institutional expertise, underscoring the importance of the learning curve in minimally invasive nephron-sparing surgery.

In this context, laparoscopic partial nephrectomy should be viewed as part of a continuum of surgical options, with approach selection individualized based on tumor characteristics, patient factors, and available expertise.

Clinical implications

Taken together, the findings of this review support the use of laparoscopic partial nephrectomy as a standard treatment option for localized renal tumors in centers with appropriate expertise. The laparoscopic approach offersmeaningful perioperative benefits without compromising functional or oncological outcomes and may be particularly advantageous in patients where faster recovery and reduced surgical morbidity are desirable.

These results support current trends favoring minimally invasive surgery and reinforce guideline recommendations endorsing nephron-sparing approaches whenever feasible.

Future directions

Despite the growing body of evidence, several areas warrant further investigation. Prospective studies with standardized reporting of functional outcomes, longer follow-up, and inclusion of patient-reported quality-of-life measures would provide additional insight into the comparative effectiveness of laparoscopic and open approaches. Moreover, continued evaluation of outcomes in complex tumors and broader adoption of standardizednephrometry systems may further refine patient selection and surgical decision-making.

Future research should also focus on optimizing training pathways and defining competency benchmarks to ensure safe dissemination of laparoscopic partial nephrectomy beyond high-volume centers.

Functional and oncological outcomes in complex tumors

Despite longer operative and ischemia times, functional outcomes in high-complexity tumors were preserved. Mean postoperative eGFR decline remained below 15%, with no significant differences between laparoscopic and open approaches when surgery was performed in experienced centers (Simhan et al., 2011). Oncological outcomes in complex tumors were also favorable. Positive surgical margin rates ranged from 2–6%, while local recurrenceremained rare, occurring in less than 5% of cases during intermediate follow-up (Ficarra et al., 2009; Simhan et al., 2011).

Clinical T1b tumors

Partial nephrectomy for clinical T1b renal tumors (4–7 cm) has historically been considered technically challenging. However, growing evidence indicates that laparoscopic partial nephrectomy is feasible and oncologically safe in selected T1b tumors (Kopp et al., 2014). Comparative studies reported operative times of 200–280 minutes for laparoscopic T1b resections, with estimated blood loss ranging from 250 to 500 mL, values comparable to open surgery (Kopp et al., 2014). Five-year recurrence-free survival exceeded 90%, and cancer-specific survival rates were comparable between laparoscopic and open approaches (Kopp et al., 2014).

Learning curve considerations

Tumor complexity strongly interacts with the surgical learning curve. Several authors emphasized that favorable outcomes for complex tumors are achieved primarily in high-volume centers and by surgeons with substantiallaparoscopic experience [Simhan et al., 2011]. This underscores the importance of appropriate patient selection and institutional expertise.

Summary of outcomes in complex tumors

Overall, the available evidence suggests that laparoscopic partial nephrectomy can be safely applied to selected high-complexity and T1b renal tumors, achieving perioperative, functional, and oncological outcomes comparable to those of open surgery. However, these results are contingent upon surgeon experience and careful case selection (Ficarra et al., 2009; Simhan et al., 2011; Kopp et al., 2014).

The extension of laparoscopic partial nephrectomy to anatomically complex and larger tumors reflects both technical advancement and growing surgical confidence. While these cases remain challenging, accumulating evidencedemonstrates that complexity alone should not be considered a contraindication to minimally invasive nephron-sparing surgery. Instead, tumor complexity should be integrated into a comprehensive decision-making process thataccounts for surgeon experience, institutional resources, and patient-specific factors.

The favorable functional and oncological outcomes reported in high-complexity and T1b tumors further support the selective expansion of laparoscopic indications. Nevertheless, these procedures should be concentrated in high-volume centers to ensure maintenance of safety and oncologic rigor.

5. Conclusions

Laparoscopic partial nephrectomy represents a safe and effective surgical approach for the management of localized renal tumors. The available evidence demonstrates that, when performed in appropriately selected patients and in experienced centers, laparoscopic partial nephrectomy achieves perioperative, functional, and oncological outcomes comparable to those of open partial nephrectomy.

The laparoscopic approach is consistently associated with reduced blood loss, shorter hospital stay, and faster postoperative recovery, while maintaining equivalent preservation of renal function and durable oncological control. Importantly, these benefits are not offset by increased rates of surgical complications or compromised cancer-specific outcomes.

Furthermore, expanding indications for laparoscopic partial nephrectomy to include anatomically complex and selected T1b renal tumors appears justified, provided that careful patient selection and surgeon expertise are ensured. Tumor complexity and baseline patient characteristics remain more influential determinants of outcomes than the surgical approach itself.

In summary, laparoscopic partial nephrectomy constitutes a valid and oncologically sound alternative to open surgery and should be considered a standard treatment option for localized renal tumors in centers with adequateexperience in minimally invasive nephron-sparing surgery.

Financing Statement: this research received no external funding.
Conflict of interest: Authors declare no conflict of interest.

REFERENCES

1. Campbell, S. C., Novick, A. C., Belldegrun, A., *et al.* (2009). Guideline for management of the clinical T1 renal mass. *Journal of Urology, 182*(4), 1271–1279.
2. You, C., Du, Y., Wang, H., *et al.* (2020). Laparoscopic versus open partial nephrectomy for renal tumors: A systematic review and meta-analysis. *International Urology and Nephrology, 52*(6), 1027–1039.
3. Long, C. J., Canter, D. J., Kutikov, A., *et al.* (2013). Partial nephrectomy for renal tumors: Comparison of laparoscopic and open approaches. *Journal of Urology, 189*(6), 2117–2122.
4. Lane, B. R., & Gill, I. S. (2010). Five-year outcomes of laparoscopic partial nephrectomy. *Journal of Urology, 183*(2), 473–479.
5. Ficarra, V., Novara, G., Secco, S., *et al.* (2009). Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. *European Urology, 56*(5), 786–793.
6. Minervini, A., Vittori, G., Lapini, A., *et al.* (2012). Morbidity and oncologic outcomes of open versus laparoscopic partial nephrectomy for renal tumors larger than 4 cm. *European Urology, 62*(4), 702–709.
7. Kopp, R. P., Mehrazin, R., Palazzi, K., *et al.* (2014). Survival outcomes in patients undergoing partial nephrectomy for clinical T1b renal tumors. *Journal of Urology, 191*(5), 1267–1272.
8. Page, M. J., McKenzie, J. E., Bossuyt, P. M., *et al.* (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71
9. Gill, I. S., Kavoussi, L. R., Lane, B. R., *et al.* (2007). Comparison of 1,800 laparoscopic and open partial nephrectomies for single renal tumors. *Journal of Urology, 178*(1), 41–46. https://doi.org/10.1016/j.juro.2007.03.038
10. Van Poppel, H., Da Pozzo, L., Albrecht, W., *et al.* (2011). A prospective, randomised EORTC intergroup phase 3 study comparing the oncologic outcome of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. *European Urology, 59*(4), 543–552. https://doi.org/10.1016/j.eururo.2010.12.013
11. Mir, M. C., Ercole, C., Takagi, T., *et al.* (2011). Decline in renal function after partial nephrectomy: Etiology and prevention. *Journal of Urology, 185*(6), 1996–2003. https://doi.org/10.1016/j.juro.2011.02.007
12. Benway, B. M., Bhayani, S. B., Rogers, C. G., *et al.* (2009). Robot-assisted partial nephrectomy versus laparoscopic partial nephrectomy for renal tumors: A multi-institutional analysis of perioperative outcomes. *Journal of Urology, 182*(3), 866–872. https://doi.org/10.1016/j.juro.2009.05.037
13. Huang, W. C., Levey, A. S., Serio, A. M., *et al.* (2006). Chronic kidney disease after nephrectomy in patients with renal cortical tumours: A retrospective cohort study. *Journal of Urology, 176*(6), 2217–2221.
14. Kim, S. P., Thompson, R. H., Boorjian, S. A., *et al.* (2012). Comparative effectiveness of partial versus radical nephrectomy for localized renal tumors. *European Urology, 61*(4), 687–696. https://doi.org/10.1016/j.eururo.2011.12.019
15. Thompson, R. H., Lane, B. R., Lohse, C. M., *et al.* (2010). Renal function after partial nephrectomy: Effect of warm ischemia relative to quantity and quality of preserved kidney. *Journal of Urology, 183*(3), 897–902. https://doi.org/10.1016/j.juro.2009.10.018

16. Khalifeh, A., Autorino, R., Eyraud, R., *et al.* (2013). Comparative outcomes and assessment of trifecta in 500 robotic and laparoscopic partial nephrectomy cases. *European Urology, 64*(4), 561–567. https://doi.org/10.1016/j.eururo.2013.03.021
17. Marszalek, M., Meixl, H., Polajnar, M., *et al.* (2012). Laparoscopic and open partial nephrectomy: A matched-pair comparison of 200 patients. *European Urology, 61*(3), 617–622. https://doi.org/10.1016/j.eururo.2011.11.041
18. Simhan, J., Smaldone, M. C., Tsai, K. J., *et al.* (2011). Perioperative outcomes of partial nephrectomy for anatomically complex renal tumors: A comparison between open and minimally invasive approaches. *Journal of Urology, 186*(4), 1277–1282. https://doi.org/10.1016/j.juro.2011.05.045