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Review

What is the optimal approach to pediatric nephrectomy? Open versus minimally invasive surgery: A narrative review

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ABSTRACT

INTRODUCTION: Nephrectomy is a cornerstone of pediatric urologic surgery for benign renal disease. Minimally invasive surgery (MIS)—transperitoneal/retroperitoneal laparoscopy, laparoendoscopic single-site surgery (LESS), and robotic platforms—has increasingly challenged open surgery, but in children it carries technical and physiological constraints, especially in infants, due to limited working space and pneumoperitoneum effects.

OBJECTIVE: To appraise contemporary evidence on the optimal approach to pediatric nephrectomy by comparing open surgery with MIS techniques.

METHODS: A SANRA-guided narrative review searched PubMed (MEDLINE) and Embase for English-language studies (Jan 1, 2015–Dec 15, 2025). Comparative studies and systematic reviews/meta-analyses on pediatric nephrectomy and nephron-sparing procedures were included; case reports, animal studies, and oncologic indications were excluded. Outcomes included operative time, length of stay (LOS), perioperative complications, and selected resource-use measures (e.g., transfusion, costs).

RESULTS: Despite heterogeneity in indications and designs, MIS was consistently associated with shorter LOS and similar overall complication rates versus open surgery. Operative time results were mixed and depended on procedure type, access route, learning curve, and platform; robotic and LESS approaches more often showed longer operative times and higher costs. Benefits of MIS appeared less consistent in very small children and in duplex-system surgery, where ureteral stump morbidity and residual moiety function are key.

CONCLUSIONS: MIS is feasible and generally safe in selected pediatric patients and typically shortens hospitalization. The approach should be individualized, weighing recovery advantages against operative efficiency, technical complexity, and resource implications.

KEYWORDS

pediatric nephrectomy, minimally invasive surgery, open surgery, laparoscopy, robotic surgery

INTRODUCTION

Nephrectomy remains a fundamental procedure in the surgical management of pediatric renal diseases [1]. The range of reasons for removing a kidney in children is diverse and extends beyond simple non-function. It includes mitigating renin-mediated hypertension and severe proteinuria, removing infected or poorly functioning renal units, and managing severely hydronephrotic kidneys [2]. Furthermore, minimally invasive surgery (MIS) has successfully been applied to malignant pathologies. Radical laparoscopic nephrectomy is often recommended for certain pediatric renal malignancies, such as Wilms tumor or renal cell carcinoma [3].Open surgery was historically the gold standard, but the surgical landscape shifted in the early 1990s when R.M. Ehrlich and M.A. Koyle and colleagues pioneered laparoscopic nephrectomy in children and infants, respectively [4]. Since those initial reports, MIS has evolved from a novel alternative to a mainstay in pediatric urology. This transition was initially impeded by technical limitations, particularly the size of access ports and the length of adult-sized instruments relative to the pediatric abdominal cavity [5]. However, rapid technological innovation has overcome these hurdles. The development of instruments dedicated to pediatrics, ranging in size from 3 to 5 mm and further miniaturized to 2.7-mm optics and instruments (e.g., GIMMI systems), has facilitated the adoption and dissemination of these techniques, even among the youngest patients [4].

Despite technical advancements, laparoscopic surgery in children, particularly infants, presents unique challenges that distinguish it from adult surgery. These nuances are deeply rooted in pediatric physiology and anatomy [6]. The distance between the trocar access point and vital intra-abdominal structures is minimal, which increases the potential for iatrogenic injury during instrument advancement. Additionally, the physiological impact of pneumoperitoneum is more significant in children [4]. The insufflation pressure can affect the respiratory, cardiovascular, renal, and gastrointestinal systems, requiring a precise anesthetic strategy and an in-depth understanding of these interactions from the surgical team [1].

Currently, surgeons have access to a variety of approaches, including transperitoneal and retroperitoneal laparoscopy. The transperitoneal approach offers familiar anatomical landmarks, while the retroperitoneal approach, performed via flank or prone positioning, is considered a direct and elegant method for treating benign pathologies [7]. This approach takes advantage of the minimal perinephric fat found in children. In particular, the prone retroperitoneal approach utilizes gravity to facilitate exposure and allows for the ergonomic use of accessory ports. This approach avoids the peritoneal violation and potential bowel complications associated with transabdominal access [4]. Furthermore, the integration of advanced technologies, such as laparoendoscopic single-site surgery (LESS) and robotic-assisted platforms, continues to reshape the field. However, issues regarding cost and instrument size remain relevant considerations [8].

The primary objective of this narrative review is to provide a comprehensive and critical evaluation of the current evidence regarding the optimal surgical approach to pediatric nephrectomy. By synthesizing empirical data drawn from the last decade (2015-2025), this study aims to systematically compare the efficacy, safety profile, and perioperative outcomes of traditional open surgery against the spectrum of minimally invasive techniques, including transperitoneal laparoscopy, retroperitoneoscopy, and emerging robotic platforms. Particular attention is devoted to dissecting the physiological and technical nuances unique to this age group, such as the cardiorespiratory impact of pneumoperitoneum and the challenges of working within a restricted anatomical domain. Ultimately, this review seeks to balance the well-documented benefits of MIS such as enhanced cosmesis, reduced postoperative pain, and shorter hospitalization against potential trade-offs involving operative duration, the learning curve, and economic implications, thereby offering a practical synthesis to guide clinical decision-making in the modern era.

METHODS

A narrative literature review was conducted in accordance with the SANRA guidelines [9] for narrative reviews, by searching two leading medical databases: PubMed (MEDLINE) and Embase. Publications released between 1 January 2015 and 15 December 2025 were eligible for analysis. Restricting the timeframe to the last decade was justified by rapid technological advances in the miniaturization of endoscopic instruments and by the evolution of anesthetic protocols in children.

Keywords and search strategy

To identify relevant articles, we used combinations of English-language keywords and controlled vocabulary terms (MeSH for PubMed and Emtree for Embase). Searches were built using Boolean operators (AND, OR), integrating four principal thematic domains:

- **Population:** newborns, children, neonatans.
- **Intervention:** minimally invasive surgery, laparoscopy, retroperitoneoscopy.
- **Comparator:** open surgery, flank incision (lumbotomy).
- **Clinical domain:** urology, hydronephrosis, pyeloplasty, nephrectomy.

The following search strings were applied:

1. **PubMed query:**
   ("Infant"[Mesh] OR "Newborn" OR "Neonate" OR “Child”) AND ("Nephrectomy"[Mesh] OR "Heminephrectomy" OR "Nephroureterectomy") AND ("Laparoscopy"[Mesh] OR "Minimally Invasive Surgical Procedures"[Mesh] OR "Retroperitoneoscopy") AND ("Open Surgery" OR "Comparative Study" OR "Treatment Outcome") AND ("2015/01/01"[Date - Publication] : "2025/12/31"[Date - Publication])
2. **Embase query:** *(syntax incorporating the Emtree hierarchy and title/abstract field searching)*
   ('newborn'/exp OR 'infant'/exp OR 'neonate' OR “child’:ti,ab) AND ('nephrectomy'/exp OR 'heminephrectomy'/exp OR 'nephroureterectomy'/exp) AND ('minimally invasive surgery'/exp OR 'laparoscopy'/exp OR 'retroperitoneoscopy':ti,ab) AND ('open surgery'/exp OR 'comparative study'/exp OR 'safety':ti,ab) AND [2015-2025]/py

Study selection

Study selection was performed in two stages: initial screening of titles and abstracts, followed by full-text assessment.

Inclusion and exclusion criteria

Preliminary eligibility was determined based on title and abstract review.

Included were:

- Comparative studies (retrospective and prospective) evaluating outcomes of open versus minimally invasive techniques.
- Meta-analyses and systematic reviews involving pediatric populations.
- Studies describing transperitoneal, retroperitoneal (retroperitoneoscopic), and robotic techniques.
- English-language publications.

Excluded were:

- Single case reports, due to limited evidentiary strength.
- Studies addressing oncologic surgery (e.g., Wilms tumor), where the surgical approach is primarily dictated by oncologic protocols rather than technical considerations alone.
- Animal studies.
- Articles in which relevant subgroup data were not reported separately.

Data extraction and endpoints

The following clinical parameters were extracted and analyzed: operative time, age, weight, length of stay (LOS), and complications.

RESULTS

The evidence summarized in Table I comprised comparative observational studies and evidence syntheses published between 2015 and 2025, including: a one large retrospective cohort, four retrospective comparative series, an analysis of a prospective robotic series, and three systematic reviews/meta-analyses. Study sizes ranged from 52 to 3494 participants, with the largest nephrectomy-focused cohort including 2629 children [2]. Included populations spanned infancy through adolescence.

Table I. Evidence comparing open and minimally invasive pediatric nephrectomy

Literature	Study Design	Study Population / Groups	Age / Weight	Operative Time	Length of Stay (LOS)	Complications	Main Conclusions
Novak et al., 2025, USA, [2]	Retrospective cohort study	*n* = 2629; Minimally invasive surgery (MIS) vs open nephrectomy	MIS: 54.9 ± 59.0 months; Open: 88.6 ± 64.3 months	MIS: 165 ± 107 min; Open: 197 ± 97 min	Shorter with MIS	Open surgery associated with higher transfusion rates	Minimally invasive surgery is associated with shorter hospitalisation and lower transfusion risk; appears preferable after infancy
Calvillo-Ramírez et al., 2025,[1]	Retrospective meta-analysis	159 minimally invasive pediatric nephrectomies vs 145 open nephrectomies	Older age in MIS group (standardised mean difference 0.37; *p* = 0.002)	Open shorter by 21.6 min ($p = 0.01$)	MIS reduced LOS by -2.16 days ($p < 0.0001$)	Similar complication rates (odds ratio 0.80; $p = 0.62$)	MIS offers reduced LOS and narcotic use with comparable safety, at the cost of longer operative time
Wang et al., 2025, China[8]	Retrospective comparative study	*n* = 105; Robot-assisted laparoscopic nephrectomy (RAL) vs conventional laparoscopic nephrectomy (LPN), both transperitoneal	RAL: 5.3 ± 2.6 years; LPN: 2.7 ± 2.2 years ($p < 0.001$)	RAL: 234.7 ± 58.0 min; LPN: 185.4 ± 54.1 min ($p < 0.001$)	RAL: 7.3 ± 1.7 days; LPN: 9.5 ± 3.3 days ($p < 0.001$)	RAL: 0/22; LPN: 1/83	RAL allows faster recovery and shorter LOS but requires longer operative time and higher costs
Bhandarkar et al., 2021, United Kingdom,[10]	Retrospective comparative study	*n* = 152; Transperitoneal laparoscopy (TP) vs retroperitoneoscopy (RP)	8 months–16 years	TP: median 145 min; RP: 156 min	Median 2 days in both groups	TP: 3 conversions (4%); RP: none; minor infectious complications only	No significant differences in perioperative morbidity between transperitoneal and retroperitoneal approaches
Neheman et al., 2019, USA/Israel,[7]	Retrospective study	*n* = 59; Open (retroperitoneal) vs laparoscopic (transperitoneal), retroperitoneoscopic, and laparoendoscopic single-site surgery (LESS)	Median age 16 months; median weight 10.7 kg	Open: 154.5 min; Laparoscopic: 190 min	Open: 3 days; Laparoscopic : 1 day	10.2% overall (all Clavien–Dindo grade II)	Minimally invasive approaches reduce LOS and analgesia; open surgery remains faster
Esposito et al., 2016, Europe/Japan[11]**,**	Retrospective multicentre comparative study	*n* = 102; Laparoscopic partial nephrectomy vs retroperitoneoscopic partial nephrectomy	Median age 4.2 years	Laparoscopic: 166 min; Retroperitoneoscopic: 255 min	3.5 vs 4.1 days	19% vs 30%	Laparoscopic transperitoneal approach associated with shorter operative time, shorter LOS, and fewer complications
Esposito et al., 2015, Europe[12]**,**	Retrospective study	*n* = 52; Laparoscopic partial nephrectomy	Median age 5.1 years	Median 166 min	Mean 3.5 days	19.2% (urinomas, urinary leaks, recurrent urinary tract infections)	Technically demanding procedure with acceptable morbidity; complications mostly managed conservatively
Herz et al., 2015–2016[13]**,**	Retrospective analysis of prospective cohort	*n* = 47; Robot-assisted laparoscopic vs laparoscopic vs open techniques	4 months–14.8 years	Comparable or improved for robotic-assisted surgery	Not reported	De novo vesicoureteral reflux in 25% of robotic heminephrectomy cases	Robotic-assisted surgery shows good overall outcomes, but some reconstructive procedures may have higher reintervention rates
Till et al., 2016, Austria[14]**,**	Systematic review	Conventional laparoscopy vs laparoendoscopic single-site surgery vs robotic-assisted laparoscopy; transperitoneal vs retroperitoneal	Not pooled	Longer operative time for minimally invasive surgery; retroperitoneal longer than transperitoneal	Shorter LOS with minimally invasive surgery	No significant differences in complications	Minimally invasive surgery reduces hospital stay and analgesia but requires longer operative times

Abbreviations: MIS (Minimally invasive surgery), OPN (Open pediatric nephrectomy), LPN (Laparoscopic nephrectomy), RAL (Robot-assisted laparoscopic surgery),TP (Transperitoneal), RP (Retroperitoneal), LESS (Laparoendoscopic single-site surgery), LOS (Length of stay), UTI (Urinary tract infection)

Across studies, minimally invasive surgery (MIS) encompassed conventional laparoscopy and, in selected reports, robot-assisted approaches. Procedures included nephrectomy and nephron-sparing surgery (partial nephrectomy/heminephrectomy).

Primary outcomes

Operative time (OT)

Across the tabled evidence, OT differences depended on procedure type and MIS modality:

- MIPN vs open nephrectomy: Meta-analysis showed longer OT with MIPN (mean difference +21.62 min; p=0.01), indicating shorter OT in the open group [1].
- Partial nephrectomy (open vs laparoscopic): In a multi-approach comparative cohort, open partial nephrectomy (OPN) had shorter OT than LPN (median 154.5 min vs 190 min) [7].
- Approach within MIS (partial nephrectomy): LPN demonstrated substantially shorter OT than RP (166.2 min vs 255 min) [11].
- TP vs RP laparoscopic nephrectomy: OT was similar between approaches (TP 145 min vs RP 156 min) with no significant between-group differences reported [10].
- Robotic vs laparoscopic partial nephrectomy: RAL had longer OT than LPN (234.68 ± 58.02 min vs 185.36 ± 54.07 min, p<0.001) [8].
- Large nephrectomy cohort: Novak et al. [2] reported shorter mean OT in MIS compared with open (165 ± 107 min vs 197 ± 97 min), highlighting that OT patterns were not uniform across datasets and may reflect case-mix and selection.

Length of stay (LOS)

LOS most consistently favored MIS in MIS–open comparisons, while differences between MIS variants were technique-dependent:

- MIPN vs open nephrectomy: Meta-analysis demonstrated a significantly reduced LOS with MIPN (mean difference -2.16 days; p<0.0001) [1].
- Partial nephrectomy (open vs MIS approaches): LOS was shorter with MIS approaches compared with OPN in the multi-approach cohort (median LOS 3 days for OPN vs 1 day for LPN; additional MIS arms reported) [7].
- Approach within MIS: LPN had shorter LOS than RP (3.5 vs 4.1 days) [11].
- Robotic vs laparoscopic partial nephrectomy: RAL had shorter LOS than LPN (7.3 ± 1.7 vs 9.5 ± 3.3 days, p<0.001) [8].
- TP vs RP laparoscopic nephrectomy: LOS was identical (median 2 days in both groups; range 1–3 days) [10].

Secondary outcomes

Complications and conversions

Overall complication rates were generally comparable between MIS and open surgery in aggregated analyses, with notable variation by specific technique and procedure:

- MIPN vs open nephrectomy: No significant difference in perioperative complications (OR 0.80; p=0.62) [1].
- Laparoscopic partial nephrectomy (single-arm): Complications occurred in 10/52 (19.2%), predominantly urinomas and prolonged urinary leaks, with 0 conversions reported [12].
- LPN vs RP (partial nephrectomy): Complications were more frequent with RP (30%) than with LPN (19%) [11].

- TP vs RP laparoscopic nephrectomy: No intraoperative complications were reported; 3 conversions occurred in the TP group (4%) and none in the RP group [10].
- Multi-approach partial nephrectomy cohort: Postoperative complications occurred in 6/59 (10.2%), all Clavien-Dindo grade 2 events [7].
- Robotic vs laparoscopic partial nephrectomy: Complications were rare (0/22 in RAL vs 1/83 in LPN) [8].
- Robotic reconstructive outcomes: In the robotic series analysis, vesicoureteral reflux (VUR) developed de novo in 4/19 (25%) after robotic heminephrectomy, with some cases requiring reintervention [13].

Transfusion, analgesia, and costs

Selected studies reported differences in resource utilization:

- In the large nephrectomy cohort, open surgery was associated with an increased risk of transfusion compared with MIS [2].
- In the TP vs RP laparoscopic comparison, opioid use beyond 24 hours was low and similar (3% in both groups) [10].
- In the robotic versus laparoscopic partial nephrectomy comparison, RAL incurred higher hospitalization expenses than LPN (5.30 ± 2.63 vs 2.67 ± 2.16, $p<0.001$; units as reported in the table) [8].

DISCUSSION

Over the last two decades, pediatric renal extirpative surgery has progressively transitioned from predominantly open approaches to a spectrum of minimally invasive strategies, including conventional laparoscopy (transperitoneal or retroperitoneal), laparoendoscopic single-site surgery (LESS), and robot-assisted techniques. The current evidence base largely retrospective and frequently heterogeneous in terms of indications and procedural type (total nephrectomy vs heminephrectomy/partial nephrectomy) supports the overall feasibility and short-term safety of minimally invasive pediatric nephrectomy and heminephroureterectomy, with the most consistent clinical signal being shorter hospitalization compared with open surgery, while operative time may increase depending on approach and learning curve.

Open versus minimally invasive nephrectomy: population-level and comparative evidence

Large administrative and institutional datasets reinforce that minimally invasive pediatric nephrectomy can be delivered with acceptable perioperative outcomes, but interpretation is limited by confounding due to age, body size, case complexity, and selection. Novak et al. [2] examined 2,629 pediatric total nephrectomies and reported that open surgery was associated with longer operative time and higher transfusion risk, while benefits of minimally invasive approaches appeared more evident beyond infancyn. Such findings are clinically plausible, yet they should be viewed through the lens of substantial baseline differences between cohorts, including younger age in children managed with open surgery, which may reflect surgeon preference and anatomical constraints rather than true technique-related disadvantages.

Earlier comparative work focused specifically on benign disease also supports a length-of-stay advantage with minimally invasive access. Ku et al. [15] compared retroperitoneal laparoscopic versus open nephrectomy/nephroureterectomy in children with benign renal disease and found successful completion of laparoscopic cases without conversion, no major perioperative complications, and a significantly shorter median hospital stay for laparoscopy (2.5 vs 4 days). This pattern-comparable safety with shorter hospitalization has remained remarkably consistent across eras, despite advancements in perioperative care that may reduce absolute length of stay in both groups.

Duplex systems and heminephroureterectomy: laparoscopy versus open surgery

Duplex collecting system anomalies represent a frequent indication for heminephrectomy/heminephroureterectomy, and this subgroup has distinct technical risks, including ureteral stump complications, urinary leakage, and injury to the functioning (“innocent”) moiety. In a comparative series, García-Aparicio et al. [16] evaluated laparoscopic versus open heminephroureterectomy for duplex anomalies and reported no conversions and no complications in either group, with a significantly shorter hospital stay for the laparoscopic cohort (approximately 2.44 vs 4.38 days), while operative times were not statistically different. Although limited by small sample size and retrospective design, this study provides direct evidence within a single indication that the postoperative recovery advantage of laparoscopy may be obtained without compromising short-term safety.

Longer-term outcomes are less frequently reported but are particularly important in duplex surgery, where preservation of the remaining moiety is central. You et al. [17] specifically analyzed late outcomes after laparoscopic heminephrectomy in children with duplex kidneys. In their cohort, laparoscopic procedures were completed as planned, and the remnant pole function was preserved in most patients; however, they documented rare but clinically meaningful adverse outcomes, including complete functional loss of the remnant pole in one case and prolonged urine leakage related to a refluxing ureteral stump in another. Importantly, they emphasized that functional impairment may not be readily apparent intraoperatively, supporting routine postoperative functional assessment (e.g., nuclear scintigraphy) when clinically appropriate. These observations underscore a key principle: excellent short-term recovery metrics do not eliminate the need for vigilance regarding late functional endpoints.

In real-world practice, duplex systems are often accompanied by lower urinary tract pathology (e.g., reflux, ureterocele, ectopic ureter) and recurrent infection, factors that can influence both the choice of procedure and the risk of persistent symptoms. Institutional longitudinal experience in “complicated duplex kidney” management further highlights that outcomes depend not only on the extirpative technique but also on comprehensive management of associated anomalies and judicious selection between upper-tract and alternative reconstructive strategies [18].

Access route: transperitoneal versus retroperitoneal considerations

Choice of access route remains an area where surgeon experience and patient-specific anatomy may outweigh consistent outcome differences. Bhandarkar et al. [10] reported comparable perioperative morbidity between transperitoneal and retroperitoneal approaches in pediatric laparoscopic nephrectomy, with similar length of stay and operative time distributions. Complementary evidence from retroperitoneal series supports retroperitoneoscopy as a viable option for pediatric nephrectomy and partial nephrectomy in appropriately selected cases, particularly when avoidance of intraperitoneal dissection is desirable [19]. Collectively, these data suggest that the "best" route is often the one that optimizes exposure and safety for a given child in a given center, rather than a universally superior approach.

Partial nephrectomy/heminephrectomy: complexity, platform, and complication profile

Partial nephrectomy and heminephrectomy are intrinsically more complex than total nephrectomy due to segmental vascular anatomy, the need for meticulous parenchymal transection, and preservation of the functioning moiety. Across platforms, typical complications include urinoma/urine leak, postoperative fluid collections, and ureteral stump-related morbidity.
Esposito et al. [12] reported laparoscopic partial nephrectomy outcomes with meaningful complication rates in pediatric duplication anomalies, emphasizing that complications were frequently manageable conservatively but nonetheless clinically relevant. In their comparative multicenter analysis, transperitoneal laparoscopic partial nephrectomy demonstrated shorter operative time and length of stay relative to retroperitoneoscopic partial nephrectomy, with a higher complication frequency observed in the retroperitoneoscopic group[11]. While these findings may reflect differences in case selection and surgeon experience, they reinforce that approach-specific nuances matter in partial nephrectomy and that "minimally invasive" should not be treated as a homogeneous exposure category.
Robotic assistance has been adopted to address technical challenges in pediatric partial nephrectomy by improving dexterity and suturing capability, but it introduces platform-related trade-offs. Mason et al. [20] reported a relatively large series of pediatric robotic-assisted laparoscopic partial nephrectomy for nonfunctioning moieties in duplicated systems, describing low major complication rates but a notable incidence of asymptomatic postoperative fluid collections on early imaging; they also observed that closure of the resection defect was associated with fewer fluid collection. These details are clinically important because they connect a modifiable intraoperative step (defect closure) to a measurable postoperative finding, and they illustrate how robotic surgery may facilitate reconstructive maneuvers that potentially mitigate approach-specific sequelae.

Similarly, Malik et al. [21] evaluated pediatric robot-assisted laparoscopic heminephrectomy in duplicated systems and reported favorable perioperative metrics and preserved remaining moiety function in their experience, while noting that secondary procedures (e.g., ureterectomy) may be required in a subset due to refluxing ureteral stump-related infection. This aligns with a broader understanding that ureteral stump management is not merely a technical detail but a determinant of late morbidity and reintervention risk in duplex surgery.

A focused comparative analysis across multiple minimally invasive approaches for pediatric partial nephrectomy in duplication anomalies (including open, laparoscopic, retroperitoneoscopic, and LESS) also supports that minimally invasive techniques can reduce hospitalization and analgesic requirements without an obvious penalty in short-term safety, although residual confounding and approach heterogeneity persist [7]. More recent evidence continues to highlight the balance between improved recovery and increased resource utilization: Wang et al. [8] found shorter hospitalization but longer operative time and substantially higher hospitalization costs with robot-assisted laparoscopic partial nephrectomy compared with laparoscopy. Therefore, the decision to use robotics should be individualized and contextualized within institutional capability, surgeon experience, and health-economic constraints rather than based solely on marginal differences in length of stay.

A contemporary review focused on robot-assisted laparoscopic partial nephrectomy for renal duplication anomalies further synthesizes available series and underscores persistent limitations: small cohorts, technique variability, inconsistent reporting of functional outcomes, and the need for standardized endpoints [22]. This type of synthesis is useful for framing what is known (feasibility, generally acceptable short-term safety) and what remains uncertain (comparative effectiveness, durability of renal function preservation, and patient-centered outcomes).

LESS versus conventional laparoscopy: cosmesis versus efficiency

LESS has been explored to optimize cosmesis by minimizing visible scars, but its incremental clinical benefit over standard laparoscopy remains debated. Tam et al. [23] compared LESS nephrectomy/heminephroureterectomy performed with standard laparoscopic setup against conventional laparoscopy in children and found similar postoperative analgesic requirement and hospital stay between groups; however, operative time was significantly longer for LESS nephrectomy, and conversion occurred in a technically challenging case. These findings support the view that, while LESS can be safe and cosmetically appealing, it may impose an efficiency penalty that is relevant in pediatric anesthesia exposure and operating room utilization, especially outside highly selected cases.

Consistent with these data, broader reviews emphasize that conventional laparoscopy remains the benchmark minimally invasive approach for pediatric nephrectomy and heminephrectomy, whereas LESS and robotic surgery frequently prolong operative time and increase costs without demonstrating uniform, clinically meaningful superiority in outcomes [14].

Methodological considerations and future directions

Across indications, a recurrent pattern emerges: minimally invasive approaches whether laparoscopic, retroperitoneoscopic, or robotic tend to provide faster postoperative recovery as reflected by shorter hospitalization, while open surgery may offer advantages in operative efficiency and resource utilization in selected contexts. However, strong causal conclusions remain limited by confounding (notably age and body size), center effects, and inconsistent outcome reporting. In duplex-system surgery specifically, short-term metrics must be interpreted alongside the unique risks of residual ureteral stump morbidity and remnant moiety functional compromise outcomes that may occur late and may not be fully captured by complication rates alone [17,21]. Future studies in pediatric nephrectomy should focus on four priorities: A). Standardized definitions of complications, including urinoma, perirenal fluid collections, and distal ureteral stump syndrome; B). Consistent reporting of functional outcomes of the remaining renal moiety, preferably with imaging-based functional assessment when indicated; C). Appropriate risk adjustment for age, body weight, renal anatomy, and associated anomalies; D). Inclusion of patient-centred outcomes, such as postoperative pain, time to return to normal activity, and validated cosmetic satisfaction measures. Until such data are available, surgical approach selection should rely on careful patient stratification, institutional expertise, and a balanced consideration of operative efficiency, resource utilisation, and the technical precision required to preserve residual renal function.

CONCLUSIONS

1. Overall outcomes: Minimally invasive pediatric nephrectomy is feasible and typically shortens hospital stay, with overall perioperative complication rates broadly comparable to open surgery.
2. Operative time: Differences in operative duration are heterogeneous and driven by procedure type, access route, and surgeon experience; efficiency should therefore be interpreted in the context of institutional expertise and patient complexity.
3. Patient selection and procedure-specific risk: In infants, very small children, and in duplex systems requiring partial or heminephrectomy, the benefits of minimally invasive surgery are less uniform and must be weighed against risks to the ureteral stump and remnant renal function, with structured functional follow-up.
4. Advanced techniques: Robotic-assisted and laparoendoscopic single-site approaches may improve dexterity and cosmesis in selected cases but involve trade-offs in operative time and resource use; until higher-quality comparative data mature, approach selection should remain individualised.

Authors' contribution
Study design – E. Mażul-Kulesza, B. Pietrzyk
Data collection – E. Mażul-Kulesza, J. Mikołajczyk, A. Joniec, T. Fajferek, W. Pierzchała
Manuscript preparation – E. Mażul-Kulesza, T. Fajferek, J. Mikołajczyk
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