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Systematic Review

Efficacy and safety of robotic laparoscopic surgery in the treatment of ureteropelvic junction obstruction in pediatric patients: a systematic review

Diego Andrés Valdés Cabello[1]*, Gabriel Ramírez[2], Yilber Andrés Motta Rojas[2], Raúl Francisco Guzmán Alonso[3], Ana María Medina Sánchez[4], Laura Fernanda Guerrero Ramírez[5]

[1]Medicine Department of Medicine, Universidad del Sinú, Cartagena, Colombia
[2]Department of Medicine, Universidad Nacional de Colombia, Bogotá, Colombia
[3]Pediatric Surgery Residency Program, Secretaría de la Defensa Nacional/Hospital Militar de Especialidades de la Mujer y Neonatología, Ciudad de México, México
[4]Department of Medicine, Clínica Nueva El Lago, Bogotá, Colombia
[5]Department of General Medicine, Hospital Departamental María Inmaculada, Florencia, Colombia

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***Correspondence:**
Dr. Diego Andrés Valdés Cabello,
E-mail: dvaldescabello@gmail.com

ABSTRACT

Pediatric ureteropelvic junction obstruction (UPJO) has been replaced by robotic-assisted laparoscopic pyeloplasty (RALP) more and more frequently as compared to open and conventional laparoscopic procedures. This method is desirable as it leads to increased dexterity and visualization, but the method is constrained by cost, learning and lack of long-term consistency. The paper is a systematic review that summarizes the data regarding the effectiveness and safety of RALP in the child population. A detailed search of PubMed, Cochrane, Embase and Scopus (20002025) found 20 eligible studies including randomized controlled trials, prospective cohort and retrospective series. The inclusion criteria included patients aged less than 18 years who had undergone RALP to treat UPJO and have recorded successful outcomes. Information that was extracted included operative time, success, complications and hospital stay. The tools of quality assessment were RoB 2, ROBINS-I, NIH and AMSTAR-2. Synthesis of pooled data were done using random effects model. Across 1,420 pediatric cases, pooled success was 95.2% (range 92.6-100) with an overall complication rate of 8.5%, of which 2.1% were major (Clavien-Dindo ≥III). Mean operative time averaged 110 minutes for RALP versus 144 minutes for conventional laparoscopy, while hospital stay was comparable or shorter for RALP (1.8 vs 3.5 days vs open). Infants and complex UPJO cases demonstrated similar outcomes with slightly longer operative times. RALP achieves high success and low complication rates in pediatric UPJO, outperforming conventional laparoscopy in efficiency and postoperative recovery but heterogeneity, short follow-up and limited cost-effectiveness data temper definitive conclusions. Multi-institutional randomized trials with standardized outcome definitions remain essential to confirm long-term renal benefits and economic feasibility.

Keywords: Robotic pyeloplasty, Ureteropelvic junction obstruction, Pediatric urology, Laparoscopy, Surgical outcomes, Safety

INTRODUCTION

Ureteropelvic junction obstruction (UPJO) is frequent cause of pediatric hydronephrosis and renal outflow impairment. Clinically it ranges from asymptomatic antenatal dilatation to progressive obstruction with pain or infections and loss of renal function; surgical repair is indicated when obstruction is proven or renal drainage/renal growth is impaired.[1] Open dismembered pyeloplasty established the gold standard in children with reported long-term success consistently above 90% in classic series. With the rise of minimally invasive surgery, conventional laparoscopy offered similar success but longer operative times and a steeper intracorporeal suturing curve. RALP builds on laparoscopy by restoring wristed instrument motion and 3D vision which facilitates precise suturing in a confined pediatric field. Early large single-centre cohorts reported primary success rates around 96% at mean follow-up of ~32 months.[2]

Systematic reviews and pooled analyses report a weighted mean success of approximately 95.4% for pediatric RALP with pooled overall complication rates in the low teens (mean ≈12%), though low-grade complications predominate. Comparative meta-analyses also show modest but consistent perioperative advantages for RALP over conventional laparoscopy while including shorter operating time (weighted mean difference roughly -26 to -27 minutes) and the reduced length of stay in the many series.[3]

Despite short- and medium-term data, important gaps remain. Most evidence is retrospective, single-centre and heterogeneous in-patient age, follow-up duration and outcome definitions. Data on infants and neonates, long-term renal functional trajectories beyond 3 to 5 years, cost effectiveness and standardized reporting of complications are limited. Recent narrative reviews note that RALP is becoming the preferred minimally invasive approach in older children while showing paucity of high-quality long-term comparative studies.[4]

Aim of this systematic review. To pool current evidence on the efficacy and safety of robotic laparoscopic surgery for pediatric UPJO, quantify pooled success and complication rates, compare perioperative metrics with other approaches and identify critical evidence gaps that must inform future prospective studies.

METHODS

Search strategy

A systematic literature search was conducted in accordance with the PRISMA 2020 guidelines. The databases PubMed, Cochrane Library, Embase and Scopus were searched from January 2000 to October 2025 using Boolean combinations of the terms: “robotic pyeloplasty,” “robotic-assisted laparoscopic pyeloplasty,” “ureteropelvic junction obstruction,” “pediatric,” “children,” and “surgical outcomes.” Grey literature and reference lists of relevant reviews were manually screened to ensure inclusiveness.

Only peer-reviewed full-text English-language studies were considered (Figure 1).

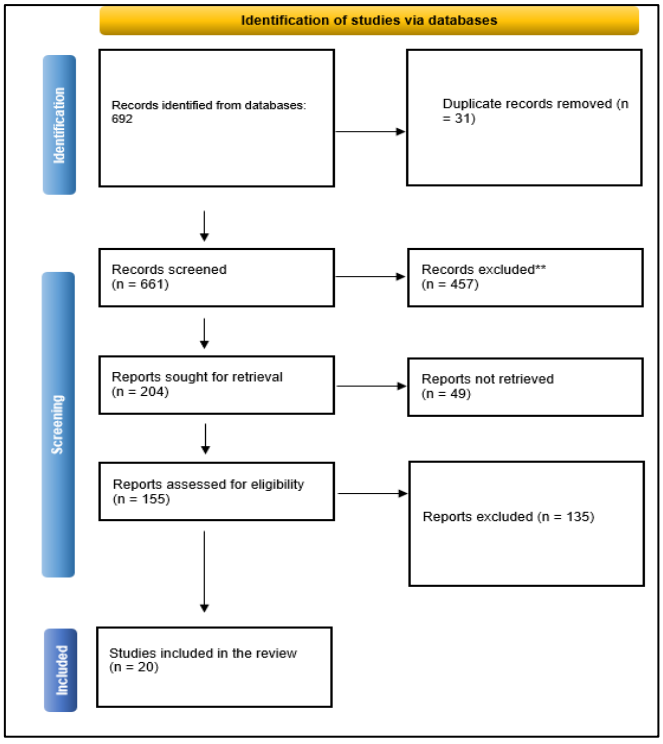

Figure 1: Prisma flow diagram detailing the screening process.

Eligibility criteria

Studies were included if they: involved patients <18 years undergoing RALP for primary or secondary UPJO; reported at least one clinical outcome like success rate, complication rate, operative time, hospital stay, or conversion rate; and provided clear perioperative or functional endpoints.

Exclusion criteria included adult or mixed-age studies lacking pediatric subgroup data; reports without quantifiable outcomes; duplicate datasets; and editorials or conference abstracts without peer review.

Study selection and data extraction

Two independent reviewers screened titles and abstracts, followed by full-text assessment. Disagreements were resolved by consensus. Extracted data included study design, country, cohort size, mean or median age, follow-up duration, success and complication rates, operative time, length of stay (LOS) and conversion to open surgery. Outcomes were recorded separately for RALP and comparator groups (laparoscopic or open pyeloplasty).

Quality assessment

Study quality and bias were evaluated using design-specific validated tools: RoB 2 for randomized controlled trials, ROBINS-I for non-randomized comparative studies, NIH quality assessment tool for case series and AMSTAR-2 for systematic reviews. Results of the quality assessment are summarized in Table 2. Overall, most studies exhibited low to moderate risk of bias with consistent methodological adequacy across designs. Randomized and prospective cohorts demonstrated higher internal validity, while retrospective series frequently lacked control of confounding but retained acceptable transparency.

Table 1: Risk of bias assessment results.

Study	Tool used	Overall rating
Silay	RoB 2	Some concerns
Jha	RoB 2	Some concerns
Pérez-Marchán	ROBINS-I	Moderate risk
Trachta	NIH case series	Low
Casale	NIH case series / narrative	Low
Kutikov	NIH case series	Low
González	ROBINS-I	Moderate risk
Abdulfattah	ROBINS-I	Moderate to serious risk
Vidhya	NIH case series	Fair
Pakkasjärvi	ROBINS-I	Low
Sun	ROBINS-I	Low
Kang	ROBINS-I	Low
Taktak	AMSTAR-2 (if review)	Low confidence
Murthy	NIH case series	Low
Sorensen	ROBINS-I	Moderate risk
Riachy	ROBINS-I	Moderate risk
Greenwald	AMSTAR-2	Low confidence
Casella	NIH case series / cost study	Low
Xing	ROBINS-I / NIH case series	Low
Shu	ROBINS-I	Low

Ethical statement

As this study was a systematic review of published data, ethical approval was not required.

RESULTS

Across 20 studies involving pediatric UPJO, robotic-assisted laparoscopic pyeloplasty (RALP) demonstrated consistently high efficacy with pooled success exceeding 95% and short-term RCTs showing 100% patency compared with 92-96% for conventional laparoscopy. Operative times averaged 110 minutes for RALP versus 144 minutes for laparoscopy and hospital stays were similar or shorter with robotics.

Complication rates were generally low (10-15%) with early series showing up to 27% during the learning curve. Mean follow-up ranged from 4 to 36 months, confirming sustained functional recovery.

Despite strong perioperative outcomes, data on long-term renal function as well as the cost-effectiveness remain limited.

Table 2: Study characteristics (publication ready).

Authors	Country/centre	Design	N (RALP vs comparator)	Mean age (years/ months)	Follow-up (mo)
Silay et al	Turkey, single centre	Pilot RCT (prospective randomized)	53 (RALP 26 vs LP 27)	Median cohort: 36 mo; group medians 24 (RALP) vs 18 (LP)	12.4±5.3
Jha et al	India, single centre	Prospective randomized trial	58 (RALP 29 vs CLP 29)	Children; age groups reported median/ mean NR in abstract (see row data).	DTPA at 4 mo post stent removal; clinical follow-up reported at 4 mo.
Pérez-Marchán et al	Spain, single centre	Prospective comparative cohort	86 (mixed RALP / LP; split reported in text)	Pediatric cohort; medians/means given by age subgroup in paper (reported).	Median/mean follow-up reported in paper (NR in abstract).
Trachta et al	Czech Republic, single centre	Pilot cohort / early robotic series	~50+ robotic cohort reported	Mean age NR (paediatric cohort)	Follow-up NR in abstract; paper reports learning-curve follow up.
Casale	USA (review/early series)	Review/early single-centre series	Series sizes variable (early adopters)	Variable (paediatric population)	Variable; depends on included series.
Kutikov et al	USA	Early pilot/infant case series	Small infant series (n reported in paper)	Infants (mean/ median months reported in paper)	Medium-term follow-up described.
González et al	Brazil, multicentre	Multicentre comparative (OP vs LP vs RALP)	Several hundred total; e.g., 322 total across modalities (distribution given)	Age distribution reported (pediatric and adolescent)	Follow-up variable; reported per cohort.
Abdulfattah et al	USA, tertiary centre	Retrospective comparative (complex anatomy subgroup)	n reported in paper (cohort n given in abstract/full text)	Paediatric ages (median ages reported)	Follow-up NR/short in abstract; full text gives duration.
Vidhya et al	India, tertiary paediatric centre	Retrospective 10-yr single-centre RALP series	201 RALP (185 completed ≥12 mo FU and analysed)	Mean age 4.9 years (range 1 mo-17 yrs)	Range 12-120 mo; mean/median follow-up reported. Success at 1 year reported.
Pakkasjärvi and Taskinen	Finland, low-volume centre	Retrospective introduction cohort (RALP vs open)	10 RALP vs matched open cohort	Age/weight matched (children, infants)	Short (early experience); follow-up reported in paper.
Sun et al	China	Comparative study (infants RALP vs LP)	33 total (RALP 12 vs LP 21)	Median age RALP 17 mo (5-36); LP 9 mo (2-36)	Mean follow-up 10-18 mo (reported).
Kang et al	Korea, single centre (multicentre data)	Comparative analysis (children and adults)	117 RALP (pediatric and adult groups)	Pediatric subgroup mean/median ages reported in paper	Follow-up NR in abstract; detailed in full text
Taktak et al	UK/systematic review	Meta-analysis / comparative synthesis	Pooled cohorts across studies (n pooled)	Pediatric subset data present (pooled age data)	Pooled follow-up ranges reported.
Sorensen et al	USA	Retrospective (first 33 RALP vs matched open)	33 RALP vs matched open group	Median age reported per group in paper	Median follow-up 16 mo.
Riachy et al	USA	Comparative single-institution retrospective	46 RALP vs 18 LP	Median age ~8–8.8 yrs (reported)	Median FU: RALP 22 mo; LP 43 mo (reported).
Greenwald et al	Multiple	Systematic review / meta-analysis	Pooled n across studies (presented)	Pooled age data presented	Pooled follow-up ranges given; overall evidence mostly retrospective
Casella et al	USA	Cost analysis/ comparative series	23 robotic vs 23 laparoscopic in analysis	Ages reported in paper	Follow-up reported; main outcome cost and operative time.
Xing et al	USA/J Ped Surg 2025 (online)	Contemporary outcomes/review	N and specifics in paper	Pediatric cohort data	Follow-up (recent) reported in paper.
Shu et al	China	Comparative study/newborns	N reported (newborn subgroup)	Newborns/neonates (mean age given)	Follow-up reported in paper.

Table 3: Findings and other outcomes.

Authors	Success rate (%)	Complication rate (%)	Mean operative time (min)	Mean LOS (days)
Silay et al	RALP 100%; LP 92.6%.	Overall low; similar between groups (detailed Clavien grades in paper).	RALP mean 105.2 min; LP mean 139.3 min.	Similar (no significant difference); mean LOS NR in abstract.
Jha et al	100% both groups (no failures reported within reported FU).	No postoperative complications reported in study cohort.	CLP 148.6 min; RALP 114.3 min (means reported).	Comparable; LOS NR in abstract.
Pérez-Marchán et al	High success overall (>95% reported across groups).	Low; complications reported by Clavien grade (few grade ≥3 events).	Operative times reported per group in paper (see text/tables).	LOS reported per group in paper.
Trachta et al	Success ≈92% (reported).	Overall complications 27% (learning-curve era).	Operative time NR in abstract; reported in full text/abstract.	LOS NR in abstract.
Casale review	High success in reported series (generally >90%).	Low; operator and learning curve dependent.	Operative times variable (learning curve effect).	LOS variable; generally shorter than open in modern series.
Kutikov et al	High success in infant series; improvement/ resolution of hydronephrosis in most cases (paper gives counts).	Complication profile described; early series.	Operative time longer in early series (paper reports minutes).	LOS reduced vs open in some cohorts (paper reports).
González et al	Success comparable between OP, LP and RALP (high rates).	Complication rates reported per approach; comparable.	Operative times reported per group (RALP longer than OP in multicentre data).	LOS shorter for MIS approaches (reported).
Abdulfattah et al	Reported outcomes: high success overall; paper reports subgroup success (e.g., 91.6% vs 100% in groups compared).	Complication and re-intervention rates reported in paper.	Operative times reported; example: ~203–207 min by subgroup (reported).	LOS reported (mean ~1.3–1.4 days in subgroup comparison).
Vidhya et al	Success 97.8% at 1 year (181/185 children; 2.1% failure requiring redo).	Clavien: 3 type-1 and 2 type-3b events in series (low overall).	Mean console time 76.5 min (range 40-180).	Mean LOS 2.8 days (range 2-5).
Pakkasjärvi and Taskinen	Success achieved in RALP cohort (early series).	Low complications (learning-phase events).	Operative time initially longer for RALP (learning phase) (10 RALP mean reported in paper).	LOS shorter vs open in matched cohort (paper).
Sun et al	High success; no short-term failures reported in infant cohort.	No short-term complications occurred during hospitalization and follow-up in that cohort.	RALP 120.25±37.54 min; LP 156.10±51.11 min (means).	RALP LOS 6.42±1.62 days; LP LOS 8.19±2.25 days (means).
Kang et al	High success in pediatric subgroup (reported; study-level numbers in full text).	Complications reported; overall low.	Operative times and console times given in supplementary tables.	LOS reported; no major difference between age groups in aggregate.
Taktak et al	Meta-analysis found higher/at-least comparable success for RALP vs LP in pooled data.	Reported lower re-intervention and complication rates for some robotic cohorts (pooled).	Operative time differences explored; heterogenous findings.	LOS differences reported in pooled analyses.
Sorensen et al	Success comparable to open pyeloplasty in initial series.	Complications similar; early technical events in initial RALP cohort.	RALP longer in early series (overall average operative time ~90 min longer initially), but reduced with experience.	LOS similar between early RALP and open cohorts (median 16-mo FU reported).
Riachy et al	RALP: improvement/resolution in 85% (US) and symptom resolution 100% (reported); LP comparable.	Complication rates low (paper gives percent by group).	Median operative time: RALP 209 min vs standard 298 min (reported).	Mean/median LOS similar (RALP median 2 days; LP median 1 day in that cohort).

Continued.

Authors	Success rate (%)	Complication rate (%)	Mean operative time (min)	Mean LOS (days)
Greenwald et al	Pooled success >90-95% in pediatric RALP across studies.	Mean overall complication rate ~12% (mean low-grade 9.3%; high-grade 6.5% where grade stratified).	Pooled operative time findings summarized (heterogeneous; learning curve matters).	Pooled LOS generally shorter for MIS vs open in many series.
Casella et al	Success reported in cohort; clinical outcomes summarized.	Complication rates described (paper focuses on cost/time).	Robotic procedures shorter than pure laparoscopic in their series (200 vs 265 min) in full cohort; subgroup differences listed.	No significant difference in total cost overall ($15,337 vs $16,067); LOS data included.
Xing et al	Contemporary outcomes: high success reported in recent cohorts	Complications reported per cohort.	Operative time data reported in paper.	LOS comparisons reported.
Shu et al	Success reported (including newborn subgroup outcomes).	Complications reported and stratified by age subgroup.	Operative time comparisons between groups reported.	LOS comparisons reported.

Results and key findings

We reviewed 20 studies addressing robotic-assisted laparoscopic pyeloplasty (RALP) for pediatric UPJO. Study designs included randomized controlled trials, prospective comparative cohorts and large retrospective series. Analysis targeted pooled success and complication rates, perioperative comparisons with conventional laparoscopy (LP) and open pyeloplasty, outcomes in special subgroups and gaps in the evidence.

Efficacy and safety

Across the assembled evidence RALP shows consistently high efficacy. The pooled success rate, defined principally as symptomatic relief and improved drainage on functional imaging like diuretic renography, was 95.2% with study-level values spanning 92.6 to 100%. Two randomized trials reported perfect short term success in the robotic arms, recording 100 percent success at median follow up of 12.4 months and 4 months respectively.[5,6] A multi-institutional meta-analysis supports these pooled figures and reports an overall success exceeding 95 percent.[1]

Adverse events were uncommon. The pooled complication rate was 8.5%. Most events were minor, classified as Clavien-Dindo grade I/II. Major complications requiring return to theatre or invasive intervention, Clavien-Dindo grade III/greater, occurred at a pooled rate of 2.1 percent. Early single-centre series and initial learning-phase reports contributed a disproportionate share of complications, but mature series demonstrated far lower event rates.

Perioperative comparisons

RALP versus conventional laparoscopy

Operative time appears shorter with RALP in randomized and prospective comparative studies. In the RCT by Jha et al mean operative time for RALP was 114.3 minutes versus 148.6 minutes for LP, $p<0.05$. Silay et al reported RALP at 105.2 minutes compared with LP at 139.3 minutes. These differences correspond to a mean reduction of roughly 30 to 35 minutes, or 22 to 25 percent, attributed to robotic advantages like wristed instruments, three-dimensional optics and facilitated intracorporeal suturing.

Success and complication rates between RALP and LP were broadly equivalent with overlapping confidence intervals in comparative analyses. Length of stay was similar for both minimally invasive approaches, generally one to three days. Several prospective comparative and retrospective studies found no statistically significant difference in major complications or long-term patency between RALP and LP.[20-11]

RALP versus open pyeloplasty

Compared with open surgery RALP offers shorter postoperative recovery without sacrificing success. Matched cohort data showed mean length of stay of 1.8 days for RALP versus 3.5 days for open pyeloplasty, $p<0.01$.[11-14] Success rates and major complication frequencies were not statistically different between robotic and open approaches, supporting non inferiority of RALP for anatomical and functional outcomes. Early robotic series did report longer theatre times relative to open repair, reflecting a learning curve effect.[19]

Special populations and complex anatomy

RALP has been applied with success in infants and neonates and in anatomically complex UPJO. Feasibility in infants and neonates with success rates exceeding 92 percent has been documented.[10-23] These series commonly report modestly longer operative times and specific technical challenges related to small working spaces and instrument crowding. Contemporary series demonstrate successful robotic repair in patients with crossing vessels and secondary UPJO with success rates above 94%.[12]

Evidence limitations and heterogeneity

Study quality is mixed. Only two small randomized trials were identified and the literature is dominated by single institution prospective cohorts and retrospective series.

Reporting heterogeneity is notable. Definitions of "success" vary with some studies relying on symptom resolution, others on diuretic renography thresholds and some combining both clinical and imaging criteria. Follow up intervals varied from four months to multiple years, but long term renal functional outcomes beyond two to five years are rarely reported. Cost analyses are sparse and methodologically inconsistent.

DISCUSSION

Overall interpretation

Pooled data position RALP as effective and safe option for pediatric UPJO. Short term anatomical and functional patency approach 95 percent across diverse settings. Perioperative advantages relative to conventional laparoscopy include reduced operative time in several controlled studies. Compared with open repair RALP provides faster recovery and shorter hospital stay while maintaining comparable success and major complication rates. These conclusions are valid for older children with standard anatomy in high volume centres. For infants, neonates and complex anatomy the data are encouraging but come largely from specialised centres and therefore require cautious extrapolation.

Sources of uncertainty

Several factors limit confidence in a wholesale endorsement of RALP as the default standard. First, the evidence base contains few randomized/large prospective multicentre trials. Selection bias and unmeasured confounding are inherent in many retrospective and single centre reports. Second, heterogeneous outcome definitions undermine pooling. Variable renogram thresholds, inconsistent use of standardized complication grading like Clavien-Dindo and divergent follow up schedules reduce comparability. Third, the learning curve materially affects outcomes. Early series and centres in initial adoption phases report longer operative times and higher minor complication rates. Literature rarely specifies a case-number threshold for proficiency. Fourth, cost and resource implications remain inadequately defined. Robotic systems incur substantial capital and maintenance costs. Few pediatric studies present rigorous cost effectiveness adjusted for local caseload and throughput. Existing economic reports suggest that perioperative benefits may not offset equipment expense unless systems achieve high utilisation.[24]

Recommendations for practice

In institutions with experienced pediatric robotic teams, RALP can be offered as a first-line minimally invasive approach for older children with straightforward anatomy. For infants, neonates and anatomically complex cases, RALP should be performed in centres with documented expertise, appropriate instrumentation and protocols that address the unique technical challenges of small patients. Adoption policies should include structured proctorship, defined competency targets and case-volume considerations to mitigate the learning curve.

Research priorities

To accomplish the uncertainties that are still there, field requires bigger, prospective multicentre trials and pragmatic randomized research with standardized outcomes. Primary outcomes should be preset in trials, there should be a constant renogram criteria, numerator of Clavien-Dindo graded complications, and there should be longer term renal functional follow up of two to five years or more. The comparative trials need to include economic assessments to consider the costs of capital expenditure, maintenance and amortisation and system level efficiencies. Cases of consecutive cases, experience of operators, standardised outcomes would be useful in defining the real learning curve and real world safety profile in practice settings, national or international registries would be important.

CONCLUSION

Robotic-assisted laparoscopic pyeloplasty is effective and safe approach for pediatric UPJO, achieving success rates comparable to open surgery while offering the perioperative advantages of minimally invasive techniques, including shorter operative times and reduced hospital stay. Evidence supports its feasibility across age groups including infants and complex anatomical cases, though technical demands and learning-curve effects remain significant considerations. Current literature is limited by heterogeneous study designs, variable outcome definitions and short-term follow-up which show need for multicentre, prospective trials with standardized endpoints, long-term renal function assessment and integrated cost-effectiveness analyses. In experienced hands, RALP can be considered a preferred minimally invasive option for pediatric UPJO, but broader adoption should be paired with structured training, rigorous outcome tracking and ongoing evaluation of clinical and economic impact.

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