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Balancing technology and resources: is robotic pyeloplasty always necessary?

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Introduction Ureteropelvic junction obstruction (UPJO) hinders urine flow from the renal pelvis to the ureter, causing renal dysfunction. Treatment focuses on relieving obstruction to restore urinary drainage and preserve renal function. Robotic-assisted laparoscopic pyeloplasty (RALP) offers enhanced precision compared to laparoscopic pyeloplasty (LP), yet limited comparative data exist for adult patients. This study compares RALP and LP outcomes in an adult cohort from a tertiary care centre.

Material and methods A retrospective cohort analysis was conducted on adult patients who underwent RALP or LP between March 2018 and May 2024. Primary outcome measures included operative time, with secondary outcomes such as estimated blood loss (EBL), hospital length of stay (LOS), complication rates, and success (defined by symptom relief and diuretic renogram improvement). Statistical analysis included Mann-Whitney, chi-square, and Fisher's exact tests, with a significance threshold of $p < 0.05$.

Results The study included 128 patients (87 RALP, 41 LP). Operative time was significantly longer for RALP (200.92 ±59.26 minutes) vs LP (161.92 ±55.21 minutes, $p < 0.001$), largely due to robotic docking. Both groups had similar EBL (47.87 ml for RALP vs 45 ml for LP, $p = 0.45$) and success rates (97.7% for RALP vs 97.4% for LP). However, RALP patients experienced a longer LOS (3.91 days vs 3.41 days, $p = 0.001$).

Conclusions RALP demonstrates technical advantages but does not reduce operative time and incurs increased resource utilisation compared to LP. Both techniques achieve high success rates, though further research is needed to assess RALP's cost-effectiveness.

Key Words: UPJO ‹› PUJO ‹› pyeloplasty ‹› laparoscopy ‹› robotic

INTRODUCTION

Ureteropelvic junction obstruction (UPJO), a condition impeding urine flow from the renal pelvis to the ureter, is predominantly caused by congenital anomalies. However, acquired factors such as calculi and surgical history also play a role. Affecting 1 in every 1,000 to 2,000 live births, it manifests in symptoms ranging from acute renal colic to persistent lumbar pain, haematuria, recurrent urinary tract infections (UTIs), and secondary hypertension. Early identification using ultrasonography, contrast-enhanced computed tomography (CT), and diuretic renography is critical to preventing long-term renal dysfunction, as these techniques assess both renal function and the degree of obstruction [1] In addition to these imaging modalities, MR urography has been increasingly used in some centres to delineate anatomical details and assess kidney function [2]

The primary goal of UPJO treatment is to alleviate the obstruction, promote urinary drainage, and preserve renal function. While minimally invasive procedures such as laparoscopic pyeloplasty (LP) have gained widespread traction, the advent of robotic-assisted laparoscopic pyeloplasty (RALP) has introduced enhanced precision and dexterity through robotic technology [3]. However, despite the rising interest in RALP, much of the comparative literature focuses on paediatric populations, leaving a paucity of data on adult patients [4]. Moreover, the inconsistency of findings related to operative efficiency, resource utilisation, and long-term outcomes warrants further scrutiny, especially within the adult cohort. This study, therefore, seeks to address this gap by presenting the largest adult cohort comparison of RALP and LP within a tertiary care setting. Furthermore, a focus on the learning curve and cost-effectiveness of each technique is critical for establishing their roles in clinical practice.

MATERIAL AND METHODS

We conducted a retrospective cohort study of all adult patients who underwent either robotic or LP at our institution between March 2018 and May 2024. Patient demographics, clinical presentations, and perioperative data were meticulously reviewed from medical records.

Inclusion criteria encompassed patients presenting with flank pain, recurrent UTIs, obstructive patterns on diuretic renography, renal stone formation, or progressive decline in renal function. Exclusion criteria included patients with advanced renal failure, those unfit for surgery due to comorbidities, and cases with previous failed pyeloplasty. Patients were assigned to RALP or LP based on surgical team preference, patient-specific factors (e.g., anatomical complexity), and resource availability. The surgeons' choice also depended on the availability of the robotic system on the surgery day.

Surgeon experience: All procedures were performed by two experienced urologists, each with over 10 years of experience in laparoscopic surgeries. One surgeon had performed over 100 robotic surgeries, while the other had equivalent laparoscopic experience but was newer to robotic surgery, reflecting the inherent learning curve.

Primary outcome measures included intraoperative time, while secondary outcomes assessed, hospital length of stay (LOS), estimated blood loss (EBL), complication rates, and overall procedural success. Success was defined by symptomatic relief and improvement on diuretic renograms at 6–12 months postoperatively. Operative times were measured from the first incision to the final closure, and perioperative complications were classified according to the Clavien-Dindo grading system.

Surgical procedure

Both groups underwent Anderson-Hynes dismembered pyeloplasty via an intraperitoneal approach. In the RALP group, the 4-arm da Vinci Xi system was utilised, while the LP group followed a standard 3-port technique. Right-sided pyeloplasties necessitated an additional port for liver retraction. All anastomoses were completed using 3-0 polyglactin 910 sutures, with an antegrade double-J (DJ) stent placed in all patients. The DJ stent used in all patients was of 6 Fr diameter, placed antegrade during surgery. The 6F stent was specifically used as it is our institutional policy. Foley catheters were removed postoperatively after 24–48 hours, and drainage tubes were removed once output decreased below 50 ml/day.

Follow-up

Postoperative follow-up occurred one week after surgery, including clinical evaluation and routine blood and urine tests. Ureteric stents were removed 4–6 weeks postoperatively, and follow-up diuretic renograms were performed at six-month intervals thereafter.

Statistical analysis

Continuous variables were compared between RALP and LP groups using the Mann-Whitney test, while categorical variables were analysed with the χ^2 or Fisher's exact test. A two-sided p-value of less than 0.05 was deemed statistically significant, and all analyses were conducted using SPSS software (version 23, IBM, Chicago, IL).

Bioethical standards

Ethical approval was obtained from the Institutional Ethics Committee under approval number IECA/2024/09/021, and informed consent was secured from all participants before the study commenced. The manuscript has been prepared in strict observation of the research and publication ethics guidelines. All studies, including human subjects or data, have been reviewed and approved. Principles embodied in the Declaration of Helsinki (2013) for all investigations involving human materials have been followed.

RESULTS

A total of 128 patients were included, with 87 undergoing RALP and 41 receiving LP. The baseline characteristics, including demographics and clinical presentations, were comparable between the two groups (Table 1).

In the RALP group, unique presentations included one patient with a horseshoe kidney and another with UPJO secondary to genitourinary tuberculosis, while the LP group had one patient with a malrotated kidney.

Operative time was significantly longer in the RALP group (200.92 ±59.26 minutes) compared to the LP group (161.92 ±55.21 minutes, $p < 0.001$). Robotic docking/undocking accounted for an average of 25 minutes, indicative of the learning curve associated with robotic surgery (Figure 1). Although docking time was noted to average 8-15 minutes in experienced hands [8], the observed prolongation here reflects the surgeons' earlier phase of the robotic learning curve. EBL between the two groups was comparable (47.87 ml in RALP vs 45 ml in LP, $p = 0.45$). The median LOS was notably longer in the RALP group (3.91 days) compared to LP (3.41 days, $p = 0.001$), though both groups demonstrated similar high success rates (97.7% in RALP vs. 97.4% in LP). Notably, no conversions to open surgery were required (Table 2).
Success rates were high in both groups (97.7% in RALP vs 97.4% in LP), and no conversions to open surgery were required. Clavien-Dindo complications were minor (Grade I-II) in 4.6% of RALP patients and 7.3% of LP patients, reflecting the safety of both techniques.

DISCUSSION

UPJO represents one of the most common causes of upper urinary tract obstruction in both pediatric and adult populations. Surgical intervention, primarily pyeloplasty, remains the definitive treatment for this condition. The emergence of minimally invasive techniques, such as LP and RALP, has transformed the management of UPJO. Our study aimed to compare these two approaches in terms of operative time, success rate, LOH, and postoperative complications, thus contributing to the growing body of literature on this subject [5, 12, 14, 15].
The findings of our study align with previous research in highlighting the advantages and limitations of both LP and RALP. LP, introduced in the

Table 1. *Showing the demographic characteristics and clinical presentation of the patients*

Demographics, characteristics	RALP (n = 87)	LP (n = 41)
Median age [years (range)]	31 (15–58)	18/21
Sex (male/female)	37/50	18/21
Side (left/right/bilateral)	34/53/3	16/23/0
Presentations		
Pain	65	28
UTI/dysuria	29	13
Haematuria	6	2
Incidental finding	0	0
Crossing vessels (%)	30 (34.5%)	14 (35.9%)
Concomitant stones (%)	3 (3.4%)	1 (2.6%)
Previous procedures: PCN	6 (6.7%)	5 (12.8%)
DJS	6 (6.7%)	2 (5.1%)

DJS PCN
UTI

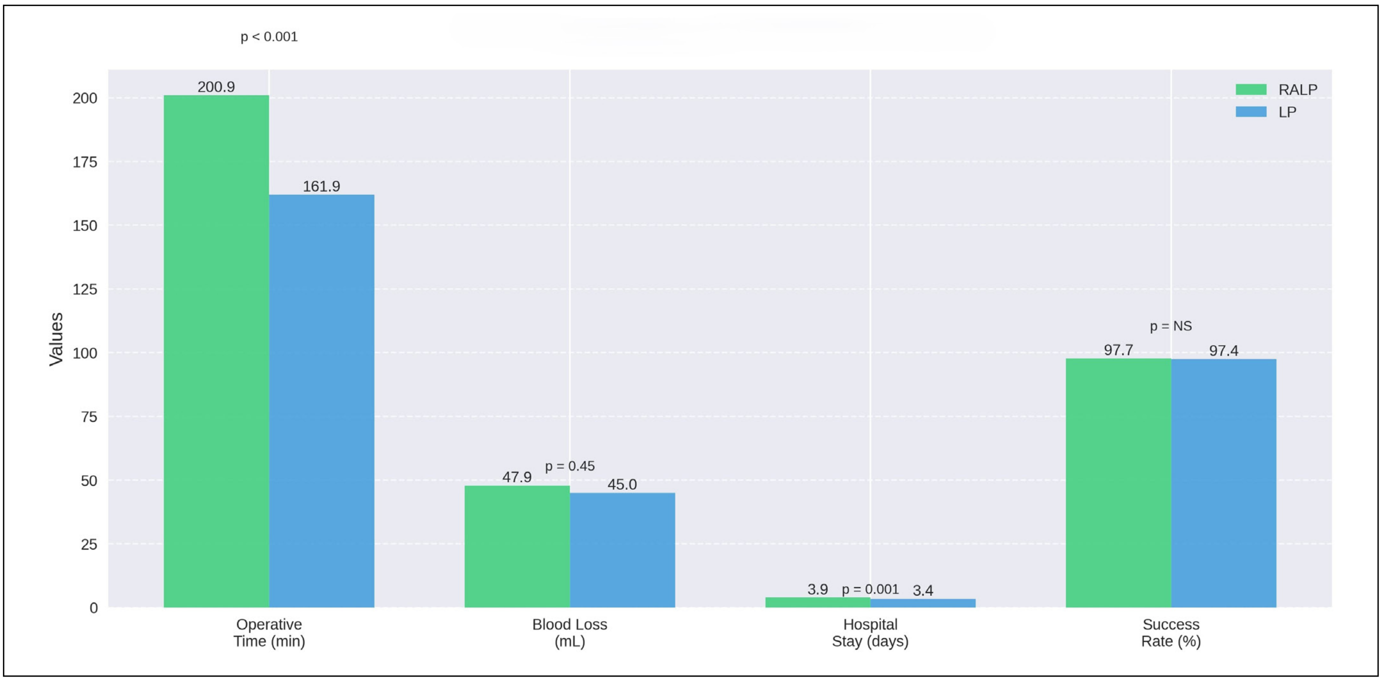

Figure 1. *Comparison of parameters between robotic and laparoscopic pyeloplasty.*

1990s, has been well-established as a minimally invasive approach with excellent success rates (Jarrett et al. [13], Hemal et al. [4]). RALP, introduced later, leverages robotic technology to improve precision and ergonomics during complex reconstructive procedures. While RALP has gained popularity in recent years, particularly in high-volume centres, the debate continues over whether its increased cost is justified by improved outcomes [4, 13].

One of the primary areas of comparison in our study was operative time. Our results indicate that RALP had a slightly shorter operative time than LP. This observation aligns with studies by Autorino et al. [3] and Link et al. [6], which reported reduced operative time with RALP due to enhanced dexterity, improved visualization, and shorter suturing times. However, the operative time in both approaches varies significantly depending on the surgeon's experience, highlighting the role of the learning curve. Studies by Guven et al. [9] and Singh et al. [22] emphasize that the learning curve for RALP tends to plateau more quickly than for LP. Our study's results corroborate these findings, suggesting that RALP may offer greater efficiency as surgeons gain experience, potentially reducing intraoperative complications and improving patient outcomes.

While the robotic docking process generally requires less than 10 minutes in experienced hands, our study reported an average of 25 minutes for docking and undocking, reflecting the surgeons' relative position on the robotic learning curve. Both operators were proficient in laparoscopic surgeries of the kidney and pelvis; however, the surgeon newer to robotic surgery required additional time for familiarisation with robotic console dynamics, especially during critical steps like precise dissection and intracorporeal suturing. Notably, the operator's relative inexperience with robotic controls may have mitigated the perceived advantage of robotic systems in tissue dissection and anastomosis. The extended operative time can thus be attributed to the combined effects of the robotic learning curve and case complexity, as some RALP patients presented with unique anatomical challenges, such as horseshoe kidneys or tuberculosis-associated UPJO.

Table 2. *Showing the outcomes and comparison between the two groups*

Outcome	RALP (n = 87)	LP (n = 41)	p
Mean docking/undocking time [min]	25 (10–27)	–	–
Total operative time [min, range]	200.92 ±59.26	161.92 ±55.21	<0.001
EBL [ml, range]	47.87 ±22.69	45.0 ±0.45	0.45
Hospital stay (days)	3.91 ±0.85	3.41 ±0.85	<0.001
Post-op complications (Clavien-Dindo grade)	3 (3.4%)	2 (4.87$)	
Success rate	85 (97.7%)	38 (97.4%)	

In terms of success rates, our study revealed no significant difference between LP and RALP. Both techniques demonstrated high success rates comparable to those reported in earlier literature (Minnillo et al. [10]; Zargar et al. [13]). This supports the notion that surgical technique, rather than the modality used, is the most critical determinant of success. However, RALP offers advantages in cases with complex anatomy or recurrent UPJO, as highlighted by Yang et al. [11] and Hung et al. [17], where the superior articulation and visualization of robotic instruments facilitate precise reconstruction.

The LOS in our study was slightly shorter for RALP compared to LP, though the difference was not statistically significant. This finding is consistent with systematic reviews by Bragga et al. [7] and Ball et al. [8], which also noted minimal reductions in hospital stay with RALP due to faster postoperative recovery. However, this modest reduction must be weighed against the higher cost of RALP, which remains a contentious issue. Our study observed a statistically significant increase in the LOS for RALP patients compared to LP patients (3.91 vs 3.41 days, p = 0.001). However, the discrepancy is relatively small (0.5 days) and could be attributed to postoperative protocols, including delayed mobilisation, prolonged observation due to perceived risks associated with the learning curve of robotic surgery, and owing to the small sample size in the cohorts. Optimising perioperative care, including enhanced recovery after surgery (ERAS) protocols, could help mitigate this issue. Standardising postoperative pathways, including earlier catheter and drain removal, may also reduce LOS, ultimately offsetting costs associated with robotic surgery.

Studies by Akbulut et al. [21] and Chang et al. [24] demonstrate that while RALP is associated with higher initial costs, these may be offset by reduced complication rates, shorter recovery times, and fewer readmissions over the long term. Our study underscores the need for a comprehensive cost-benefit analysis, particularly in low-resource settings, to determine the most appropriate modality for UPJO repair.

Postoperative complications in our study were comparable between the two groups, which aligns with the findings of multiple studies (Autorino et al. [3]; Molina et al. [10]) that report low complication rates for both LP and RALP. The robotic approach may offer a slight edge in reducing the likelihood of suture-related complications due to its precision, but this difference is not clinically significant. Moreover, studies by

Gundeti et al. [15] and Tan et al. [16] emphasize the safety and feasibility of both approaches in pediatric populations, further underscoring their versatility.
Another important consideration is the impact of surgeon expertise on outcomes. Link et al. [6] and Singh et al. [22] highlight that the learning curve plays a critical role in determining operative time, complication rates, and overall success. LP requires advanced laparoscopic skills, particularly for intracorporeal suturing, which can be challenging for less experienced surgeons. Conversely, RALP's intuitive controls and three-dimensional visualization may shorten the learning curve, making it more accessible for urologists without extensive laparoscopic experience. Our study confirms that surgeon experience is a key variable, regardless of the chosen modality, and emphasizes the importance of adequate training and mentorship programs.
Several studies have also explored long-term outcomes of LP and RALP. The meta-analysis by Bragga et al. [7] and long-term follow-up studies by Minnillo et al. [10] and Gettman et al. [25] demonstrate durable success rates for both techniques, with minimal risk of recurrence. These findings are consistent with our results, which showed no significant difference in long-term outcomes between LP and RALP. However, Yang et al. [17] suggest that RALP may offer better outcomes in highly complex cases, an observation that warrants further investigation.
Our study contributes to the growing body of evidence supporting both LP and RALP as effective options for UPJO repair. While RALP offers advantages such as shorter operative times, a potentially faster learning curve, and improved ergonomics for the surgeon, these benefits must be balanced against the significantly higher costs. Conversely, LP remains a cost-effective option with comparable success rates and outcomes, particularly in resource-constrained settings. The choice of modality should be individualized, taking into account patient factors, surgeon expertise, and institutional resources [18–21, 23].
In conclusion, while our study reinforces many of the findings in existing literature, it also highlights important nuances, such as the role of surgeon expertise and the need for cost-effectiveness analyses, in determining the most appropriate approach for UPJO repair. Future research should focus on randomized controlled trials with larger sample sizes and more extended follow-up periods to further delineate the comparative advantages of LP and RALP. Additionally, efforts to make robotic technology more affordable could help bridge the gap in accessibility, particularly in low- and middle-income countries.
This study has several limitations that warrant discussion. Firstly, there was an inherent selection bias for RALP patients, as inclusion depended on patient-specific factors such as anatomical complexity, which may have influenced both operative times and outcomes. Secondly, the study's retrospective design limits its ability to establish causal relationships. Thirdly, the operators' varying experience with robotic systems contributed to prolonged operative times, underscoring the impact of the robotic learning curve. Finally, the economic implications of robotic surgery in resource-constrained settings were not comprehensively addressed, which is an area requiring further investigation through cost-benefit analyses.

CONCLUSIONS

RALP represents a promising advancement in urological surgery, yet its prolonged operative times and heightened resource utilisation may limit its broader application, especially in settings where robotic technology is less accessible. LP, by contrast, remains an equally effective but less resource-intensive option, with comparable success rates. As the landscape of minimally invasive surgery evolves, future research must continue to evaluate the long-term value of RALP, particularly in light of its cost implications and the potential for optimising patient outcomes across various healthcare environments.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL STATEMENT

The study was approved by the Institutional Ethics Committee under approval number IECA/2024/09/021.

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