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TOPIC PAPER

Robot-assisted laparoscopic pyeloplasty in infants and children: is it superior to conventional laparoscopy?

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Abstract

Introduction Open pyeloplasty (OP) has been the first-line treatment for ureteropelvic junction obstruction (UPJO) since it was first described by Anderson and Hynes. The use of minimally invasive surgery (MIS) to treat UPJO in the pediatric population has increased in recent years, due to decreased morbidity and shorter recovery times. Recently, robot-assisted laparoscopic pyeloplasty (RALP) has seen a steady expansion. Unlike laparoscopic pyeloplasty (LP), RALP comes with a more manageable learning curve aided by specialized technological advantages such as high-resolution three-dimensional view, tremor filtration with motion scaling, and highly dexterous wrist-like instruments. With this review, we aim to highlight the trend toward robotic pyeloplasty over laparoscopy and current available evidence on outcomes.

Methods We systematically searched the PubMed and EMBASE databases, and we critically reviewed the available literature on the use of laparoscopy and robotic technology in pediatric patients with UPJO.

Results Overall, we selected 19 original articles and 5 meta-analyses. The available literature showed that the robotic approach to the UPJO allowed for decreased operative times, shorter length of hospital stay, lower complication rates, with success rates comparable to LP. Conflicting results persist regarding robotic platform and equipment costs.

Conclusion While laparoscopy requires advanced skills for complex reconstructive procedures, such as pyeloplasty, robot-assisted surgery offers the valuable potential of making MIS more accessible to these types of procedure. Robotic technology has contributed to shortening the learning curve by acting as a bridge between open and endoscopic approach. There is still a strong need for higher quality evidence in the form of prospective observational studies and clinical trials, as well as further cost-effectiveness analyses. As robotic surgical technology spreads, future systems will be developed, offering smaller and more flexible tools, allowing enhanced applications on pediatric patients.

Keywords Pediatric urology · Ureteropelvic junction obstruction · Robot-assisted laparoscopic pyeloplasty · Robotic pyeloplasty · Laparoscopic pyeloplasty

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Introduction

Open pyeloplasty (OP) has been the first-line treatment for ureteropelvic junction obstruction (UPJO), since it was first described by Anderson and Hynes [1]. Overall, there has been a 7% decline in the number of pyeloplasty performed annually, likely due to decreased birth rates and, therefore, congenital abnormalities [2–4]. Despite this decline, the use of minimally invasive surgery (MIS) to treat UPJO in the pediatric population has increased from 0.34% in 2000 to 11.7% in 2009 [2]. This progressive shift towards MIS may be attributed to decreased morbidity and shorter recovery times while maintaining a similar success rate to that found in OP [5]. A recent meta-analysis in children with UPJO showed that laparoscopic pyeloplasty (LP) was associated with decreased length of hospital stay (LOS) and complication rates, but prolonged operative times (OTs) when compared with OP [6]. Both LP and OP had equal success rates. Additionally, since the 1990s, LP has been described as a safe and effective approach in infants as young as 2 months of age [7–10]. Despite the increased popularity of MIS, LP has remained stable since 2003 [11, 12], with its use limited to selected patients and only performed by few experts, likely due to its technical challenges, such as intracorporeal suturing, longer OTs (59 min longer than OP, on average), and steep learning curve [5]. Similarly, the lack of adoption of retroperitoneoscopic pyeloplasty (RP) can be attributed to small working space in the pediatric retroperitoneum and, despite encouraging OTs (143–155 min, on average) and comparable results to the open approach, it remains a technically challenging procedure [13, 14]. In addition, with the decreasing number of cases, trainee hour restrictions, and the steep learning curve, it is increasingly difficult to pursue complex reconstructive laparoscopic cases.

In contrast, robot-assisted laparoscopic pyeloplasty (RALP) has seen a steady expansion, since its implementation in 2002 [15, 16], with an annual increase rate of 29% [4], and accounting for more than 80% of all MIS pyeloplasty, and for 40% of pyeloplasty performed in children [4, 17]. Unlike conventional MIS (LP and RP), RALP comes with a more manageable learning curve aided by specialized technological advantages such as high-resolution three-dimensional view, tremor filtration with motion scaling, and highly dexterous wrist-like instruments [15]. Furthermore, RALP provides the ability to perform complex reconstructive procedures not otherwise possible through a conventional laparoscopic approach. Despite these perceived benefits, no prospective randomized studies comparing outcomes of RALP and LP have been reported thus far, and evidence has been limited to retrospective cohort studies and meta-analyses. Nonetheless, these reports have shown that RALP has considerable benefits such as shortened LOS, decreased peri-operative pain, and improved cosmesis, as well as limitations including higher costs and OTs when compared to an open approach [2, 18]. Furthermore, RALP can be used as a gateway procedure to bridge the learning gap and perform more complex reconstructive operations. With this review, we aim to analyze the current available literature and compare RALP with LP on success and complication rates, as well as OTs, LOS, ureteral stent management and costs.

Methods

A literature search of PubMed and EMBASE databases was conducted to identify all relevant articles published between 2005 and 2018, containing clinical outcomes of patients with UPJO after LP and RALP. The search string was (‘pyeloplasty’) AND (‘robotic pyeloplasty’) OR (‘robot-assisted laparoscopic pyeloplasty) OR (‘robotic-assisted laparoscopic pyeloplasty) AND (‘laparoscopic pyeloplasty’) OR (‘minimally invasive pyeloplasty’). The references of the extracted articles and abstracts presented at conferences were also reviewed to look for additional pertinent studies. The selected inclusion criteria were: studies published in English language; studies reporting results for pediatric patients; studies explicitly describing the clinical outcomes for LP and RALP; studies containing original data and meta-analyses. The selected exclusion criteria were: insufficient original data; articles that reported data already included in other selected references; simple reviews, case reports, commentary or opinion pieces. From each study, the following information were extracted: first author; year of publication; study type; primary diagnosis; number of patients treated; intra-operative data; treatment success and failure; post-operative complications; need for re-do pyeloplasty; ureteral stent management; costs, when available.

Results

Overall, we selected 19 original articles and 5 meta-analyses. Results of the original studies have been summarized in Table 1. Below, we report our review findings on success/failure, complications, and re-do pyeloplasty rates, as well as OTs, LOS, ureteral stent management and cost analysis.

Success rates

Success rates were comparable between the two minimally invasive approaches, with average rates of 98.5% and 96.9% at a follow-up of 14.1 and 26.3 months for RALP and LP, respectively [19–28]. However, there was some heterogeneity in defining success. Some authors suggested that a MAG3 renography showing improved split renal function and no obstruction at 1-year follow-up can be used as predictor of long-term success [29–32]. Most of the authors described a 2-year follow-up period with regular ultrasounds as ideal, considering that the majority of recurrences and reoperations occur within this time frame [31, 32].

When specifically evaluating pyeloplasty in infants, defined as children ≤ 12 months of age, very few studies directly compared RALP with LP. A multi-institutional study reported similar success rates for RALP and LP (95.2% vs 92.3%), at 11.5- and 5.5-month follow-up, respectively. The authors defined success as an improvement in pelvic diameter on renal ultrasound (US) [33]. Another multicenter retrospective study on RALP reported that 89% of infants improved on renogram at median follow-up of 12 (5–33) months [34]. Similarly, a single-center study showed a 100% success rate at 10-month follow-up [35]. Finally,

Table 1 Result summary of the original studies selected

	Number of patients	Follow-up (months)	OT (min)	LOS (days)	Complications (%)	Success (%)	Re-do (%)
Subotic et al. [28]							
RALP	19	10 (6–24)	165 (104–255)	6 (4–12)	31.6	17/19 (90)	2/19 (10.5)
LP	20	21 (6–48)	248 (165–334)	7 (5–12)	25	18/20 (90)	2/20 (10)
Riachy et al. [24]							
RALP	46	22 (2–36)	209 (109–540)	2 (1–6)	4.3	45/46 (98)	1/46 (2)
LP	18	43 (12–53)	298 (145–387)	1 (1–4)	11.1	17/18 (94.4)	0
Ganpule et al. [20]							
RALP	19	18.3 ± 8.2	155 ± 46.59	3.52 ± 1.5	5.3	18/19 (94.6)	N/A
LP	25	24.8 ± 7.4	167 ± 49.7	5.04 ± 1.56	4	24/25 (96)	N/A
Patel et al. [23]							
RALP	55	N/A	237 (199–259)	1.17 (1.08–1.71)	3.6	52/52 (100)	N/A
LP	13	N/A	259.8 (241.8–291)	1.67 (117–1.79)	0	11/12 (91.67)	N/A
Silay et al. [26]							
RALP	185	12.8 ± 9.8	173.1 ± 50.7	2.1 ± 2.1	7	184/185 (99.5)	N/A
LP	390	45.2 ± 33.8	173.8 ± 55.2	4.6 ± 2.4	15.1	381/390 (97.7)	N/A
Song et al. [27]							
RALP	10	16.6 ± 10.3	254.1 ± 46	3.2 ± 1.0	0	10/10 (100)	0
LP	30	20.1 ± 15.1	197 ± 38.9	5.8 ± 1.4	13.3	27/30 (90)	2/30 (7)
Franco et al. [19]							
RALP	15	9	223.1 ± 46.5	3	13.3	15/15 (100)	0
LP	12	9	236.5 ± − 24.1	3	16.7	11/12 (97.7)	N/A
Kim et al. [25]							
RALP	84	10 (6–28)	188 ± 68.7	0.9 ± 0.3	0	83/84 (98.8)	N/A
LP	58	10 (6–28)	196 ± 57	1.5 ± 0.8	3.4	56/58 (96.6)	N/A
Casella et al. [41]							
RALP	23	N/A	200	2	N/A	N/A	N/A
LP	23	N/A	265	2	N/A	N/A	N/A
Chan et al. [50]							
RALP	633	N/A	N/A	1.8	3	N/A	N/A
LP	46	N/A	N/A	2.4	2.2	N/A	N/A
Gatti et al. [21]							
RALP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LP	50	13.7	139.5 (94–213)	1.08	6	47/50 (94)	2/50 (4)
Salo et al. [32]							
RALP	31	25 ± 4.6	249 ± 52	3.4 ± 2.6	29	29/31 (94)	3/31 (9.7)
LP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maheshwari et al. [30]							
RALP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LP	82	41.6 (8–75)	151 (78–369)	4.9 (2–11)	26	68/74 (92)	2/74 (2.7)
Ansari et al. [29]							
RALP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LP	53	24 (4–45)	181 (78–369)	5 (2–11)	28	44/49 (89.7)	2/49 (4.1)
Infants							
Neheman et al. [33]							
RALP	21	11.5	156 (125–249)	1 (1–3)	23.8	20/21	1/21 (4.2)
LP	13	5.5	192 (98–229)	7 (7–12)	30.8	12/13	1/13 (7.7)
Avery et al. [34]							
RALP	60	12 (5–33)	232 ± 43	1 (1–2)	11.8	54/59 (91.5)	1/59 (1.7)
LP	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 1 (continued)

	Number of patients	Follow-up (months)	OT (min)	LOS (days)	Complications (%)	Success (%)	Re-do (%)
Bansal et al. [35]							
RALP	9	10 (7.2–17.8)	115 (95–205)	1 (1–2)	N/A	9/9 (100)	0
LP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kutikov et al. [36]							
RALP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LP	8	6	108	1.2	N/A	8/8 (100)	0
Turner et al. [37]							
RALP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LP	29	13.9	245 ± 44	1.3 (1–9)	10	22/24 (91.7)	2/24 (8.3)

two more studies reported data on LP only, with success rates of 92% and 100% at a follow-up of 6 and 14 months, respectively [36, 37].

Complication rates

In five studies, RALP favored lower complication rates as compared to LP, with a combined rate of 7.2% in the RALP group vs 14.3% in the LP group [19, 24–27]. The vast majority of complications were Clavien–Dindo grades I–III, and included post-operative urinary tract infections (UTIs), ureteral stent or nephrostomy tube dislodgement, ileus, urine leak, hematuria, bleeding, and visceral organ injury.

Data on complication rates in infants were scarce, and varied between 11.8% and 23.8% for RALP, and between 10% and 30.8% for LP [33, 34, 37].

Re-do pyeloplasty

The preferred management of recurrent UPJO after pyeloplasty is a Re-do of the operation, due to improved success rates when compared to endoscopic techniques [38]. Of all the selected studies, only ten reported data on Re-do pyeloplasty for LP and RALP. The cumulative rates of Re-do pyeloplasty were 3.8% and 4.6% for RALP and LP, respectively. Ahn et al., in a small case series, reported a 100% success rate for Re-do pyeloplasty performed with the robot. In addition, for difficult Re-do cases, such as patients with significant fibrosis or challenging mobilization of the renal pelvis not allowing for a tension-free anastomosis, the authors suggested the use of buccal mucosal grafts [39].

Finally, a meta-analysis of re-operative pyeloplasty reported decreased OTs for Re-do OP and decreased LOS for Re-do LP. No difference was noted in post-operative outcomes, boasting success rates of 97–100% for both OP and LP [40].

Operative time

It has been recognized that the robotic approach to the UPJO allows for decreased OTs as compared to LP. In a meta-analysis, Cundy et al. reported 33 min shorter OTs for RALP as compared to LP [18, 19, 25, 28, 41]. Accordingly, Casella et al. reported an OT advantage of 65 min in RALP over LP [41]. A most recent meta-analysis by Light et al., which also included studies on adult patients, reported decreased OTs for RALP as compared to LP by 27 min [42]. We further identified six articles directly comparing OTs on pediatric patients alone [20, 23, 24, 26–28], and five out of six demonstrated decreased OTs for RALP as compared to LP, with an average improvement of 25 min [20, 23, 24, 26, 28]. A modest reduction in OTs was also described in infants. The few available studies reported an average OT of 167.6 min for RALP as compared to the 181 min for LP [33–37].

Length of hospital stay

Six studies comparing RALP with LP reported significantly shorter LOS for RALP, with a cumulative average of 2.9 days, as compared to the 4.2 days for LP [20, 23, 25–28]. Extracting data specific to infants, the average LOS was similar between RALP and LP [33–37].

Postoperative ureteral stent management

The optimal placement and post-operative removal timeframe of ureteral stents are still a matter of debate. Decreasing the duration of ureteral stenting or avoiding its placement at all would lead to a decreased stent-related morbidity, such as stent migration, UTIs, pain and bladder spasms. In adult patients undergoing pyeloplasty, no difference in success rate was found when stratified by indwelling stent times (1 vs 4 weeks) [41]. The utilization of the externalized uretero-pyelostomy (EUP) stent is a strategy to decrease stent-related complications. A retrospective review of 76 pediatric patients undergoing open or LP showed no difference in success rates, OTs, LOS and overall post-operative complications when using EUP vs double J (DJ) stent [43]. Some authors have reported their experience with stent-less RALP, for both adult and pediatric patients, boasting a 100% success rate [44, 45]. In addition, when comparing costs between EUP, DJ and stent-less techniques, EUP and stent-less approaches were favorable [46].

Ultimately, the need of an antibiotic prophylaxis for patients with a ureteral stent in place has also been questioned. Ferroni et al. [47], in a retrospective study involving 163 pediatric patients undergoing RALP or LP, showed that extended antibiotic prophylaxis had no significant impact on post-operative rate of UTIs [47].

Cost analysis

Robotic surgery has been criticized for the prohibitive cost of platform and disposable instruments. However, a recent study comparing RALP to LP did not find a significant difference in costs [41]. The authors argued that, although equipment may be costlier up front ($3,674 for RALP vs $1,374 for LP), the decreased OTs associated with RALP (200 vs 265 min) make up for the additional equipment cost ($15,337 for RALP vs $16,067 for LP). However, when compared to OP, RALP remains costlier, despite lower LOS [48].

Discussion

After its introduction in 1995, LP showed to be a safe and effective minimally invasive treatment option for UPJO. However, LP presents some shortcomings, such as steep learning curve, fulcrum effect, relatively low dexterity of the instruments, which make it technically challenging even for skilled surgeons. Therefore, LP has not been routinely adopted worldwide. The robotic platform mitigates many of the problems of conventional laparoscopy, because it provides new functions, such as three-dimensional (3D) view, tremor filtration, motion-scaling, and wristed instruments. Thus, the stereoscopic 3D-view combined with the enhanced dexterity facilitates the performance of more challenging tasks, such as intracorporeal suturing and working within small anatomical spaces. The technical benefits of RALP are particularly evident during the critical steps of this procedure, such as ureteric spatulation, pelvis reduction, and uretero-pelvic anastomosis. The European Society for Pediatric Urology (ESPU) guidelines recently reported similar success rates between MIS (LP and RALP) and open approach for pyeloplasty, estimated to be around 90–95% [26]. However, they acknowledged the superiority of the robot due to the lower LOS and complication rates. Accordingly, the present review shows no differences between RALP and LP in terms of operative success and Re-do rates, but outcomes for LOS, OTs and complication rates were in favor of RALP. Furthermore, the robotic technology seems to be easier to learn and it has contributed to shorten the learning curve as compared to laparoscopy. One of the major advantages of this technology is that surgeons can become proficient with the robot by transferring their open skills, without the need of prior laparoscopic experience [49]. By acting as a bridge between open and MIS, the robot has made it possible to perform complex reconstructive operations that were previously completed only with a traditional open approach. In this setting, RALP offers also the advantage of being a gateway procedure for surgeons who strive to perform even more complex robotic operations, such as bladder reconstruction.

In the MIS era, the most suitable approach to UPJO should be safe, effective, and easy to learn. This is why RALP has been taking over LP for children with UPJO, and also for more challenging cases, such as infants and Re-do pyeloplasty. This trend is undoubtedly supported by the current literature, which shows promising results. However, there is still a need for higher quality evidence in the form of prospective observational studies and clinical trials, as well as further cost-effectiveness analyses. Of note, the current robotic surgical system remains in a first-generation platform, expensive, and designed for the adult patient. As robotic surgical technology spreads, future systems will be developed, offering smaller and more flexible tools, allowing enhanced applications on the pediatric patient.

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Compliance with ethical standards

Conflict of interest Dr. Mohan S. Gundeti is co-director for the NARUS course. The other authors have no conflicts of interest to declare.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Does not apply.

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