The learning curve for robotic-assisted pyeloplasty in children: Our initial experience from a single center

Noor Nabi Junejo1,2, Anwar Alotaibi3, Saeed Malwi Alshahrani4, Ahmad Alshammari25, Craig A. Peters6, Hamdan Alhazmi7, Santiago A. Vallasciani8

1Urology Department, King Faisal Specialist Hospital and Research Centre and College of Medicine, Alfaisal University, 2Pediatric Urology Division, Urology Department, King Faisal Specialist Hospital and Research Centre, 3Biostatistics, Epidemiology and Scientific Computing Department, King Faisal Specialist Hospital and Research Centre, 4King Faisal Medical City for Southern Region, Abha, 5Pediatric Urology Division, Department of Surgery, King Abdullah Specialized Children Hospital, National Guard Health Affair, Riyadh, Saudi Arabia, 6Children’s Medical Centre, University of South-Eastern, Dallas, Texas, USA, 7Urology Division, Department of Surgery, King Saud University Medical City and College of Medicine, King Saud University, Riyadh, Saudi Arabia, 8Pediatric Urology Division, Surgery Department, Sidra Medical and Research Center, Doha, Qatar

Abstract

Background: Robotic-assisted pyeloplasty surgery has become the preferred approach of ureteropelvic junction obstruction (UPJO) in pediatrics. However, to our knowledge, there is limited data on the learning curve for robotic-assisted pyeloplasty in children and no similar study from Saudi Arabia.

Aims: The objective of the study was to evaluate the progression of the surgical team performing robotic-assisted laparoscopic pyeloplasty (RALP) and to assess the feasibility of the RALP in children, since it is having been recently started in the Kingdom.

Settings and Design: Retrospective charts and surgical videos review at the tertiary care centre.

Subjects and Methods: After approval from the internal review board (IRB), we reviewed the surgical video recording of the RALP procedure of 15 patients presented with UPJO from January 2016 to October 2017. Statistical analysis was done for the variables includes dissection time, pyelotomy, anastomosis on both sides, and total surgery time and calculated in minutes. Renal ultrasound reviewed to assess any change in grade.

Results: Fifteen patients with UPJO underwent RALP. Of 15 cases, nine were primary and six cases as secondary UPJO. The median age was 8 (3–15) years. Out of 15 cases, 13 and 2 patients diagnosed as Society for Fetal Urology grades of 4 and 3, respectively. Total operative time was prolonged in secondary group as compared to primary pyeloplasty group (mean [standard deviation (SD)]: 166.3 [35.1], range: 125–223, \( P = 0.0028 \) versus mean (SD): 149.17 (30.4), range: (114–207), \( P = 0.0008 \)). The success rate was 100% in primary and 84% in secondary cases. The median length of follow-up was 12.0 (7.0–18.0) and 10.0 (8.0–12.5) months in primary and secondary cases, respectively. The overall complication rate was 13% (2/15) (Clavien grade: 1–2).

Conclusions: The evaluation of the learning curve of RALP for this group of patients concluded that total operative time for RALP, performed by the pediatric urology team, steadily decreased with collective surgical experience.

Keywords: Learning curve, pediatric, pyeloplasty, robotics

Address for correspondence: Dr. Noor Nabi Junejo, Department of Urology, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia.

E-mail: drnoorjunejo@gmail.com

Received: 06.08.2019, Accepted: 21.11.2019, Published: 23.12.2019.
INTRODUCTION

The “gold standard” procedure for the correction of ureteropelvic junction obstruction (UPJO) has been the Anderson-Hynes dismembered pyeloplasty technique and open approach being the most common with success rates of 90%–100%, overall.\(^1\)\(^2\) Now a day, there is an increasing trend towards the robotic approach to be a new gold standard option for the pediatric population as published in the literature\(^3\) with similar outcomes as the open pyeloplasty.\(^4\)

Robotic surgery in pediatrics urology has gained popularity since its introduction almost two decades ago. Robotic-assisted pyeloplasty is the most common procedure performed in pediatric urology.\(^5\) Robotic technology alleviates the limitations of conventional laparoscopic surgery, and the robot-assisted laparoscopic pyeloplasty (RALP) has to become the most common robotic surgery performed in pediatric urology.\(^6\)

We conducted a retrospective study to determine the learning curve for pediatric urology team progression for surgical steps in performing robotic pyeloplasty. We define the learning curve as the improvement in total operative time.

We report our experience of 15 pediatric patients who underwent RALP between 2016 and 2017. The aim was to evaluate the progression of the surgical team performing RALP in a single Center and its recent introduction in the kingdom. Furthermore, to our knowledge, there is limited data on the learning curve internationally and no similar studies in Saudi Arabia.

SUBJECTS AND METHODS

After approval by the internal review board (IRB), we reviewed retrospectively the video records of RALP conducted in our center from January 2016 to October 2017.

We included cases between 2 and 15 years underwent RALP for primary and secondary UPJO; we exclude any case with concomitant other renal pathologies such as renal stone or ectopic kidney.

Patients’ data were reviewed retrospectively for pre-, intra-, and postoperative details. Preoperative details included age, sex, type of UPJO, clinical presentation, renal ultrasonography for hydronephrosis grades, and type of nuclear scan. Intraoperative details included procedure performed, patient position and preparation, the introduction of trocars, robot docking, initial dissection and application of stay suture over the renal pelvis, pelvic opening, ureter spatulation, ureteropelvic anastomosis on each side, operative time, and any complication. Postoperative details included any immediate or late complication and length of hospital stay. Our primary the outcome measure was the success of the pyeloplasty as demonstrated by renal ultrasound and/or the resolution of the symptoms and the presence or absence of complications. The secondary outcome was total surgery time, which calculated in minutes. Renal ultrasound findings were reviewed for grades of hydronephrosis, according to the Society for Fetal Urology (SFU). Preoperatively we used diuretic renography to determine the severity and functional significance of UPJO. In most of the patients, we did Technetium-99 m mercaptoacetyltriglycine (\(^{99m}\)Tc-MAG-3) nuclear scan as it is ideal for the pediatric population.

We categorized the complications using the Clavien grading system as minor (Clavien 1–2) or major (Clavien 3–4).\(^3\)

All procedures were done by primary pediatric urology as a team, with similar previous laparoscopic experience. The idea was to see how the robotic program has grown as one team in our center. Hence, it was an evolution as a team with at least two of three surgeons present in the operating room and sharing the console for all the cases. We have also included video to see the steps of robotic pyeloplasty [Video 1].

All the statistical analyses performed using the JMP Version 14 (SAS Institute, Cary, North Carolina) for Macintosh. Regression analysis was performed to find the trend of the time of the surgeries. Continuous variables were reported by mean values and 95% confidence intervals. \(P < 0.05\) is considered to be statistically significant.

RESULTS

Fifteen pediatric patients presented with UPJO at out center who underwent RALP. Out of 15 cases, nine patients were primary and six cases as secondary UPJO (those who operated before). The demographic profile and preoperative details are shown in Table 1. We divided patients into two groups, i.e., primary versus secondary to review surgeons learning curve in different surgical steps. The median age was 8 (3–15) years. Patients presented with a history of flank pain, abdominal swelling, and worsening of hydronephrosis with impairment of renal functions in 60%, 26.7%, and 13.35 cases, respectively. Out of 15 cases, 13 and two patients diagnosed as SFU grade of 4 and 3, respectively. The intraoperative and postoperative results of primary and secondary cases are shown in Table 2. In our
results, total operative time was prolonged in secondary pyeloplasty group as compared primary pyeloplasty group (mean [standard deviation (SD)]: 166.3 [35.1], range: 125–223, P = 0.0028 versus mean [SD]: 149.17 [30.4], range: 114–207, P = 0.0008). The success rate was 100% in primary and 84% in secondary cases. One patient of the secondary case was failed and further required redo pyeloplasty. We followed our patients every 6 months with a renal ultrasound and renal functions. The median length of follow-up was 12.0 (7.0–18.0) months and 10.0 (8.0–12.5) months in primary and secondary cases, respectively. The overall complication rate was 13% (2/15) (Clavien grade: 1–2), complaining of severe postoperative vomiting and managed conservatively. There was no intraoperative complication in either cohort [Table 2].

Tables 3-5 show the descriptive analysis outcomes of all surgical steps for overall all cases, primary and secondary cases, respectively. There was a significant decrease in the total operation time overall of 40% from first to the last case with P = 0.260. The overall success rate was 94% in our study compared with other studies [Table 6].

Graphical presentation of outcomes for all cases, primary and secondary cases [Graphs 1-3 respectively] shows that there was an improvement in skills and the decrease in operative time with an increase in the number of cases, especially in primary cases, as we found postoperative adhesions in secondary cases and took longer time [Graphs 1-3].

DISCUSSION
RALP represents one of the modern and promising high-tech developments in the urological procedures for pediatrics. However, there are insufficient data about the learning curve of RALP in children. Our study represents one of the first studies from Saudi Arabia on the outcomes of the learning curve for RALP for the pediatric age group. This study resulted in RALP is feasible, potentially safe, satisfactory outcomes in terms of symptoms free, resolution/reduction of hydronephrosis grade, short hospital stays, and we found improvement in learning curve after 15 cases.

Table 1: Demographic profile and preoperative details

| Variables                                             | n (% )      |
|-------------------------------------------------------|-------------|
| Total number of patients                              | 15          |
| Median age (years)                                    | 8 (3–15)    |
| Male                                                  | 9 (60)      |
| Female                                                | 6 (40)      |
| Clinical presentation number of cases (%)             |             |
| Pain                                                  | 9/15 (60)   |
| Abdominal swelling                                    | 4/15 (26.70)|
| Worsening of renal functions                          | 2/15 (13.3) |
| Laterality (number of patients)                       |             |
| Left                                                  | 7 (47)      |
| Right                                                 | 8 (53)      |
| Type of cases (Nos)                                   |             |
| Primary                                               | 9 (60)      |
| Secondary                                             | 6 (40)      |
| Grade of hydronephrosis (SFU) preoperative            |             |
| SFU Grade 4                                           | 13          |
| SFU Grade 3                                           | 2           |
| Preoperative nuclear scan                             |             |
| MAG-3                                                 | 11          |
| DMSA                                                  | 4           |

MAG-3: Mercaptoacetyltriglycine, DMSA: Dimercaptosuccinic acid, SFU: Society for fetal urology

Table 2: Intraoperative and postoperative details of robotic-assisted laparoscopic pyeloplasty for primary and secondary ureteropelvic junction obstruction cases

| Variable (time) min | Primary UPJO | Secondary UPJO | P    |
|---------------------|--------------|----------------|------|
| Number of patients  | 9/15         | 6/15           |      |
| Induction time, mean (SD) (range) | 26.89.4 (2.76) (24.4–32) | 25.83 (2.64) (22–30) | 0.9326 |
| Positioning and prep, mean (SD) (range) | 27.78 (4.63) (20–33) | 24.67 (2.58) (20.0–28) | 0.0663 |
| Total dissection and applying stay suture, mean (SD) (range) | 26.17 (6.99) (17–37) | 34.5 (6.89) (25–45) | 0.0156 |
| Renal pelvis opening and ureteric spatulation, mean (SD) (range) | 39.22 (7.56) (30–55) | 42.83 (10.62) (30–60) | 0.0092 |
| First side anastomosis, mean (SD) (range) | 15.44 (7.14) (7–28) | 20.83 (11.23) (9–38) | 0.0213 |
| Second side anastomosis, mean (SD) (range) | 14.22 (6.98) (8–38) | 17.67 (6.71) (11–30) | 0.0630 |
| Total surgery, mean (SD) (range) | 140.17 (39.42) (114–207) | 166.33 (35.16) (125–223) | 0.0260 |
| Crossing vessel | 2            | 0              |      |
| Hospital stay (days) median | 4.0 (3–4) | 5.0 (4–6) | 0.311 |
| Median follow-up, months (IQR) | 12.0 (7.0–18.0) | 10.0 (8.0–12.5) |      |
| Grade of hydronephrosis (SFU) postoperative |             |                |      |
| SFU Grade 1 | 7/9          | 3/6            |      |
| SFU Grade 2 | 2/9          | 2/6            |      |
| SFU Grade 3 | 1/6 (failed) |                |      |
| Complications (%) |            |                |      |
| Intraoperative | 0            | 0              |      |
| Postoperative | 11           | 16             |      |
| Success rate (%) | 100          | 84             |      |

SD: Standard deviation, SFU: Society for fetal urology, UPJO: Ureteropelvic junction Obstruction, IQR: Interquartile range
Table 3: Time trend change over in all cases (n=15)

| Variable time in minutes | Mean (SD) | Minimum | Maximum | Confidence interval (95.0%) | Percentage change | Percentage change (last/first) | r | P   |
|--------------------------|-----------|---------|---------|-----------------------------|------------------|-------------------------------|---|-----|
| Induction time           | 26.46 (2.66) | 22      | 32      | -0.529–0.494                | 0                | -12                           | -0.024 | 0.9326 |
| Position prep time       | 26.53 (4.13) | 20      | 33      | -0.79–0.035                 | 0                | -13                           | -0.486 | 0.0663 |
| Dissection time          | 14.53 (4.75) | 8       | 22      | -0.466–0.556                | 15               | 0                             | 0.06  | 0.8281 |
| Stay suture              | 2.70 (0.88)  | 2       | 5       | -0.641–0.354                | 9                | -33                           | -0.19 | 0.4911 |
| Further dissection       | 12.47 (4.00) | 7       | 20      | -0.883–0.256                | -2               | -61                           | -0.68  | 0.0053 |
| Total dissection + stay suture | 29.50 (7.92) | 17      | 45      | -0.706–0.247                | 6                | -32                           | -0.30  | 0.2709 |
| Renal pelvis open and ureteric spatulation | 40.67 (8.87) | 30      | 60      | -0.87–0.201                | -1               | -45                           | 0.65  | 0.0092 |
| First side anastomosis   | 17.60 (9.04) | 7       | 38      | -0.845–0.107                | 16               | -68                           | -0.59  | 0.0213 |
| Second side anastomosis  | 15.60 (6.85) | 8       | 30      | -0.802–0.028                | 4                | -63                           | -0.49  | 0.0630 |
| Total surgery time       | 156.03 (32.34) | 114     | 223     | -0.838–0.083                | -1               | -40                           | -0.57  | 0.0260 |

SD: Standard deviation

Table 4: Time trend change over in primary cases (n=9/15)

| Variable time in minutes | Mean (SD) | Minimum | Maximum | Confidence interval (95.0%) | Percentage change | Percentage change (last/first) | r   | P   |
|--------------------------|-----------|---------|---------|-----------------------------|------------------|-------------------------------|-----|-----|
| Induction time           | 26.89 (2.76) | 24      | 32      | -0.291–0.861                | 3                | 20                            | 0.462 | 0.21 |
| Position prep time       | 27.78 (4.63) | 20      | 33      | -0.99–0.799                 | -5               | 38                            | -0.956 | <0.0001 |
| Dissection time          | 11.44 (2.92) | 8       | 16      | -0.973–0.507                | -8               | -50                           | -0.87  | 0.002 |
| Stay suture              | 2.77 (0.44)  | 2       | 3       | -0.88–0.177                 | -3               | -33                           | -0.552 | 0.1233 |
| Further dissection       | 12.56 (3.84) | 7       | 18      | -0.99–0.809                 | -11              | -61                           | -0.958 | <0.0001 |
| Total dissection + stay suture | 26.17 (6.99) | 17      | 37      | -0.984–0.679                | -9               | -54                           | -0.9235 | 0.0004 |
| Renal pelvis open and ureteric spatulation | 39.22 (7.56) | 30      | 55      | -0.976–0.543                | -7               | -45                           | -0.887 | 0.0014 |
| First side anastomosis   | 15.44 (7.14) | 7       | 28      | -0.98–0.67                  | -16              | -75                           | -0.923 | 0.0004 |
| Second side anastomosis  | 14.22 (6.98) | 8       | 30      | -0.95–0.19                  | 13               | -70                           | -0.759 | 0.0175 |
| Total surgery time       | 149.17 (30.42) | 114     | 207     | -0.98–0.599                 | -7               | -45                           | -0.903 | 0.0008 |

SD: Standard deviation

Table 5: Time trend change over in secondary cases (n=6/15)

| Variable time in minutes | Mean (SD) | Minimum | Maximum | Confidence interval (95.0%) | Percentage change | Percentage change (last/first) | r   | P   |
|--------------------------|-----------|---------|---------|-----------------------------|------------------|-------------------------------|-----|-----|
| Induction time           | 25.83 (2.64) | 22      | 30      | -0.867–0.736                | -2               | -12                           | -0.188 | 0.7220 |
| Position prep time       | 24.67 (2.58) | 20      | 28      | -0.625–0.91                 | 3                | 12                            | 0.378  | 0.4594 |
| Dissection time          | 19.17 (2.56) | 16      | 22      | -0.99–0.72                  | -6               | -27                           | -0.967 | 0.0016 |
| Stay suture              | 3.33 (1.03)  | 2       | 5       | -0.99–0.36                  | -16              | -60                           | -0.907 | 0.0126 |
| Further dissection       | 12.33 (4.58) | 7       | 20      | -0.97–0.20                  | -14              | -65                           | -0.728 | 0.1003 |
| Total dissection + stay suture | 34.5 (6.89)   | 25      | 45      | -0.99–0.31                  | -11              | -44                           | -0.896 | 0.0156 |
| Renal pelvis open and ureteric spatulation | 42.83 (10.92) | 30      | 60      | -0.99–0.088                 | -13              | -50                           | -0.986 | 0.0003 |
| First side anastomosis   | 20.83 (11.23) | 9       | 38      | -0.99–0.86                  | -25              | -76                           | -0.985 | 0.0003 |
| Second side anastomosis  | 17.67 (6.71) | 11      | 30      | -0.99–0.36                  | -17              | -63                           | -0.908 | 0.0123 |
| Total surgery time       | 166.33 (35.16) | 125     | 223     | -0.96–0.99                  | -11              | -44                           | -0.957 | 0.0028 |

SD: Standard deviation

Table 6: Robotic-assisted laparoscopic pyeloplasty: Outcomes of comparative studies

| Study            | Year | Study type   | Patients | Success rate (%) | Complication rates (%) definition | Mean OT (min) |
|------------------|------|--------------|----------|------------------|-------------------------------|--------------|
| Olsen et al.     | 2007 | Case series  | 67       | 94               | 13.8 OC                       | 143 (93-300) |
| Franco et al.    | 2007 | Comparative  | 15       | 100              | Not reported                   | 236          |
| Sorensen et al.  | 2011 | Comparative  | 33       | 97               | 15.0 OC                       | 326          |
| Subotic et al.   | 2011 | Comparative  | 19       | 100              | 28.0 OC                       | 165          |
| Barbosa et al.   | 2012 | Comparative  | 58       | 74               | 1.7 (needed redo pyeloplasty)  | -            |
| Riachy et al.    | 2012 | Comparative  | 46       | 100              | 4.0 OC                        | 209          |
| Saló et al.      | 2016 | Comparative  | 39       | 96               | 3.2 (Grade 3 complication)    | -            |
| Kassite et al.   | 2018 | Case series (interphase comparisons) | 39 | 95 phase 1 94 phase 2 | 19 (phase 1and 2) 17 (phase 3) | 200 |
| Morales-López et al. | 2019 | Case series  | 41       | 95               | 9.7                            | 135          |
| Present study    | 2019 | Case series  | 15       | 94               | 13.0 OC                       | 156 (114-223) |

OT: Operative time, OC: Overall complications
The learning curve for RALP in the management of pediatric urology patients has reported in the literature.\textsuperscript{[9,15]} The robotic tools allow for three-dimensional imaging, motion scaling, tremor sifting, an ergonomic installed position, and wrist movement allowing autonomy of up to 7° comparable to open surgical instruments. Subsequently, the system is proficient in producing very subtle changes, perfect for urologic surgery within the smaller pediatric patient. Furthermore, these robotic properties have expressively reduced the learning curve for intracorporeal suturing compared to conventional laparoscopy.\textsuperscript{[16]}

A smaller learning curve permits further surgeons to offer a minimally invasive method to the pyeloplasty, reduces operating room times and subsequent cost, and decreases the risk of complications in patients as the surgeon obtains the skill. O’Brien and Shukla\textsuperscript{[17]} have shown a shortened learning curve for the robotic pyeloplasty, presenting that it needs diminutive previous laparoscopic or robotic experience and established in comparing outcomes, analgesic requirements, and length of stay with age-matched laparoscopic and open patients from the pediatric literature.\textsuperscript{[17]}

We reported our initial experience of 15 RALP cases in pediatric patients. Sorensen et al.\textsuperscript{[9]} evaluated the learning curve and outcomes, comparing RALP against the open approach. Similar results reported between the two procedures after approximately twenty cases, which is a much-shortened course compared to the vertical learning curve for laparoscopy. Therefore, in adding to its efficacy in smaller patients, RALP may be stress-free to learn compared to conventional laparoscopic pyeloplasty, increasing access to minimally invasive methods in the field of pediatric urology.

Tasian et al.\textsuperscript{[15]} reported the learning curve of robotic pyeloplasty for children with UPJO. They observed an improvement of 3.7 minutes per case with excellent surgical outcomes. Authors\textsuperscript{[18]} understood that if surgical time is used to define the learning curve, it must be measured accompanied by the surgical outcomes. Surgical simulation has the potential to develop patient safety, increase surgical training competence, and to lessen operating room expenditures.\textsuperscript{[18]}

To manage the secondary (recurrent) UPJO after primary pyeloplasty poses a substantial surgical challenge, particularly in complex cases. In our study, total operative time was prolonged in the secondary pyeloplasty group as compared primary pyeloplasty group (mean [SD]: 166.3 [35.1], range: 125–223, $P = 0.0028$ versus mean [SD]: 149.17 [30.4], range: 114–207, $P = 0.0008$).

Sorensen et al.\textsuperscript{[9]} reported that after 15–20 robotic cases, the overall operative time for RALP cases was constantly within 1 SD of average open pyeloplasty time with no
significant variance in complete operative time ($P = 0.23$) and concluded that operative time decreased after gaining more experience.

Recently, Kassite et al.\(^{[14]}\) has conducted a study on the learning curve of RALP in children: a multi outcome approach. They enrolled patients such as 1–12, 13–22, and 2–39 cases in Phase 1, 2, and 3 and three periods (learning, consolidation and increased competence), respectively. The interphase evaluation indicated a substantial decrease in operation time, length of stay, and postoperative pain ($P = 0.0001$; $P = 0.0076$; $P = 0.039$), respectively. Results showed a mean operation time was mean (SD) 200 (72.8) min. They concluded that more complex features impact surgical outcomes. Table 6 shows the comparative operation time results.

Thom et al.\(^{[19]}\) performed a study on robotic-assisted pyeloplasty to review the outcomes for primary and secondary repairs. They included 55 patients who underwent RAP 926 left/29 right for UPJO, which included 46 primaries and 9 secondary cases. The mean operative time was 194 min, and they found lengthier time for secondary cases 205 min.

Success rates and complications: in our study, the overall complication rate was 13% (2/15) (Clavien grade: 1–2). Moreover, the overall success rate was 94% (14/15). We compared the success rates and complications with other studies [Table 6].

**Limitations**

Our study has limitations: (1) Retrospective study and (2) single-center experience of RALP; hence a much broader picture of the status of RALP in Saudi Arabia is yet to be defined and addressed through Multi-Institutional Study.

**CONCLUSIONS**

The evaluation of the learning curve of RALP for this group of patients showed that total operative time for RALP, performed by the pediatric urology team, steadily decreased with collective surgical experience. As a result, surgeons with limited laparoscopic experience can more readily acquire surgical skills, and the utilization of RALP is growing rapidly, signifying that the robotic approach may be the new gold standard for minimally invasive pyeloplasty; however, further studies need to publish from Saudi Arabia.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

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