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Research Article

Learning Curve and the Influence of Patient Age on Operative Times in Pediatric Robotic Pyeloplasty: A Single-Center Experience.

M. Ruiz, L Zelaya, V Vargas, JI Garrido, RM Paredes, A Parente.

Pediatric Surgery Department, Reina Sofia University Hospital. Cordoba, Spain.

Abstract

Objective: To assess the learning curve and the influence of patient age on operative times in pediatric robotic pyeloplasty, and to determine the safety and effectiveness of the procedure based on our institutional experience.
Methods: A retrospective observational study was conducted including 16 pediatric patients diagnosed with ureteropelvic junction obstruction (PUJO) who underwent robotic-assisted pyeloplasty using the Da Vinci Xi system between 2022 and 2025. Clinical and surgical variables were analyzed, including age, laterality, etiology, docking and closure time (DCT), console time (CT), total operative time (TOT), and complications. To evaluate the learning curve, cases were divided chronologically into three groups of five patients each. Linear regression analysis and ANOVA tests were used to assess correlations between case number, patient age, and operative times.
Results: Eighty percent of the obstructions were left-sided, and 53% were intrinsic. The mean patient age at surgery was 65 months. No conversion to open surgery was required. The mean DCT was 47 minutes, CT was 102 minutes, and TOT was 149 minutes. A significant correlation was found between the number of cases and the reduction in DCT ($R=0.678$, $p<0.05$), indicating progressive improvement with surgical experience. No correlation was observed between patient age and operative times. No major intraoperative or postoperative complications were reported.
Conclusions: Robotic-assisted pyeloplasty is a safe and effective approach for pediatric PUJO. Operative times decrease with increasing surgical experience, reflecting a relatively short learning curve, while patient age does not significantly impact technical complexity or operative duration.

Keywords: Pediatric surgery, Robotic surgery, pyeloplasty, children.

INTRODUCTION

Ureteropelvic junction obstruction (PUJO) is one of the most common causes of hydronephrosis in children, and pyeloplasty remains the surgical treatment of choice for its correction. Traditionally, this procedure has been performed through open surgery, which has long been regarded as the gold standard. In recent years, however, advances in minimally invasive surgery have transformed the management of UPJO, with robot-assisted pyeloplasty emerging as a preferred approach that combines precision, superior ergonomics, and surgical safety (1).

Since the first pediatric laparoscopic pyeloplasty was reported in 1995 (2), several technical limitations of laparoscopy have been recognized, particularly those related to intracorporeal suturing, suboptimal ergonomics, and a steep learning curve (2,3). In this context, robot-assisted surgery represents a natural evolution that addresses many of these challenges. The Da Vinci robotic system, with its three-dimensional vision, instruments that replicate human wrist movements, tremor filtration, and enhanced surgeon ergonomics, offers clear advantages that translate into improved surgical precision and operator comfort (4–6).

Despite these technological advances, the role of robotic surgery in younger pediatric patients remains a topic of debate, mainly due to anatomical, technical, and cost-effectiveness concerns. Nonetheless, our experience suggests that robotic pyeloplasty can be safely and effectively performed in younger children. In this study, we present our series of pediatric robotic pyeloplasties, describing our learning curve and analyzing the evolution of operative times throughout consecutive cases.

***Corresponding Author:** **Alberto Parente**, Pediatric Surgery Department, Reina Sofia University Hospital. Cordoba, Spain. **Email:** parente80@hotmail.com, **ORCID:** https://orcid.org/0000-0003-4838-603X.
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MATERIALS AND METHODS

Study design

A retrospective observational study was conducted, including all pediatric patients diagnosed with pyeloureteral junction obstruction (PUJO) who underwent robot-assisted pyeloplasty at our institution between 2022 and 2025.

Surgical indication was established on the presence of an obstructive curve on diuretic renography, impaired renal function, pyonephrosis, or extrinsic PUJO secondary to a crossing polar vessel.

The following variables were recorded: patient age, etiology (intrinsic PUJO or secondary to a crossing vessel), laterality, docking time, console time, total operative time, length of hospital stay, and intraoperative and postoperative complications.

To evaluate the learning curve, cases were divided chronologically into three groups of approximately five patients each.

- Group 1: the first six cases performed between 2022 and 2023
- Group 2: cases 7–10 performed in 2024
- Group 3: cases 11–16 performed in 2025

All procedures were performed by the same surgeon using Da Vinci surgical system.

Preoperative antibiotic prophylaxis consisted of a single intravenous dose of cefazolin (50 mg/kg). A dismembered Anderson–Hynes pyeloplasty was performed using three trocars arranged in a straight line for abdominal access. The pyeloureteral anastomosis was completed with two running sutures of absorbable monofilament (4-0 Monocryl).

A double-J ureteral stent and a Foley urinary catheter were left in place in all patients. The stent was removed within six weeks postoperatively to minimize the risk of infection. Surgical drains were not routinely placed.

RESULTS

Sixteen patients diagnosed with PUJO were analysed, of whom 80% were on the left side and 20% on the right side. Fifty-three percent of the obstructions were intrinsic, while 46% were extrinsic, secondary to a crossing polar vessels. The mean age at the time of surgery was 65 months (**Table 1**).

Table 1.

Mean age at surgery	**71. 88 months (13 ± 168)**		
Sex	Male = 13 (81%)	Female = 3 (19%)	
Laterality	Left = 12 (75%)	Right = 4 (25%)	
Docking + Closure time	Group 1: 53.8 minutes	Group 2: 50 minutes	Group 3: 38 minutes
Operative Time	Group 1: 106 minutes	Group 2: 102 minutes	Group 3: 101.5 minutes
Total Time	Group 1: 159 minutes	Group 2: 156 minutes	Group 3: 140 minutes

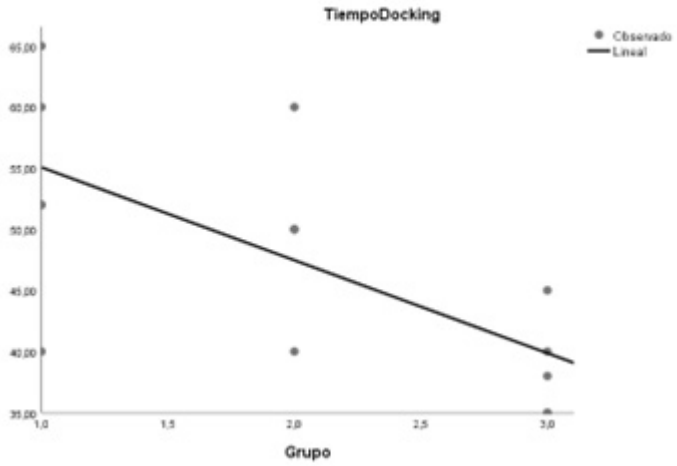
No patient required conversion to open surgery. One intraoperative incident occurred due to a temporary robotic system malfunction that limited arm movement, which was solved by restarting the system. No further intraoperative complications were recorded.

The mean docking and incision closure time (DIC) was 47 minutes, the mean console time (CT) 102 minutes, and the mean total surgical time (ST) 149 minutes.

A progressive decrease in surgical times was observed as surgical experience increased. To evaluate this trend, a linear regression model was applied, considering the number of cases as the independent variable and DIC, CT, ST as dependent variables.

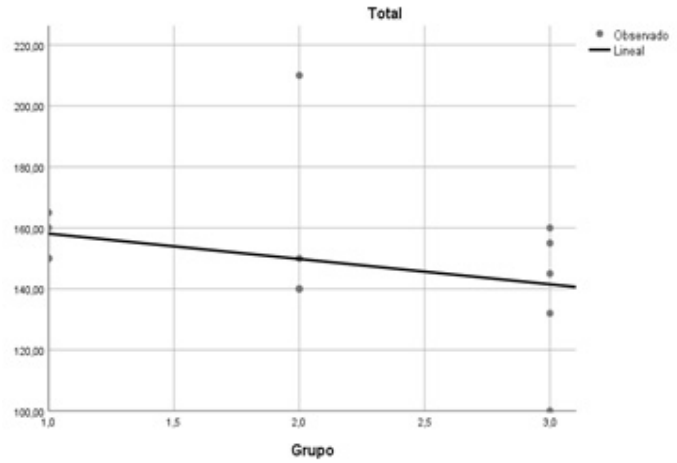
Analysis of docking and closure time revealed a significant negative correlation with surgical experience (Pearson's $R = 0.678$, $p < 0.05$), indicating shorter times with increasing case numbers. The ANOVA model confirmed the validity of this regression ($p \leq 0.05$) (**Figure 1**).

Figure 1.



Regarding total surgical time, a moderate correlation was observed with the number of cases (R = 0.309, p < 0.05). Although the ANOVA model allowed a linear relationship, the differences did not reach statistical significance , likely due to the limited sample size. (**Figure 2**).

Figure 2.



When comparing operative times across experience groups, a mean reduction of 18 minutes was observed in Group 3 (last six cases) compared to Group 1 (first five cases), representing an improvement of more than one minute per case—slightly exceeding values reported in the literature (7). However, these differences were not statistically significant, probably due to the small cohort.

The hypothesis proposed in previous studies (8), suggesting greater technical difficulty in younger children, was also explored. However, in our analysis, when evaluating the three time variables (TDC, TC, and TT) independently, low correlation coefficients were obtained:

- TDC: R = 0.099
- CT: R = 0.020
- TT: R = 0.024

These results indicate a minimal correlation between patient age and operative times, suggesting that, in our experience, robotic pyeloplasty in younger children does not entail increased technical difficulty.

DISCUSSION

Robotic pyeloplasty has progressively established itself as an effective and safe alternative to open or laparoscopic surgery for the correction of paediatric pyeloureteral junction obstruction (PUJO). Multiple studies have demonstrated comparable functional outcomes, with additional advantages in surgical precision, ergonomics, and postoperative recovery, particularly in experienced hands (9–11).

In our series, the progressive reduction in operative times with increasing case numbers clearly reflects a surgical learning curve. Although this trend aligns with the findings of Boysen and Gundeti (12), our results differ in the number of cases required to achieve stabilization. Those authors reported significant improvements in console and total operative times after 15–20 procedures. Similarly, Sorensen et al. (13) and Esposito et al. (14) observed that surgical performance markedly improves after a moderate number of cases, reaching a plateau at approximately 25 procedures. In contrast, in our experience, a comparable improvement in time reduction was achieved after 10 cases.

This observation suggests a shorter learning curve than previously reported. Several factors may account for this difference. It is plausible that concurrent acquisition of robotic skills through other urologic procedures contributes to an accelerated learning process. Future analyses including all robotic urologic surgeries, rather than pyeloplasties alone, may provide a more comprehensive understanding of this phenomenon.

We consider our learning curve to have stabilized in Group 3. Notably, our mean console time (102 minutes) was shorter than the average reported for European pediatric robotic surgeons. According to data from the Da Vinci Xi surgical system, the mean console time among surgeons with 25–50 prior cases is approximately 119 minutes, suggesting that our team has surpassed the initial learning phase.

Although linear regression analysis demonstrated a significant correlation between case number and docking plus closure time (R = 0.678, p < 0.05), the association with total surgical time did not reach statistical significance, likely due to the limited sample size. This finding is consistent with observations by Chiu et al. (15), who noted that preparatory steps—such as patient positioning, port placement, and anastomosis—tend to improve earlier than overall operative time.

Regarding patient age, several authors have suggested that robotic surgery may present greater technical difficulties in

very young children (<1 year or <10 kg), mainly due to the reduced intra-abdominal space, the proximity of the trocars, and the rigidity of the instruments (16-18). However, our results showed no correlation between age and surgical times, suggesting that age did not significantly influence the technical complexity or surgical time. These results are in line with the study by Dangle et al. (19), who reported similar outcomes between infants and older children when procedures were performed by experienced teams with meticulous port planning.

Regarding intraoperative and postoperative outcomes, our findings are consistent with previous reports showing extremely low rates of conversion to open surgery or major complications (20–21). In addition, rapid recovery and short hospital stays observed in our cohort reinforce the value of this minimally invasive approach, even in young paediatric patients.

Finally, while our study is limited by its retrospective design and small sample size, it provides meaningful evidence supporting the safety and technical feasibility of pediatric robotic pyeloplasty. Larger multicenter studies are warranted to validate these results and to further elucidate the factors that influence the learning curve and surgical efficiency.

CONCLUSIONS

Robotic pyeloplasty appears to be a safe and effective treatment for PUJO in pediatric patients. Our study demostrate a progressive reduction in operative times with increasing surgical experience, confirming the presence of a favorable learning curve that stabilizes after a relatively small numer of cases.

Furthermore, patient age was not associated with longer operative times, suggesting that robotic surgery can be safely performed in younger children. In our series, no major complications or conversions to open surgery were observed, supporting the safety and technical feasibility of robotic pyeloplasty in pediatric population.

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Maria Ruiz and Alberto Parente. The first draft of the manuscript was written by Maria Ruiz and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Statements & Declarations

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