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Comparison of clinical outcomes of robotic versus open pyeloplasty in infants under 6 months

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Abstract

Introduction:
Robotic pyeloplasties have become the popular approach for surgical repair of ureteropelvic junction obstruction (UPJO) in the pediatric population. In infants less than 6 months old, there is concern for lack of intra-abdominal working space and lack of benefit compared to an open approach. Our aim was to compare the peri-operative and post-operative outcomes of patients undergoing open versus robotic pyeloplasty under six months of age.

Methods:
A retrospective review was performed of patients less than six months of age undergoing robotic or open pyeloplasty between 2020-2024 at a single institution. Patient demographics and clinical outcomes were collected and compared. Surgical success was defined as a >50% reduction in the antero-pelvic diameter (APD) of the affected kidney at one year post pyeloplasty.

Results:

A total of 32 patients were identified (16 robotic and 16 open), median age at surgery was 4 months old. There was no significant difference in length of hospital stay or narcotic usage between the two groups. The robotic cohort had a significantly longer operative time (209.5 minutes vs 142.5 minutes, $p<0.001$) compared to the open cohort. There was no significant difference between post-operative complication or surgical success rates between the two groups.

Conclusion:
In this small series, robotic and open pyeloplasty both remain viable options for infants less than 6 months of age with equivalent surgical outcomes and lengths of hospital stay.

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Introduction:

Hydronephrosis is one of the most common findings on prenatal ultrasounds being detected in 1-5% of pregnancies, with ureteropelvic junction obstruction (UPJO) being one of the most common underlying causes [1]. In the last ten years, there has been a shift in surgical technique for repairing UPJOs in pediatric patients largely from an open approach to a minimally invasive approach, either laparoscopic or robotic. The robotic approach can be advantageous with literature supporting reduced postoperative pain, shorter hospital stays, and improved cosmetic outcomes, making it an attractive choice across pediatric age groups [2-4]. Despite its growing popularity, there remains hesitation in performing robotic surgery on infants younger than six months. This reluctance is due to concerns about limited intra-abdominal space complicating the use of robotic instruments, as well as a lack of benefit over open surgery for this particular age group [5-7]. Previous studies comparing robotic versus open pyeloplasties in pediatric patients have demonstrated significantly shorter hospital stays with a robotic approach, with no difference in surgical outcomes or complication rates [8-9]. While some studies have looked at patients younger than a year of age [10], there have been no studies focusing on infants specifically younger than six months of age. This continues to be the age where there is considerable resistance against the use of minimally invasive techniques.

At our institution, both open and robotic pyeloplasties are performed on infants younger than six months of age. The approach chosen is dependent on multiple factors including equipment availability, family and surgeon preference. Our aim was to compare the peri-operative and post-operative outcomes, and surgical success rates of patients undergoing open versus robotic pyeloplasty under six months of age.

Materials and methods:

A retrospective review was performed of patients less than six months of age undergoing robotic or open pyeloplasty between January 2020 – December 2024 at a single institution. Ethical approval was obtained from our Institutional Review Board (IRB16-00249). Pre-operative and intra-operative data collected included patient age, weight, surgical time, and narcotic usage. Post-operative data collected included length of hospital stay, 30-day complication rate, and follow-up duration. The antero-pelvic diameter (APD) of the affected kidney was recorded on pre-operative and post-operative renal ultrasounds for comparison. Inclusion criteria included surgical intervention for UPJO and age ≤6 months old. Open pyeloplasties were performed using the traditional flank approach, and robotic pyeloplasties were performed using a transperitoneal approach.

Robotic Operative Details

All robotic pyeloplasties were performed using the DaVinci Xi Surgical System (Intuitive Surgical, Sunnyvale, CA). Robotic cohort patients were initially placed in the dorsal lithotomy position for cystoscopy, retrograde pyelogram and retrograde double-J ureteral stent placement. If a ureteral stent

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could not be inserted, then this was completed anterograde intra-operatively. The patient was then re-positioned supine for robotic port placement in the HiDES configuration [11]. An infra-umbilical incision was made and Veress needle was used to gain access into the intra-abdominal cavity. The abdomen was then insufflated to 10 mmHg of pressure at a flow of 5L per minute. This pressure is maintained throughout the procedure. Four 8mm robotic ports are then placed at the infra-umbilical incision, suprapubic midline region, right lower quadrant medial to the anterior superior iliac spine (ASIS) and left lower quadrant medical to the ASIS. The table is then tilted to an angle of 20 degrees.

Peri-operative and post-operative management

Reduction pyeloplasty is not routinely performed by any surgeon at our institution—it is only performed if there is such a redundant pelvis that it is thought it will prevent adequate urinary drainage based on intra-operative assessment. Operative notes were reviewed to record if any patients underwent reduction pyeloplasty. Two surgeons performed exclusively robotic pyeloplasties, four surgeons performed exclusively open pyeloplasties, and one surgeon performed both robotic and open for this patient cohort. Patients undergoing an open approach had either general or spinal anesthesia at the discretion of the anesthesia team. All patients had a stent placed at time of pyeloplasty. Patients who underwent open pyeloplasty had a Salle stent placed which was sutured exteriorly to the flank, allowing for removal in clinic. Patients who underwent robotic pyeloplasty had a double-J ureteral stent placed. Depending on the discretion of the surgeon, the string was left on to allow for removal in clinic. If this was the case, the strings were secured to the suprapubic area with mastisol adhesive, steri-strips and a Tegaderm dressing. All patients are kept on trimethoprim-sulfamethoxazole 2mg/kg daily as prophylaxis until subsequent stent removal. All patients had intra-operative urine cultures collected—those that yielded bacterial growth were treated appropriately.

Intra-operative, and post-operative outcomes were compared using Fisher's exact, Wilcoxon rank-sum, and Pearson's chi-squared tests, as appropriate. A p-value of ≤ 0.05 was considered statistically significant. All analyses were conducted in SAS Enterprise Guide 8.4 (SAS Institute, Inc., Cary, NC).

The primary outcomes measured were 30-day complication rates and rates of surgical success. Surgical success was defined as greater than 50% reduction in the APD on 12-month postoperative renal ultrasound. This marker was used based on studies by Romao et al. and Rickard et. al which demonstrated that post-operative percent improvement in APD is a strong predictor of pyeloplasty success and can also serve as a measurable, objective marker in follow-up for those who may be at risk of recurrent UPJO [12,13]. Secondary outcomes included operative time, hospital stay duration, and the use of perioperative narcotics.

Results:

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A total of 32 patients were identified (16 robotic and 16 open). Overall, the median age at time of surgery was 4 months old and median pre-operative APD was 29.5mm. There was no significant difference in patient demographics. Complete results summarized in Table 1.

Peri-operative Outcomes

Median length of hospital stay was 23.0 hours with no significant difference between the robotic and open cohorts, respectively (22.0 vs 23.0 hours, p=0.80). 25% of patients in the open pyeloplasty cohort received spinal anesthesia. Overall, 43.8% of patients received narcotics for pain control during their hospital stay with a median of 0.07mg/kg morphine equivalents. 3 patients in the robotic cohort and 2 patients in the open cohort underwent reduction pyeloplasty for very large, redundant pelvises. There was no significant difference in narcotic usage or narcotic dose between the two cohorts. The robotic approach had a longer median operative time (209.5 minutes vs 142.5 minutes, p<0.001) than the open approach. 50% of patients who underwent robotic pyeloplasty had strings left on the ureteral stent which allowed for subsequent removal in clinic. All patients in the open cohort had the Salle stents removed in clinic. Complete results summarized in Table 2.

Clinical Outcomes

Median follow up time overall was 22 months. In the robotic cohort, 4/16 patients had a 30-day post operative complication—three patients developed pyelonephritis requiring hospital admission and intravenous antibiotics and one developed urinary retention requiring catheter re-insertion. Pyelonephritis was defined by fever >38.0ºC and bacterial growth of >50,000 colony forming units/mL and a urinalysis with pyuria (≥10 WBCs/HPF) from a catheterized urine specimen, or bacterial growth on blood cultures. Overall, there was a median 64.5% reduction in APD at 12-month post-operative renal ultrasound with no significant difference in APD reduction percentage between the robotic and open cohorts (65.33% vs 64.32%, p>0.9). Complete results summarized in Table 3.

Discussion:

Since the early 2000s, the introduction of robotics has led to a steady increase in the number of robotic pyeloplasties performed annually with an associated decrease in the percentage of open and laparoscopic pyeloplasties performed [2]. Many studies have demonstrated the benefits of robotic surgery in pediatric patients including shorter hospital stays and decreased narcotic usage, with equivalent surgical outcomes. Additionally, the introduction of HIdES port placement further improves cosmesis without compromising surgical technique [9-11, 14-15]. While a recent publication showed feasibility and potential benefits for the robotic approach over the open approach in patients less than a year of age, there is still concern around intra-abdominal working space in infants less than six months of age [10]. There being little literature looking specifically at this age group for pyeloplasty outcomes, we decided to do a retrospective review of robotic versus open pyeloplasty at a single institution in infants six months or younger.

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Peri-operative Outcomes

Overall, we had a sub-24 hour stay in both patient groups and the overall narcotic usage of 43.8% primarily represents a single dose in the immediate post-operative period. A robotic approach did take significantly longer from an operative standpoint, but this time difference continues to decrease with surgeon experience and surgical team proficiency with port placement and robot set up. Additionally, all patients in the robotic cohort underwent cystoscopy, retrograde pyelogram with retrograde ureteric stent placement at the beginning of the procedure which may have contributed to overall operative time. 75% of the open pyeloplasties were performed by senior surgeons with more than 20 years of surgical experience, while all the robotic pyeloplasties were performed by surgeons with 5-15 years of surgical experience. We must be considerate that the clinical outcomes of each cohort may be impacted by the length of surgical experience, including operative time.

It is important to mention that 25% of patients in the open pyeloplasty cohort underwent spinal anesthesia versus all robotic patients who underwent a general anesthetic. Those patients in the open cohort who had a general anesthetic also had a shorter duration of anesthesia with the overall shorter operative time. Additionally, 50% of patients in the robotic cohort required a second general anesthetic for double-J ureteral stent removal. There are mixed reports in the literature regarding anesthesia exposure in infants less than 6 months old and subsequent neurodevelopmental outcomes [16]. Recent publication by McCann et al demonstrated that there was no difference in neurodevelopmental outcomes at both two and five year follow-up for infants who underwent general anesthesia versus spinal anesthesia in early infancy [17]. An open approach will always remain a viable option for young infants as some families may prefer having the possibility to avoid a general anesthetic entirely for their child while also avoiding a second general anesthetic for ureteral stent removal.

Robotic cohort patients had 4 surgical incisions measuring 8mm each, adding up to 32mm of total incision length. Open patients had a single incision measuring 30-50mm. There remains debate around if having multiple smaller incisions is any different to having one larger incision if the total incision length is equal. Using the HiDES port placement technique may allow for better concealment of incision scars and literature has shown that total tension across multiple incisions is less than total tension of an incision of the same total length [18].

Clinical Outcomes

There was no significant difference between post-operative APD percent reduction rates between the two cohorts. All 30-day complications occurred in the robotic arm and the lack of statistical significance in this comparison may be a result of the study being underpowered. Other multi-institutional reviews with significantly larger cohorts for comparison did not identify a difference in complication rates between open and robotic pyeloplasties [8,10,19]. Further studies comparing robotic versus open surgery in this specific age group are important to ensure there is not an increased risk due to limited intra-abdominal

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space or other factors. All patients who developed pyelonephritis were taking the prescribed antibiotic prophylaxis but all cultures taken at the time of infection demonstrated bacterial growth with species resistant to trimethoprim-sulfamethoxazole. Increasing rates of bacterial resistance specifically after Urologic procedures at our institution has prompted new quality improvement initiatives to determine if there are underlying causes and areas of improvement. Two of the patients who developed pyelonephritis had the strings left on the ureteral stent for subsequent clinic removal. The remaining patient developed pyelonephritis after scheduled intra-operative stent removal and urine culture taken at the time of stent removal was sterile. Bacterial growth was only detected in subsequent blood cultures. Batie et al performed a review of 245 pediatric patients undergoing upper urinary tract surgery and determined there was no significant risk of UTI in patients with stent extraction strings barring the patient had no medical history of UTIs [20]. However, in their study the median patient age was 6.4 years and this likely represents a different patient population as majority were already toilet-trained. Further review needs to be done to determine whether there is a significant increased risk of post-operative infection in patients with indwelling stents on strings that are not yet toilet-trained who are at higher risk of stool contamination. Patients in the open cohort had Salle stent removal 10-14 days after pyeloplasty, while timing of stent removal in the robotic cohort was dependent on whether strings were present for removal in clinic. Patients in the robotic cohort with a ureteral stent on strings had stent removal 10-14 days after pyeloplasty, versus those with no strings had stent removal 4 weeks after pyeloplasty. For the one robotic patient who developed pyelonephritis after intra-operative stent removal—the longer duration of indwelling stent time may have been a contributing factor to subsequent infection.

Limitations

There are limitations to this study. An inherent weakness to this study is that it is retrospective in nature. The overall small denominator of patients means this review lacks significant power to detect statistical differences between robotic and open approaches. Evaluation of a larger cohort may illicit different statistically significant results. There is inherent selection bias within this study since the choice of surgical approach was made based on surgeon and family preference. Surgeons more comfortable with an open approach in this patient age group performed open pyeloplasty, and those more comfortable robotically opted for a robotic approach. Families are offered both approaches at initial surgical discussion—but we did not review the percentage of families that underwent pyeloplasty with a different surgeon based on their preference of surgical approach. Additionally, the inter-surgeon variability within the robotic and open cohorts may affect outcomes including operative length, admission length, and post-operative complications. One robotic patient underwent simultaneous bilateral pyeloplasties. The specific operative time length for each side was not determined so the operative time for this patient was not altered—we acknowledge this as an outlier in our analysis.

Conclusion

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In this small series, robotic and open pyeloplasty both remain viable options for infants less than 6 months of age with equivalent surgical outcomes and lengths of hospital stay. Additional studies including a larger patient population would be beneficial to further compare robotic versus open techniques for infants in this specific age group.

Conflicts of Interest

None.

Funding Sources

None.

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	N	Overall N = 32	Open N = 16	Robotic N = 16	p-value
Weight at time of surgery (kg) (median, [IQR])	32	6.50 [6.05-7.57]	6.67 [5.82-7.04]	6.39 [6.18-7.97]	0.4
Age at time of surgery (months) (median, [IQR])	32	4.00 [2.90-5.00]	3.00 [2.00-5.00]	4.17 [3.14-5.54]	0.2
Pre-operative RUS APD (mm) (median, [IQR])	32	29.50 [20.00-35.50]	32.00 [20.00-39.50]	28.00 [19.00-32.50]	0.3

Table 1. Patient demographics undergoing robotic or open pyeloplasty

	N	Overall N = 32	Open N = 16	Robotic N = 16	p-value
Side of surgery	32				0.7
Bilateral		1 (3.1%)	0 (0.0%)	1 (6.3%)	
Left		19 (59.4%)	9 (56.3%)	10 (62.5%)	
Right		12 (37.5%)	7 (43.8%)	5 (31.3%)	
Stent left on a string	32	8 (25.0%)	0 (0.0%)	8 (50.0%)	**0.002**
Operative time (min) (median, [IQR])	32	170.00 [139.00-209.50]	142.50 [114.50-162.00]	209.50 [177.00-226.00]	**<0.001**
Hours of stay (median, [IQR])	32	23.00 [18.00-26.00]	23.00 [19.00-24.50]	22.00 [12.00-26.00]	0.8
Narcotic use	32	14 (43.8%)	8 (50.0%)	6 (37.5%)	0.5
Morphine equivalents (mg/kg) (median, [IQR])	14	0.07 [0.07-0.15]	0.10 [0.06-0.24]	0.07 [0.07-0.10]	>0.9

*robotic console time compared to open operative time

Table 2. Peri-operative and post-operative outcomes of patients undergoing open and robotic pyeloplasty

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	N	Overall N = 32	Open N = 16	Robotic N = 16	p-value
Follow up length (months) (median, [IQR])	32	22.27 [9.47-28.29]	22.83 [8.58-28.82]	21.92 [10.02-28.29]	>0.9
30 day complication rate	32	4 (12.5%)	0 (0.0%)	4 (25.0%)	0.10
1 year post-op RUS APD (mm) (median, [IQR])	32	10.00 [6.00-15.00]	12.00 [7.00-16.00]	9.00 [5.00-15.00]	0.3
% APD reduction at 1 year (median, [IQR])	32	64.50 [48.53-70.29]	64.32 [53.24-71.67]	65.33 [41.86-69.50]	>0.9

Table 3. Surgical outcomes and complication rates of patients underoing open and robotic pyeloplasty

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