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Outcomes after pediatric open, laparoscopic, and robotic pyeloplasty at academic institutions

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Summary

Introduction—Patient age and hospital volume have been shown to affect perioperative outcomes after pediatric pyeloplasty. However, to date, there are few multicenter studies that focus on outcomes at teaching hospitals, where many of the operations are performed.

Objective—The goal was to determine if surgical approach, age, case volume, or other factors influence perioperative outcomes in a large contemporary cohort.

Study design—Using the clinical database/resource manager (CDB/RM) of the University Health-System Consortium (UHC), children who underwent open, laparoscopic, or robotic pyeloplasty from 2011 to 2014 were identified at 102 academic institutions. Surgery type, age, race, gender, insurance type, geographic region, comorbidities, surgeon volume, and hospital volume were measured. Multivariable mixed-effects logistic regression analysis was used to analyze independent variables associated with complication rates, length of stay (LOS), readmission rates, and ICU admission.

Results—A total of 2,219 patients were identified. Complication rates were 2.1%, 2.2%, and 3% after open, laparoscopic, and robotic pyeloplasty, respectively. Approximately 12% of patients had underlying comorbidities. Comorbidities were associated with 3.1 times increased odds for complication ($p = 0.001$) and a 35% longer length of stay ($p < 0.001$). Age, gender, insurance type, and hospital volume had no effect on complication rates. A trend was seen towards a lower rate of complications with higher surgeon volume ($p = 0.08$). The mean LOS was 2.0 days in the open pyeloplasty group, 2.4 days in the laparoscopic group and 1.8 days in the robotic group. Patients who underwent robotic surgery had an estimated LOS 11% shorter than those after open surgery ($p = 0.03$) (table). Patients aged 5 years and under who had robotic surgery had an estimated LOS 14% shorter than those after open surgery ($p = 0.06$). ICU admission and hospital readmission were not associated with any variables.

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Conflict of interest
None.

Discussion—The study is limited by the accuracy of the data submitted by the hospitals and is subject to coding error. Complication rates remain low in all three approaches, validating their safety. Patients, including younger patients, had shorter lengths of stay after robotic surgery. The statistically significant differences between approaches were small so clinically there may not be a difference.

Conclusions—This large multicenter analysis demonstrates that patient comorbidity had the greatest impact upon complication rates and length of stay. Previous work showed that the benefits of laparoscopy were limited to older children. However, this large multicenter study suggests that these benefits now extend to young children with the application of robotics.

Keywords

Ureteral obstruction; Laparoscopy; Robotics; Treatment outcome

Introduction

Ureteropelvic junction (UPJ) obstruction is a common cause of pediatric hydronephrosis. Since 1949, the Anderson–Hynes open dismembered pyeloplasty (OP) has been the gold standard treatment [1]. Laparoscopic pyeloplasty (LP), first implemented in a 7-year-old child in 1995 by Peters and colleagues [2], offered a safe and effective minimally invasive approach. Adoption of laparoscopic pyeloplasty into common practice was limited by a steep learning curve, with practitioners citing anatomical limitations in the pediatric population, difficulty with instrument maneuverability, and challenges of intracorporeal suturing as contributing factors [2–4]. The robotic interface has helped minimize this learning curve and increased the utilization of laparoscopy [5,6]. Robot-assisted laparoscopic pyeloplasty (RALP) has been shown to be feasible and safe in the pediatric population [7].

LP and RALP offer a shorter length of stay (LOS) and decreased analgesia demands in older patients [4,8]. A few studies have evaluated predictors of good postoperative recovery and the incidences of intraoperative and postoperative complications after open, laparoscopic and RALP. A previous study by Tanaka et al. [8] demonstrated that higher surgeon volume is associated with shorter LOS after LP and that the LOS benefit of LP was limited to children older than 10 years of age. Using the Nationwide Inpatient Sample (NIS) database, which consists of information provided predominantly by community hospitals, Sukumar et al. [9] revealed that postoperative complications were higher in low-volume centers (≤ 16 OP per year). However, to date, there have been few multicenter studies that focus on outcomes at teaching hospitals, where many of the surgeries are performed. The goal was to determine if age, case volume, or other factors were associated with perioperative outcomes. Based on Tanaka et al.'s [8] study that showed that the benefits of laparoscopy were limited to older children, we hypothesized that a benefit of shorter LOS after robotic pyeloplasty would also be limited to older children.

Methods and materials

Data source

The University Health-System Consortium (UHC) is a non-profit, member-driven alliance of more than 117 academic medical centers and over 333 of their affiliated hospitals. Its clinical database/resource manager (CDB/RM) provides comparative data in clinical and surgical outcomes. Compared to certain databases where data collection is not standardized across states, CDB/RM is a more consistent database that has been used by many investigators to study clinical and surgical outcomes [10–13].

In this study, pediatric admissions from 2011 to 2014 were obtained using the age criterion less than 18 years as the query strategy. The International Classification of Diseases – ninth revision (ICD-9) procedure code 55.87 was used to limit our cohort to pediatric patients undergoing pyeloplasty. ICD-9 codes 17.42 and 54.21 were used to identify RALP and conventional laparoscopic pyeloplasty, respectively. Patients undergoing concomitant surgeries and those who were admitted prior to the date of pyeloplasty were excluded from analysis.

Statistical analysis

For all patients, the variables analyzed included surgery type, age, race, gender, insurance type (Medicaid, private, uninsured, or other), geographic region, comorbidities, surgeon volume, and hospital volume. Comorbid conditions were defined using the criteria published by Elixhauser et al. [14]. These conditions include diagnoses for congenital anomalies and spina bifida (Supplementary Table 1). The outcomes examined were LOS, ICU admission, hospital readmission and complications. Complication ICD-9 codes were adapted from Sukumar et al. [9] with the addition of potential intraoperative complications during pyeloplasty, including injury to the spleen, liver, and intestine (Supplementary 4 2). Any of these codes reported during the admission and not present on admission were considered a complication.

The associations between complications or ICU admission and patient/surgery characteristics were analyzed using multivariable mixed-effects logistic regression models. The associations between LOS and patient/surgery characteristics were analyzed using a multivariable mixed-effects lognormal–Poisson mixture model, which is similar to a negative binomial model.

All models included fixed effects for surgery type, age, sex, insurance type, comorbidities, surgeon volume, and hospital volume, and random effects for surgeon and hospital. In addition to analyzing age as a continuous variable, a model for LOS also included an interaction effect between surgery type and age groups (ages 0–5, 5–10, 10–17 years) to provide a stratification for possible clinical utility. We chose these age groups based upon previous literature showing that age 10 years was of significance.

Patients with comorbidities may or may not be offered a particular surgical approach because of their condition or perceived risk, which might add a bias. Since a small group of patients with comorbidites can significantly affect the results, we performed a subset analysis of "healthy" patients, without comorbidity or complication, to determine if the association between surgical approach and LOS persisted when only healthy patients without perioperative events were included.

The analysis data set was constructed using SAS software for Windows, version 9.4 (SAS Institute, Cary, NC). Statistical analyses were conducted using the statistical software environment R, version 3.2.1. Mixed-effects modeling was conducted using the R package lme4, version 1.1-8.

Results

Univariate analysis

A total of 2,219 patients from 102 academic centers met the inclusion criteria. Of these, 1,540 underwent OP, 46 underwent LP, and 633 underwent RALP. The median age was 36 months. Forty percent of the patients had Medicaid and 58% had private insurance. Approximately 12% of the patients had underlying comorbidities (Table 1). The mean LOS was 2.0 days in the OP group compared with 2.4 days in the LP group and 1.8 days in the RALP group (Table 2 and Summary table). ICU admission rates were similar between the OP and RALP groups, 3% and 3.6% respectively (Table 2). Only 9% of ICU admissions were neonatal. In the "healthy" cohort, the mean LOS was less at 1.8 days in the OP group, 1.9 days in the LP group, and 1.6 days in the RALP group (Table 2).

Multivariate analysis

Complications—Adjusting for all other variables, subjects with comorbidities had 3.1 times higher odds for complication than patients without comorbidities ($p = 0.001$). The most common complication was pulmonary collapse/atelectasis, which accounted for 19% of the cases (Supplementary Table 3). A trend was seen towards a lower rate of complications with higher surgeon volume ($p = 0.08$). Despite analyzing 300 surgeons, this study was not powered to detect a significant effect of surgeon volume on complication incidence because complications were rare (Table 3). There were no associations found between patient age or surgical approach with type of complication (Supplementary Table 3).

Length of stay

Multivariable analysis of LOS demonstrated that age, gender, surgeon volume, and hospital volume were not associated with LOS. Patients who had RALP had an estimated LOS 11% shorter than those who had open surgery ($p = 0.03$) (Table 4 and Summary table). When each age group was considered separately, patients aged 5 years and under who had RALP tended to significance with an estimated LOS 14% shorter than those who had OP ($p = 0.06$, CI 0.77–1.0). Likewise, no significant difference in LOS was seen between robotic and open surgery in other age groups. Adjusting for all other variables, subjects with private or military insurance were estimated to have a LOS 12% shorter than subjects with other insurance types ($p < 0.001$), and subjects with comorbidities were estimated to have a LOS 34% longer than subjects without comorbidities ($p < 0.001$) (Table 4).

Table 4 shows results of the mixed-effects lognormal–Poisson regression model of LOS in healthy subjects (those without comorbidity or complication). Adjusting for all other variables, healthy subjects who had RALP were estimated to have a LOS 17% shorter than subjects who had OP ($p = 0.005$). When each age group was considered separately, subjects aged 5 years and under who had RALP were estimated to have a LOS 22% shorter than those who had OP ($p = 0.008$). No significant differences in LOS were seen by surgery type in other age groups. Adjusting for all other variables, subjects with private or military insurance were estimated to have a LOS 9% shorter than those with other types of insurance ($p = 0.017$).

Readmission

Readmissions for all patients within 14 days of pyeloplasty were queried to capture diagnoses of delayed postoperative complications requiring admission. There were 28 (1.26%) readmissions. Seven readmissions were associated with stent removal, 18 with stent placement and three with percutaneous nephrostomy tube placement. This database only includes inpatient encounters. Using a separate UHC billing database of a similar cohort, which includes inpatient and outpatient encounters, we have previously shown that most postoperative ureteral stent and nephrostomy tube placements are performed as an outpatient basis. The associations between surgical approach, patient variables and need for postoperative stents are detailed in that manuscript [15]. For this study, we found no other same hospital readmissions other than for stent placement.

Discussion

There is an increasing trend towards robotic pyeloplasty. Liu et al. [6] demonstrated that LP decreased from 12% to 3% from 2003 to 2009 (Kids' Inpatient Databases [KID]) and RALP increased to 12% of cases in 2009. Review of the NIS database by Sukumar et al. [16] demonstrated that LP and RALP accounted for 17% of the cases between 2008 and 2010 [6]. Varda et al. [18] reviewed the Perspective database from 2003 to 2010 and also demonstrated a steady increase in robotic pyeloplasty. Compared with these recent analyses of KID (an extrapolation of 320 RALP) and NIS (an extrapolation of 206 LP+RALP cases), this large and current analysis (633 RALP cases) revealed decreased use of LP (2%) and a much higher application of robots (29%) at academic centers. We also found the mean age at surgery for RALP has also substantially decreased. Thus, utilization of RALP continues to rise and age to decrease, particularly at academic centers.

In a recent study, Koh et al. showed that shorter LOS correlated with less parental wage loss and lower hospital expenses [17]. Length of stay after RALP is shorter than OP and LP, and surprisingly, this effect is present in patients aged 5 and under in the healthy cohort. However, there was no significant difference in LOS in older age groups between surgical approaches. This result disproves our initial hypothesis that the benefits of RALP are limited to older children. In the past, it was believed that the advantages of laparoscopy were limited to the older pediatric population [4,8]. Varda et al. [18] demonstrated that patients aged 11–18 years had 40 times the odds of undergoing robotic pyeloplasty compared with infants (95% CI 8.6–191). However, there has been an increase in RALP in infants [6]. Avery et al.

[19] recently demonstrated a 91% success rate after RALP in infants. Two small center series have demonstrated the efficacy of RALP in infants with perioperative outcomes similar to open surgery and lower analgesic requirements [20,21]. Collectively, these findings suggest that urologic surgeons are slowly traversing the initial technical limitations of robot-assisted laparoscopy in infants and the application of this technology in younger children is increasing at academic centers.

Multivariate analysis indicated that surgical approach had minimal effect on the rates of intraoperative and postoperative complications. ICU admissions were minimal in all surgical groups. This is in accordance with other database and single center studies [18,22,23]. There was a significant association between the presence of underlying medical comorbidities and complication rates. Specifically, those with comorbidities had three times the odds of having complications compared with those without underlying medical issues. We are limited by the nature of a retrospective database study to evaluate association between comorbidities and intraoperative anatomical and technical challenges. However, this finding nevertheless highlights that patients with underlying medical issues are at higher risk for intra- and/or perioperative complications.

An NIS study found that low-volume hospitals were associated with higher complications [9]. Without the ability to identify surgeons in that study, it is quite possible the hidden variable of low-volume surgeon was the critical factor affecting complication rates. Although the results of our study did not indicate a significant effect of hospital or surgeon volume on complication rates, a trend toward lower complications with higher surgeon volume was noted ($p = 0.08$). This is in accordance with our previous studies of pediatric ureteral reimplant and hypospadias surgery in which we found surgeon volume, not hospital volume, was significantly associated with reduced perioperative morbidity [24,25].

The study is limited by the accuracy of the data submitted by the hospitals and is subject to coding error. Owing to the limitations of a retrospective database study, we were unable to determine the conversion rates to the open approach. To our knowledge, conversion rates for pediatric RALP range from zero to 1.4% from multi-institution studies to zero in single center studies [19,26,27]. Complications managed on an outpatient basis or possibly at hospitals not within the UHC database were not captured. Despite the statistical significance and very low p values, the confidence intervals approach 1.0 in both the standard and healthy cohort analyses. Thus, the associated decrease in LOS after RALP is very small and may not be clinically significant. Although no regional difference in LOS was found, many unknown variables including traffic, availability of transport, and weather, which do not equally distribute across populations, may also contribute to this finding. Nevertheless, this large, retrospective analysis of 102 academic centers and 300 surgeons demonstrates that complication rate and LOS are very similar to either the open or the robotic approach for all ages. At the authors' institution, RALP has been utilized for progressively younger patients but not infants. The results of this large, multicenter analysis prompt consideration of a further decrease in age selection for RALP at appropriate centers as the benefits of RALP may not be limited to older children as previously believed.

Conclusions

This large multicenter analysis demonstrates that patient comorbidity had the greatest impact upon complication rates and length of stay. Previous work showed that the benefits of laparoscopy were limited to older children. However, this large multicenter study suggests that these benefits now extend to young children with the application of robotics.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Data from the UHC Clinical Data Base/Resource Manager, Chicago, IL: UHC; 2012. https://www.uhc.edu. Accessed July 8, 2014; used by permission of UHC. All rights reserved. The information contained in this article was based in part on the Performance Package data maintained by the University HealthSystem Consortium (UHC). Copyright 2015 UHC. All rights reserved.

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Table 1

Patient characteristics by surgery type (all patients).

Patient characteristic	**Open (*n* = 1,540)**	**Laparoscopic (*n* = 46)**	**Robotic (*n* = 633)**	**All subjects (*n* = 2,219)**
Age (months)				
Mean (SD)	42.8 (57)	102.9 (68)	110.3 (65)	63.3 (66)
Median (range)	13 (0–215)	91.5 (4–214)	105 (2–215)	36 (0–215)
Age group *(n*, %)				
5 years and under	1,191 (77%)	14 (30%)	210 (33%)	1,415 (64%)
6–10 years	192 (13%)	16 (35%)	182 (29%)	390 (18%)
11–17 years	157 (10%)	16 (35%)	241 (38%)	414 (19%)
Sex (*n*, %)				
Male	1,120 (73%)	29 (63%)	388 (61%)	1,537 (69%)
Female	420 (27%)	17 (37%)	245 (39%)	682 (31%)
Race (*n*, %)				
White	1,012 (66%)	38 (83%)	486 (77%)	1,536 (69%)
Black	170 (11%)	1 (2%)	42 (7%)	213 (10%)
Asian	65 (4%)	1 (2%)	15 (2%)	81 (4%)
Other	293 (19%)	6 (13%)	90 (14%)	389 (18%)
Insurance type (*n*, %)				
Medicaid	652 (42%)	16 (35%)	230 (36%)	898 (41%)
Private	866 (56%)	30 (65%)	395 (62%)	1,291 (58%)
Uninsured/self-pay	9 (0.6%)	0	2 (0.3%)	11 (0.5%)
Other/unknown	13 (0.8%)	0	6 (0.9%)	19 (0.9%)
Region (*n*, %)				
Midwest	488 (32%)	12 (26%)	186 (29%)	686 (31%)
Northeast	372 (24%)	14 (30%)	225 (36%)	611 (28%)
South	395 (26%)	15 (33%)	148 (23%)	558 (25%)
West	285 (19%)	5 (11%)	74 (12%)	364 (16%)
Comorbidities (*n*, %)				
No	1,396 (91%)	32 (70%)	534 (84%)	1,962 (88%)
Yes	144 (9%)	14 (30%)	99 (16%)	257 (12%)

Table 2

Patient outcomes by surgery type.

Patient outcome	Open (*n* = 1,540)	Laparoscopic (*n* = 46)	Robotic (*n* = 633)
All patients			
LOS			
Mean (SD)	2.0 (1.2)	2.4 (1.7)	1.8 (1.3)
ICU admission (n, %)	56 (3.6%)	0	19 (3%)
ICU days			
Mean (SD)	0.1 (0.3)	0 (0)	0.1 (0.4)
Any complications (*n*, %)	33 (2.1%)	1 (2.2%)	19 (3%)
	Open (*n* = 1,278)	**Laparoscopic (*n* = 29)**	**Robotic (*n* = 478)**
Healthy patients			
LOS			
Mean (SD)	1.8 (1)	1.9 (1)	1.6 (0.8)

Table 3

Multivariable mixed effects logistic regression analysis of any complications (all patients)

Covariate	**Odds ratio (95% CI)**	***p***
Surgery: laparoscopic vs. open	0.42 (0.05, 3.60)	0.43
Surgery: robotic vs. open	1.15 (0.54, 2.43)	0.72
Surgery: robotic vs. laparoscopic	2.73 (0.33, 22.8)	0.35
Age (years)	1.01 (0.95, 1.07)	0.74
Sex: female vs. male	0.95 (0.51, 1.77)	0.88
Insurance: private/military vs. other	0.83 (0.46, 1.50)	0.54
Comorbidities (yes vs. no)	3.00 (1.58, 5.71)	0.001
Hospital volume (cases/year)	0.97 (0.90, 1.04)	0.36
Surgeon volume (cases/year)	0.85 (0.71, 1.02)	0.08

Table 4

Multivariable mixed effects lognormal–Poisson regression analysis of length of stay

Covariate	Rate ratio (95% CI)	*p*
All patients		
Surgery: laparoscopic vs. open	1.06 (0.86, 1.31)	0.57
Surgery: robotic vs. open	0.90 (0.82, 0.99)	**0.03**
Surgery: robotic vs. laparoscopic	0.85 (0.68, 1.05)	0.12
Age (years)	1.00 (0.98, 1.02)	0.81
Sex: female vs. male	1.00 (0.94, 1.07)	0.99
Insurance: private/military vs. other	0.89 (0.83, 0.95)	**< 0.001**
Comorbidities (yes vs. no)	1.34 (1.23, 1.46)	**< 0.001**
Surgeon volume (cases/year)	0.99 (0.97, 1.01)	0.53
Hospital volume (cases/year)	1.00 (0.99, 1.01)	0.92
Surgery: laparoscopic vs. open (≤ 5 years)	1.11 (0.77, 1.59)	0.59
Surgery: robotic vs. open (≤ 5 years)	0.88 (0.77, 1.00)	0.06
Surgery: robotic vs. laparoscopic (≤ 5 years)	0.79 (0.54, 1.16)	0.23
Surgery: laparoscopic vs. open (6–10 years)	0.92 (0.64, 1.32)	0.64
Surgery: robotic vs. open (6–10 years)	0.91 (0.77, 1.06)	0.22
Surgery: robotic vs. laparoscopic (6–10 years)	0.99 (0.68, 1.42)	0.95
Surgery: laparoscopic vs. open (11–17 years)	1.19 (0.86, 1.65)	0.30
Surgery: robotic vs. open (11–17 years)	0.91 (0.79, 1.06)	0.25
Surgery: robotic vs. laparoscopic (11–17 years)	0.77 (0.56, 1.06)	0.11
Healthy patients		
Surgery: laparoscopic vs. open	0.94 (0.70, 1.25)	0.66
Surgery: robotic vs. open	0.85 (0.77, 0.95)	**0.005**
Surgery: robotic vs. laparoscopic	0.91 (0.68, 1.22)	0.54
Age (years)	1.01 (0.99, 1.04)	0.22
Sex: female vs. male	1.01 (0.93, 1.09)	0.86
Insurance: private/military vs. other	0.91 (0.85, 0.98)	**0.02**
Surgeon volume (cases/year)	1.00 (0.98, 1.02)	0.83
Hospital volume (cases/year)	1.00 (0.99, 1.01)	0.70
Surgery: laparoscopic vs. open (≤ 5 years)	0.89 (0.55, 1.44)	0.64
Surgery: robotic vs. open (≤ 5 years)	0.82 (0.71, 0.96)	**0.01**
Surgery: robotic vs. laparoscopic (5 years)	0.92 (0.56, 1.51)	0.75
Surgery: laparoscopic vs. open (6–10 years)	0.93 (0.58, 1.50)	0.77
Surgery: robotic vs. open (6–10 years)	0.87 (0.72, 1.04)	0.13
Surgery: robotic vs. laparoscopic (6–10 years)	0.93 (0.58, 1.51)	0.78
Surgery: laparoscopic vs. open (11–17 years)	0.99 (0.60, 1.64)	0.97
Surgery: robotic vs. open (11–17 years)	0.88 (0.73, 1.05)	0.15
Surgery: robotic vs. laparoscopic (11–17 years)	0.88 (0.54, 1.45)	0.63

Table

LOS by surgery type and multivariate analysis of LOS (all patients)

	Open (*n* = 1,540)	**Laparoscopic (*n* = 46)**	**Robotic (*n* = 633)**
LOS (days) mean (SD)	2.0 (1.2)	2.4 (1.7)	1.8 (1.3)
Multivariable mixed-effects lognormal–Poisson regression analysis			
Covariate	Rate ratio (95% CI)	*p*	
Surgery: laparoscopic vs. open	1.06 (0.86, 1.31)	0.57	
Surgery: robotic vs. open	0.90 (0.82, 0.99)	**0.03**	
Surgery: robotic vs. laparoscopic	0.85 (0.68, 1.05)	0.12	
Age (years)	1.00 (0.98, 1.02)	0.81	
Sex: female vs. male	1.00 (0.94, 1.07)	0.99	
Insurance: private/military vs. other	0.89 (0.83, 0.95)	**< 0.001**	
Comorbidities (yes vs. no)	1.34 (1.23, 1.46)	**< 0.001**	
Surgeon volume (cases/year)	0.99 (0.97, 1.01)	0.53	
Hospital volume (cases/year)	1.00 (0.99, 1.01)	0.92	