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ORIGINAL ARTICLE

Comparison of 30-day perioperative outcomes in adults undergoing open versus minimally invasive pyeloplasty for ureteropelvic junction obstruction: analysis of 593 patients in a prospective national database

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Abstract
Purpose The surgical correction of ureteropelvic junction obstruction (UPJO) is indicated to prevent progression to chronic renal insufficiency. Minimally invasive surgery (MIS) has become increasingly popular as an approach to UPJO correction. We compared the perioperative outcomes between minimally invasive (MIP) and open pyeloplasty (OP) in the adult population.
Methods The current study was performed using the American College of Surgeons National Surgical Quality Improvement Program. Patients were identified using Current Procedural Terminology codes for pyeloplasty between 2005 and 2012, and were stratified according to either MIS or open approach. Patients with a diagnosis of malignant neoplasm of the kidney were excluded. Following exclusions, 593 patients remained for analysis. Primary outcomes of interest were overall perioperative complications, need for transfusions, re-intervention rate, prolonged operation time (pOT), prolonged length of stay (pLOS), readmission and mortality within 30 days of surgery. Multivariable logistic regression analyses were performed to examine the association between preoperative outcomes and surgical approach.
Results In this study, 423 (71.3 %) patients underwent MIP and 170 (28.7 %) underwent OP. Patients who underwent MIP had a decreased risk of wound [Odds ratio (OR) 0.06, $p < 0.009$] and overall complications (OR 0.21,

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$p < 0.001$), transfusions (OR 0.04, $p = 0.004$) and pLOS [pLOS (OR 0.08, $p < 0.001$)]. Conversely, MIP was associated with an increased likelihood of pOT (OR 2.26, $p = 0.002$).

Conclusion Adults with UPJO undergoing MIP have a lower risk of overall complications, transfusions and pLOS compared to OP. Further studies are needed to determine whether these benefits offset the increase in expenditures, related to longer operative time and costs of disposables.

Keywords Ureteropelvic junction obstruction · Pyeloplasty · Adult · Minimally invasive · NSQIP

Introduction

Ureteropelvic junction obstruction (UPJO) is defined as impeded urine flow from the renal pelvis into the corresponding ureter due to a blockade [1]. The reasons for UPJO are multiple and can be subdivided into intrinsic versus extrinsic and congenital versus acquired. UPJO in adults is more likely to be associated with acquired causes such as kidney stones or ureteric strictures. Alternatively, UPJO in adults can be associated with a lower pole renal crossing vessel that may not have caused symptoms at a younger age [1]. In patients with significant pain or decreased renal function, the surgical correction of UPJO is necessary to prevent subsequent development of interstitial fibrosis and progression to chronic renal insufficiency [2].

Dismembered pyeloplasty as described by Anderson and Hynes is the gold standard for the surgical management of UPJO via an open approach (OP) [3]. However, recent advances in laparoscopic and robotic surgery have made these approaches more popular. Schuessler et al. [4] were the first to report on the performance of laparoscopic pyeloplasty in adults. Further studies have demonstrated the effectiveness for both approaches with decreased postoperative morbidity in those undergoing minimally invasive surgical pyeloplasty (MIP) [5]. In consequence, MIP has been widely adopted over the last two decades [6]. This trend has been confirmed by high success rates, fewer complications and decreased surgical morbidity [7, 8].

Perioperative outcomes of MIP compared to OP in adults have not been described in a prospective national cohort. On the basis of these considerations, we assessed the comparative effectiveness of the two surgical approaches for pyeloplasty in an adult population.

Material and methods

Data source

The current study was performed using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP). This database has its origins in the early 1990s based on the National Veterans Administration Study [9]. It relies on the ACS NSQIP Participant User File [10] and contains risk-adjusted surgical patient data from member hospitals to facilitate the assessment of perioperative outcome measures following surgery. Validated data from randomly assigned patients' medical charts that were collected by a trained surgical clinical reviewer allow quantification of 30-day risk-adjusted surgical outcomes, including post-discharge information. In 2012, the ACS NSQIP included data from 374 participant institutions with more than 2.3 million cases having been contributed. No information about the institution or surgeon was available.

Study population

Patients undergoing MIP or OP were identified in the ACS NSQIP (2005–2012) using Current Procedural Terminology (CPT) codes: 50544 for minimally invasive and 50400, 50405 and 50540 OP, respectively. Patients with ICD-9 code 189 (malignant neoplasm of kidney) were excluded. Overall, 593 were available for analysis.

Covariates

For each patient, age at the time of surgery, gender, race, body mass index (BMI), smoking status, preoperative serum creatinine (SCr) and American Society of Anesthesiologists (ASA) score were considered in the multivariable analyses.

Endpoints

Our primary outcome was postoperative complications. Complications were grouped into the following categories [11]: cardiovascular (including postoperative cardiac arrest and myocardial infarction), pulmonary (including pneumonia, need for postoperative reintubation and ventilatory support >48 h), thromboembolic (including deep venous thrombosis and pulmonary embolism), septic (including sepsis and septic shock), renal (including acute renal failure and progressive renal insufficiency), urinary tract infections (UTI) and wound complications (including superficial, deep and organ space surgical site infections and wound dehiscence). Overall complication

rate was defined as the occurrence of any complication. Additional outcomes examined the need for perioperative blood transfusion, the need for operative re-intervention, pOT, pLOS, readmission and perioperative mortality. Prolonged operating time and prolonged length of stay were defined as an operating time and a hospital length of stay greater than the 75th percentile (>236 min and >4 days, respectively). Thirty-day readmission data used in this study were reported starting January 1, 2012. Perioperative mortality was defined as death within 30 days of surgery.

Statistical analyses

Descriptive statistics of categorical variables focused on frequencies and proportions. Medians and interquartile ranges were reported for continuously coded variables. Chi-square and independent *t* tests were used to identify associations between the two study cohorts. Multivariable regression models were used to analyze the association between outcomes and surgical approach. All models were adjusted for surgical approach, age, gender, race, BMI, SCr and ASA score. Covariates were tested for interactions and for collinearity. Model discrimination was evaluated with the C-statistic and calibration with the Hosmer–Lemeshow goodness-of-fit statistic.

All statistical analyses were two-sided with a level of significance set at $p < 0.05$. Analyses were performed using SPSS, version 22 (IBM, Armonk, New York). An institutional review board waiver was obtained prior to conducting this study, in accordance with institutional regulation when dealing with de-identified administrative data.

Results

Baseline patient characteristics

Between 2005 and 2012, 593 adults undergoing OP or MIP for UPJO were captured by NSQIP. Patient and surgical characteristics are summarized in Table 1. A total of 423 (71.3 %) patients underwent MIP. Patients undergoing MIP were younger compared to those undergoing OP (median age 46 vs. 48 years, respectively; $p < 0.001$). Overall, the majority of patients were female (56.5 %) and white (74.9 %). However, among the OP and MIP groups, there was no significant difference with regard to gender and race. Patients undergoing OP had a higher BMI, ASA score and baseline SCr compared to those undergoing MIP (all $p < 0.01$)

Table 1 Descriptive characteristics of 593 adult patients undergoing pyeloplasty stratified according to approach (MIP vs. OP); National Surgical Quality Improvement Program (NSQIP) Database 2005–2012

Variables	Overall	MIP	OP	*p* value
Patients [*n* (%)]	593 (100)	423 (71.3)	170 (28.7)	–
Age (years)				**0.001**[#]
Median (IQR)	48 (32–62)	46 (30–61)	48 (33–61)	
Age [*n* (%)]				**0.001**
18–35	173 (29.3)	139 (33.0)	34 (20.0)	
36–55	197 (33.3)	142 (33.7)	55 (32.4)	
56–75	186 (31.5)	113 (26.8)	73 (42.9)	
>75	33 (5.6)	25 (5.9)	8 (4.7)	
Unknown	2 (0.3)	2 (0.5)	0 (–)	
Gender [*n* (%)]				0.356
Male	258 (43.5)	179 (42.3)	79 (46.5)	
Female	335 (56.5)	244 (57.7)	91 (53.5)	
Race [*n* (%)]				0.465
White	444 (74.9)	315 (74.5)	129 (75.9)	
Black	28 (4.7)	17 (4.0)	11 (6.5)	
Asian	11 (1.9)	7 (1.7)	4 (2.4)	
Hispanic	17 (2.9)	12 (2.8)	5 (2.9)	
Unknown	93 (15.7)	72 (17.0)	21 (12.4)	
BMI (kg/m^2) [*n* (%)]				**<0.001**
<18.5	24 (4.1)	22 (5.2)	2 (1.2)	
18.5–25.0	227 (38.4)	182 (43.1)	45 (26.6)	
25.1–30.0	179 (30.3)	116 (27.5)	63 (37.3)	
>30	161 (27.2)	102 (24.2)	59 (34.9)	
Creatinine (mg/dl) [*n* (%)]				**0.011**
<1.2	423 (78.5)	310 (81.4)	113 (71.5)	
≥1.2	116 (21.5)	71 (18.6)	45 (28.5)	
ASA score				**<0.001**
1—no disturbance	86 (14.5)	73 (17.3)	13 (7.6)	
2—mild disturbance	329 (55.6)	255 (60.4)	74 (43.5)	
3—severe disturbance	156 (26.4)	88 (20.9)	68 (40.0)	
≥4—life threat	21 (3.5)	6 (1.4)	15 (8.8)	

Bold *p* values indicate significance

MIP minimally invasive pyeloplasty, *OP* open pyeloplasty, *BMI* body mass index, *ASA* American Society of Anesthesiologists (Score), *IQR* interquartile range

[#] Kruskal–Wallis test

Perioperative outcomes

Perioperative outcomes were stratified by surgical approach (Table 2). There were a total of 32 (5.4 %) complications between both groups. Patients undergoing MIP experienced fewer pulmonary (0.2 vs. 1.8 %, $p = 0.04$), thromboembolic (0.5 vs. 2.4 %, $p = 0.039$), septic (0 vs. 3.5 %, $p < 0.001$), renal (0 vs. 1.8 %, $p = 0.006$) and wound complications (0.2 vs. 5.3 %, $p < 0.001$) compared to OP.

Table 2 Perioperative outcomes of 593 adult patients undergoing pyeloplasty stratified according to approach (MIP vs. OP); National Surgical Quality Improvement Program (NSQIP) Database 2005–2012

Variables	Overall	MIP	OP	*p* value
Patients [*n* (%)]	593 (100)	423 (71.3)	170 (28.7)	–
Complications [*n* (%)]				
Overall	32 (5.4)	13 (3.1)	19 (11.2)	**<0.001**
Cardiovascular	1 (0.2)	1 (0.2)	0 (–)	0.526
Pulmonary	4 (0.7)	1 (0.2)	3 (1.8)	**0.04**
Thromboembolic	6 (1.0)	2 (0.5)	4 (2.4)	**0.039**
Sepsis/shock	6 (1.0)	0 (–)	6 (3.5)	**<0.001**
Renal failure	3 (0.5)	0 (–)	3 (1.8)	**0.006**
UTI	13 (2.2)	9 (2.1)	4 (2.4)	0.865
Wound	10 (1.7)	1 (0.2)	9 (5.3)	**<0.001**
Blood transfusion [*n* (%)]	15 (2.5)	1 (0.2)	14 (8.2)	**<0.001**
Re-intervention [*n* (%)]	11 (1.9)	4 (0.9)	7 (4.1)	**0.01**
pOT (>236 min)* [*n* (%)]	151 (25.5)	125 (29.6)	26 (15.3)	**<0.001**
pLOS (>4 days)* [*n* (%)]	152 (25.6)	50 (11.8)	102 (60.0)	**<0.001**
Readmission (2012) [*n* (%)]	9 (4.8)	4 (2.8)	5 (10.4)	**0.033**
Perioperative mortality [*n* (%)]	1 (0.2)	0 (–)	1 (0.6)	0.114

Bold *p* values indicate significance

MIP minimally invasive pyeloplasty, *OP* open pyeloplasty, *UTI* urinary tract infection, *OR* operating room, *pOT* prolonged operation time, *pLOS* prolonged length of stay

* ≥75th percentile

Kruskal–Wallis test

Table 3 Multivariable logistic regression analysis for perioperative outcomes of 593 adult patients undergoing pyeloplasty stratified according to approach in the National Surgical Quality Improvement Program (NSQIP) Database 2005–2012

Outcomes	MIP versus OP		
	OR**	95 % CI	*p* value
Overall complications	0.21	0.09–0.47	**<0.001**
UTI	0.61	0.16–2.37	0.48
Wound	0.06	0.01–0.49	**0.009**
Blood transfusion	0.04	0.01–0.35	**0.004**
Re-intervention	0.30	0.07–1.23	0.09
pOT (>236 min)*	2.26	1.36–3.70	**0.002**
pLOS (>4 days)*	0.08	0.05–0.14	**<0.001**
Re-admission (2012)	0.15	0.02–1.11	0.06

Bold *p* values indicate significance

MIP minimally invasive pyeloplasty, *OP* open pyeloplasty, *OR* odds ratio, *CI* confidence interval, *UTI* urinary tract infection, *pOT* prolonged operation time *pLOS* prolonged length of stay, *Ref* reference, *SCr* serum creatinine

* ≥75th percentile

** Model adjusted for surgical approach ([Ref. OP]; MIP), age (continuous variable), gender ([Ref. male]; female), race ([Ref. male]; female), BMI [Ref. < 18.5]; 18.5–25.0, 25.1–30.0, >30.0), SCr ([Ref. ≤ 1.2]; >1.2) and ASA score ([Ref. < 3]; ≥3)

Furthermore, patients undergoing MIP had significantly lower transfusion rates (0.2 vs. 8.2 %, $p < 0.001$), pLOS (11.8 vs. 60.0 %, $p < 0.001$), re-interventions (0.9 vs. 4.1 %, $p = 0.01$) and re-admissions (2.8 vs. 10.4 %, $p = 0.033$). However, patients undergoing MIP had significantly higher pOT (29.6 vs. 15.3 %, $p < 0.001$) compared to OP.

In multivariable analyses, patients who underwent MIP had a decreased risk of overall complications (OR 0.21, $p < 0.001$); more specifically, they had a lower risk of wound complications (OR 0.06, $p < 0.009$) and were less likely to need a blood transfusion (OR 0.04, $p = 0.004$). Furthermore, patients who underwent MIP were less likely to experience a pLOS (OR 0.08, $p < 0.001$). Conversely, MIP was associated with increased odds of pOT (OR 2.26, $p = 0.002$) (Table 3).

Discussion

Accurate characterization of perioperative morbidity facilitates patient counseling and identifies targets for quality improvement interventions. We report the results of perioperative outcomes of MIP versus OP in a large cohort of patients between 2005 and 2012 at hospitals participating in the ACS NSQIP. Several of our findings are noteworthy.

First, the majority of the patients included in our cohort underwent MIP instead of open surgical approach. Our results corroborate findings from previous studies [6, 12]. Specifically, Sukumar et al. [6] showed an increase of MIP between 1998 and 2008 from 2.4 to 55.3 % in the Nationwide Inpatient Sample. Liu et al. [13] found similar results in the pediatric population using the Kid's Inpatient Database from 2000 (0.34 %) to 2009 (11.7 %). Varda et al. [14] also confirmed these findings with data from the Perspective database between 2003 and 2010.

Second, overall risk of complications was lowest in patients undergoing MIP compared to OP. These findings are similar to the results of Liapis et al. and Klingler et al. [15, 16]. Both studies reported fewer complication rates after MIS for UPJO. Furthermore, the significant decreased risk of wound complications in patients undergoing MIP of our study is in agreement with the findings of a study by Singh et al. [7] where they found that wound complications were significantly less common in patients undergoing MIP (OR 0.06, $p < 0.009$). Our observations align with the findings of the study from Varela et al. [17] in which they detected fewer surgical site infections (SSI) in patients who underwent laparoscopic surgery for appendectomy, cholecystectomy, anti-reflux surgery or gastric bypass. Other studies have reported that MIS and

open surgery have equivalent risks of wound complications [18]. On the other hand, other prior studies recorded no postoperative wound complications difference between MIP and OP [19, 20]. Recently, Gandaglia et al. performed a study using the NSQIP database to investigate the risk of surgical site infections after MIS and open surgery. This study included 254,008 cases making it the largest cohort studied. They found that MIS is significantly associated with lower odds of SSIs [21]. Other advantages of MIS include smaller surgical incisions and elimination of mechanical retraction of the surgical site [21]. Based on these considerations, several hypotheses have been proposed. Nguyen and colleagues postulate that a lower systemic stress response after laparoscopic (compared to open) gastric bypass surgery leads to lower levels of metabolic, acute phase and cytokine levels [22]. The immune system seems to play an important role in mediating the beneficial effects of MIS by decreasing the inflammatory response to iatrogenic trauma and a significant reduction in the delayed-type hypersensitivity [23, 24]. Moreover, MIP was associated with a lower likelihood of transfusion in our study. This finding corroborates the results of Pahwa et al. [25], where they showed higher mean blood loss in OP (114.47 ml) compared to MIP (55.24 ml), particularly after robotic pyeloplasty (46.37 ml). Interestingly, Sukumar et al. [26] found that children who underwent robot-assisted pyeloplasty had a higher rate of blood transfusions and possibly caused by the very narrow operative field compared to adults.

Third, the risk of pLOS is significantly decreased in patients undergoing MIP. This result was shown in one of the first studies by Brooks et al. [5] and was confirmed recently by Pahwa et al. [25], as well as in pediatric studies [13, 27, 28]. Decreasing length of hospitalization after surgery has a profound impact on health care expenditures [14, 29, 30]. Given that MIP is generally a longer procedure, and the prohibitive costs of disposables in laparoscopic and especially robotic surgery, shortening length of stay may help bridge the cost difference between OP and MIP. Indeed, Varda et al. suggest that there is a $3000+ differential between open and robotic pyeloplasty. Further studies are needed to assess the value of reduced length of stay, as well as accelerated recovery and consequently reduced work absenteeism.

To our knowledge, our study is the first to compare the surgical outcomes of OP and MIP using the prospectively gathered data from the NSQIP database and has several strengths. Previous studies have used only retrospective data to evaluate perioperative outcomes of adult patients who underwent laparoscopic or OP [7]. Prospective studies evaluating outcomes of laparoscopic and OP have so far only been carried out in children [27, 28]. In addition, our study relies on rigorous data collection, rather than administrative claims. In comparison with administrative claims, the NSQIP database offers more perioperative patient-specific variables as well as postoperative outcomes within 30 days [31]. These data are collected and validated by a trained surgical clinical reviewer [10]. Taken together, the NSQIP database has been a better tool for predicting complications after surgery [32].

Our study is not devoid of limitations. Despite its prospective nature, NSQIP only has 30-day patient follow-up after surgery. Long-term outcomes are not available in this database; however, other studies have shown that MIP has a similar if not better long-term success rate relative to OP [1]. Furthermore, we could not distinguish robotic-assisted laparoscopic procedures from pure laparoscopic procedures since separate CPT codes for robotic surgery are missing in this dataset [10]. In addition, another important consideration is the lack of adjustment for case complexity (primary vs. redo pyeloplasty) and pyeloplasty technique (for example, dismembered vs. Y-V plasty). Important anatomical parameters such as the presence of aberrant vessel and the length of stricture are not reported within NSQIP. It is possible that more complex redo cases are done in an open fashion, which would overstate the odds of complications after OP. Furthermore, studies have demonstrated that complicated UPJO can be managed with MIP with similar results to OP [33, 34]. Finally, other important technical confounders such as the use and removal of postoperative upper (ureteral stent) and lower tract (Foley catheter) drainage could not be accounted for in this study. It is possible that subtle variations in these parameters may affect 30-day postoperative outcomes.

Another limitation of this dataset is the lack of surgeon or hospital identifiers, which precludes adjustment for surgeon experience and hospital volume. Finally, it is not possible to estimate representative temporal trends from the NSQIP database as the demographics of voluntary participant hospitals change from 1 year to another [10].

Conclusion

The study demonstrates that approach for pyeloplasty has a significant impact on perioperative outcomes. Given the favorable outcomes with MIP, it may be considered the first-line treatment for UPJO treatment. Further studies are needed to determine whether these benefits offset the increase in expenditures, related to longer operative time and costs of disposables.

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Conflict on interest All authors confirm that there is no conflict of interest.

Ethical standard This study was done with patient data, and therefore, ethics committee approval was not necessary.

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