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Open versus minimally invasive ureteroneocystostomy: a population-level analysis

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Summary

Introduction—Open ureteroneocystostomy (UNC) is the gold standard for surgical correction of vesicoureteral reflux (VUR). Beyond single-center reports, there are few published data on outcomes of minimally invasive (MIS) UNC. Our objective was to compare postoperative outcomes of open and MIS UNC using national, population-level data.

Method—We reviewed the 1998–2012 Nationwide Inpatient Sample to identify pediatric (≤18 years) VUR patients who underwent either open or MIS UNC. Demographics, National Surgical Quality Improvement Program (NSQIP) complications, length of stay (LOS), and cost data were extracted. Statistical analysis was performed using weighted, hierarchical multivariate logistic regression (complications) and negative binomial regression (LOS, cost).

Results—We identified 780 MIS and 75,976 open UNC admissions. Compared with patients undergoing open UNC, patients who underwent MIS UNC were likely to be older (6.2 versus 4.8 years, p<0.001), publically insured (43 versus 26%, p<0.001), and treated in recent years (90 versus 46% after 2005, p<0.001). MIS admissions were associated with a significantly shorter length of stay (1.0 versus 1.8 days, p<0.001) and higher cost ($9,230 versus $6,304, p=0.002). After adjusting for patient-level confounders (age, gender, insurance, treatment year, and comorbidity), and hospital-level factors (region, bedsize, and teaching status), MIS UNC was associated with a significantly higher rate of postoperative urinary complications such as UTIs, urinary retention, and renal injury (OR 3.1, p=0.02), shorter LOS (RR 0.8, p=0.02), and higher cost (RR 1.4, p=0.008).

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Conflict of interest
None.

Ethical Approval: This protocol was reviewed by the Duke Institutional Review Board and deemed exempt from review. Administrative approval was given by HCUP.

Discussion—Strengths of this study are its large cohort size, long time horizon, national estimation, and cost data. Most prior studies are case-series limited to the size of the institutional cohort. Our analysis of 76,756 operative encounters revealed that open UNC continues to be performed at far greater frequency than MIS UNC, outpacing the latter modality by nearly 100:1. Children treated with MIS UNC had three times greater odds of developing postoperative urinary complications, and MIS UNC patients incurred average costs per admission that were nearly 1.5 times higher than those of children who underwent open UNC. These children were also likely to be older, publically insured, and treated in more recent years. On the other hand, patients treated with MIS UNC required substantially shorter postoperative hospitalization, with an average LOS roughly half that of open UNC cases. Limitations include the retrospective nature of the administrative database, lack of detailed patient-level data, and no available long-term postoperative outcomes. Compared with open surgery, MIS UNC was associated with shorter LOS but higher costs and possibly higher urinary complication rates.

Keywords

Vesicoureteral reflux; Complication; Surgery; Ureteroneocystostomy; Minimally invasive

INTRODUCTION

Vesicoureteral reflux (VUR) is a commonly encountered problem in pediatric urologic practice, affecting approximately 1% of all children and up to 70% of those presenting with a febrile UTI [1]. Given this common incidence, the economic impact from VUR has been found to be significant, with care-related charges exceeding $100 million annually in the USA [2]. Optimal management strategies for this condition are controversial and continue to be debated as our understanding of its pathophysiology, clinical course, and long-term sequelae evolve [3,4]. Although the vast majority of cases of VUR resolve spontaneously and do not require surgical management, surgical interventions may be warranted in patients with persistent VUR and/or recurrent febrile UTI to reduce risk of renal scarring and loss of kidney function [3,5].

Open ureteroneocystostomy (UNC) has served as the cornerstone of surgical management of VUR for over 50 years and continues to play a prominent role in modern management algorithms [6,7]. Endoscopic correction of VUR with injection of bulking agents has been available in the USA for over 10 years, but its success rate has never equaled that of UNC, particularly in higher grades of VUR [8]. Significant advances in laparoscopic and robotic technology have coupled with a paradigm shift among providers and families favoring preferential use of less-invasive surgical approaches in children and resulted in a rise in the use of minimally invasive surgery (MIS) in pediatric urology, including MIS-UNC [9]. Yet, despite substantial differences in invasiveness, cost, and intra/postoperative characteristics, there are few multi-center studies directly comparing operative outcomes between open and MIS UNC approaches [9]. Given current efforts to improve care quality and optimize cost management, broader-encompassing comparisons are particularly salient.

We sought to characterize postoperative outcomes, including length of stay (LOS), cost, and National Surgical Quality Improvement Program (NSQIP) postoperative complication rates, for pediatric (aged ≤18 years) patients who underwent surgical intervention for VUR with either open or MIS UNC between 1998 and 2012 using the Nationwide Inpatient Sample (NIS), a nationally representative inpatient administrative database. We hypothesized that complication rates and cost would be higher for MIS surgeries, whereas LOS would be longer for open surgeries.

Materials and methods

Data source

NIS is an all-payer database managed by the Healthcare Cost and Utilization Project (HCUP) and sponsored by the Agency for Healthcare Research and Quality (AHRQ). NIS is derived from a 20% stratified probability sample of US hospitals, including both children's and adult hospitals, based on five hospital characteristics including ownership status, number of beds, teaching status, urban/rural location, and geographic region. NIS includes post-stratification discharge weights that may be used to calculate national estimates [10].

Selection of patients and covariates

We identified all inpatient hospital encounters occurring between 1998 and 2012 for pediatric patients (aged ≤18 years) with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code for VUR (593.7) who underwent UNC (56.74). MIS UNC was differentiated from open UNC using additional procedure codes 17.4, 54.21, 54.51, indicative of UNC involving robotic surgery (17.4) or laparoscopy (54.21, 54.51).

Predictor variables were a priori selected based on biologic plausibility and/or demonstrated associations in the literature. Covariates included basic patient demographics: age, gender, race, insurance payer (public vs. private), median household income quartiles by zip code, Charlson comorbidity index, treatment year, and treatment modality (open versus MIS). We also extracted hospital-level factors: hospital characteristics such as hospital teaching status (metropolitan non-teaching, metropolitan teaching, and non-metropolitan) and geographic region (Northeast, South, Midwest, and West), and center size.

Outcome selection

The primary outcome was in-hospital postoperative complications; these were identified by the ICD-9-CM code (Appendix 1) as defined by NSQIP [11,12]. We included UTI, postoperative urinary complications including urinary retention, acute renal insufficiency, urinary tract infections (ICD-9-CM diagnosis code 997.5), pneumonia, and bleeding as the main outcomes. We also examined length of stay (LOS), and total hospital costs per admission. Rare complications ($n \leq 15$) were removed from the analysis as per AHRQ regulations prohibiting publication of rare events. Among the NSQIP-identified complications, there were too few events for postoperative surgical site infection (superficial and deep), peritoneal abscess, acute renal failure, respiratory complications, ARDS, pulmonary embolism, postoperative respiratory insufficiency, prolonged mechanical ventilation (>96 hours), sepsis, cerebrovascular accident, postoperative cardiac complications, acute myocardial infarction, cardiac arrest or other cardiac complications, deep vein thrombus, or in-hospital death to perform a thorough analysis; these complications were, therefore, excluded.

Statistical analysis

Bivariate analyses were performed to compare patient demographics and hospital-level characteristics of patients who received open and MIS UNC. We used the Rao-Scott chi square test, *t* test, or Wilcoxon rank-sum test as appropriate based on data characteristics and distribution. All analyses were weighted using NIS-specific estimated weights and covariance matrices accounting for the complex survey design. NIS cost-to-charge files were used to convert hospital charges to cost [2]. Multivariate logistic regression (NSQIP in-hospital postoperative complications, in-hospital deaths) and negative binomial regression (LOS, cost) were fitted to examine factors, specifically surgical modality (open versus MIS), that predicted the outcomes. Generalized estimating equations were used to account for complex survey design of NIS in addition to hospital clustering effects.

An alpha of 0.05 and 95% CI were used as criteria for statistical significance. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA).

Ethical approval

This protocol was reviewed by the Duke Institutional Review Board and deemed exempt from review. Administrative approval was given by HCUP.

Results

Demographics

UNC (Table 1). Mean patient age was 4.8±0.1 years. Males constituted 26% of the overall cohort. Most of the patients (87%) received UNC in an urban teaching hospital.

Compared with patients undergoing open UNC, patients who underwent MIS UNC were likely to be older (6.2 versus 4.8 years, $p<0.001$), publically insured (43% versus 26%, $p<0.001$), treated in recent years (90% versus 46% after 2005, $p<0.001$), and at larger hospitals (94% versus 83% in medium-sized hospitals, $p=0.02$).

Postoperative complications

On bivariate analysis (Table 2), patients who received MIS UNC were more likely to suffer from ICD-9-identified “postoperative urinary complications” (OR 2.63, $p=0.04$) compared with patients who received open UNC. No significant difference was observed in rates of postoperative urinary tract infection or overall complications.

After adjusting for age, gender, insurance, year, comorbidity, and hospital-level factors (teaching status, region, and hospital size) (Summary Table), VUR patients who underwent MIS UNC remained more likely to suffer from postoperative urinary complications (OR 3.13, $p=0.02$) compared with patients who underwent open UNC.

Economic impact

On bivariate analysis, compared with VUR admissions received, open UNC, MIS UNC admissions were associated with a shorter median length of stay (1.0 versus 1.8 days, *p*<0.001; Table 1). This trend was notable even after adjusting for age, gender, insurance, treatment year, comorbidity, hospital teaching status, hospital region, and hospital size (RR 0.80, *p*=0.02; Table 3).

Similarly, MIS UNC were found to have significantly higher median overall inpatient costs per admission ($9,230 versus $6,304, *p*=0.002). After adjusting for age, gender, insurance, treatment year, comorbidity, hospital teaching status, hospital region, and hospital size, MIS UNC admissions remained significantly associated with increased hospital cost (RR 1.40, *p*=0.01). There was no significant trend in MIS cost over time (*p*=0.84).

DISCUSSION

To our knowledge, this study is the largest investigating surgical outcomes on open versus MIS UNC. Our analysis of 76,756 operative encounters revealed that open UNC continues to be performed at far greater frequency than MIS UNC, outpacing the latter modality by nearly 100:1. This is not surprising as open UNC has long been the gold standard for surgical management of reflux in children. One of the earliest descriptions of open UNC in the treatment of VUR was published by Politano and Ledbetter in 1958, with further descriptions by Glenn, Anderson, Cohen, and others throughout the 1960s [13–15]. Open UNC has been proven highly effective, with studies demonstrating successful resolution of reflux following initial treatment in more than 95% of patients and a further 57% risk reduction in the development of future febrile UTIs [15].

By comparison, the history of MIS UNC is considerably more recent, with laparoscopic UNC first successfully employed in children by Ehrlich in 1994, and robotic-assisted UNC by Peters *et al.* a decade later [7,16]. Initial success in reflux resolution following treatment with MIS UNC was far more variable, likely as a result of lack of provider experience with such approaches and the resultant learning curve [16–21]. More recent series have found treatment efficacy with MIS UNC to be higher, although typically still not as high as open UNC [9,19,20,22]. MIS UNC has been associated with decreased postoperative pain and shorter LOS, as well as improved cosmesis and corresponding patient/parent satisfaction in some studies [21,23,24], although outpatient open UNC has been reported from several centers [25,26]. However, these benefits come at some expense, both clinically and financially. Several small cohort studies have mirrored our findings of increased incidences of postoperative urinary complications, often including urinary retention, urine leakage, and voiding dysfunction [21,24,27,28]. The reasons for this phenomenon are currently unknown and warrant additional future study, but may speculatively stem from nerve injury through the extravesical approach, lack of sufficient tactile feedback, and difficulty with fine instrument movements.

Despite shorter average LOS, patients in our cohort who underwent MIS UNC incurred per-admission costs nearly 1.5 times those of their open UNC counterparts. This may be partially attributable to higher cost incurred in the management of postoperative complications (i.e. urinary complications, as mentioned above). Additionally, high purchase and maintenance costs associated with advanced laparoscopic instruments, and especially with surgical robots, as well as longer average operative times for MIS UNC procedures may also be reflected in this finding [17,21,24,29–31].

In spite of its rich history and high efficacy, open UNC is inherently more invasive, requiring larger incisions and dissection compared with MIS-UNC. These attributes often necessitate lengthier postoperative hospitalization and recovery times, likely contributing to the greater average LOS for open UNC patients observed in our own analysis and by others [24]. The larger incision is also associated with poorer cosmesis, which is a non-trivial consideration in children given the length of time they will bear visible post-surgical scars; evidence suggests larger surgical scars are associated with decreased parent and patient satisfaction [23]. However, it is worth noting that a standard Pfannenstiel incision is rarely seen given its low-lying location, whereas port site incisions may be more visible if they are placed above the belt line.

The findings of our study must be interpreted in the context of study limitations. NIS represents a 20% stratified sample of US hospital admissions. As such, our reported results may not be generalizable to encounters not in the sample pool. However, NIS does provide meticulous tracking of discharge and hospital weights to minimize the risk of sampling bias [32]. Additionally, NIS is a large retrospective administrative database that might be affected by miscoding bias. Our analysis relies on the accuracy of the diagnostic and procedure codes included in NIS; although the accuracy level of NIS is high for an administrative database, it is possible at least some portion of our cohort may be incorrectly coded. However, we have no reason to believe that miscoding errors would be preferentially more likely in either procedure cohort; thus we do not think it is likely that this potential error is a source of bias impacting our results. Furthermore, the NSQIP complications that we identified may represent associated comorbidities and not true postoperative complications, as NIS does not provide temporal relationships between different diagnosis codes. This can be further aggravated by the NSQIP complications being ill-defined, such as "postoperative urinary complications." Whether this represents a truly significant finding such as frank urinary retention or a potentially minimal issue such as post-MIS oliguria cannot, unfortunately, be teased out from this data source. Despite these limitations, as noted above, the NIS database is rigorously monitored and audited for coding accuracy by AHRQ and, we believe, represents a reasonably reliable panorama of the characteristics of an inpatient surgical cohort.

A similar concern is our inability to tease apart pure laparoscopic from robotic-assisted laparoscopic procedures purely based on procedure codes. Many centers (including our own) do not routinely use robotic-specific codes, thus we did not attempt to differentiate MIS procedures, as the risk of misattribution was prohibitively high. Although there may be specific technical differences between laparoscopic and robotic techniques (and potentially differences in complication rates), we suspect that the grand majority of MIS procedures described here are robotic. Thus, unfortunately, we cannot comment on the potential implications of pre-peritoneal versus intraperitoneal approaches, for example.

Additionally, our analysis likely underestimates the true incidence of postoperative events. Because NIS represents admission-based rather than patient-based data, it is impossible to track a given patient across time. We were not able to assess post-hospital outcomes nor whether individual patients were readmitted or underwent repeat procedures. Our picture of postoperative complications is limited by the inpatient-only nature of NIS, precluding analysis of outpatient encounters not captured in the database, such as those from urgent care and primary care centers where patients may reasonably present post-discharge manifesting symptoms of a postoperative complication. Finally, we are unable to determine the success of each individual UNC procedure in correcting VUR.

The retrospective nature of NIS also limits available data and possible analyses. Detailed patient-level clinical factors such as reflux grade, laterality, prior UTI episodes, renal scarring, and bowel-bladder dysfunction, were not available. It is thus entirely possible that the MIS patients were systematically different from open UNC patients, either because of patient selection or to secular trends; it is also possible that pediatric urologists who offer MIS UNC might recommend open UNC to some patients and MIS to others, which might potentially affect our reported complication rate. It is important to bear in mind that modality of choice is likely multifactorial and provider/setting-specific. Either open or MIS UNC may be a more appropriate approach for a particular child based on institutional resources, provider proficiency, and patient/parental preferences. Therefore, we chose to present these data without the suggestion that one modality is "better" than another, but rather as a snapshot reflective of contemporary clinical practice patterns and outcomes, which will hopefully pique interest in future prospective trials investigating this subject and a robust discussion of the merits of each approach as new clinical guidelines are formulated by advisory groups.

Conclusion

Compared with open surgery, MIS UNC was used in far fewer cases for the surgical management of VUR between 1998 and 2012; the use of MIS increased over the study period but remained relatively rare. Pediatric patients undergoing MIS UNC experienced shorter LOS but higher costs than open surgical patients. Postoperative complications were rare in both groups, but higher postoperative urinary complication rates appeared to be more common among MIS patients. Further study is needed to assess the factors influencing treatment choice and outcomes between these two modalities, as well as their economic impact.

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Highlight

Ureteroneocystostomy (UNC) is the gold standard for surgical correction of vesicoureteral reflux (VUR). However data comparing surgical outcomes between open and minimally-invasive UNC is scarce. Compared to open surgery, we found that MIS UNC was associated with shorter LOS, higher costs and **potentially** higher urinary complication rates.

Table 1

Patient and hospital characteristics by surgery type

Characteristics	Total (*n*=76,756)	MIS (%) (*n*=780)	Open (%) (*n*=75,976)	*p* value
Age in years (mean, SD)	4.8 (0.1)	6.2 (0.4)	4.8 (0.1)	<0.001
Gender				0.62
Male	19,981	184 (24)	19,797 (26)	
Female	56,064	579 (74)	55,485 (73)	
Insurance				0.001
Public	20,393	334 (43)	20,059 (26)	
Private	51,571	392 (50)	51,179 (67)	
Others	4,791	54 (7)	4,737 (6)	
Treatment year				<0.001
1998–2004	41,246	79 (10)	41,167 (54)	
2005–2012	35,509	701 (90)	34,808 (46)	
Income				0.11
Q1	8,755	159 (20)	8,596 (11)	
Q2	11,483	140 (18)	11,343 (15)	
Q3	12,514	259 (33)	12,255 (16)	
Q4	13,348	172 (22)	13,176 (17)	
Hospital region				0.20
Northeast	16,344	175 (22)	16,169 (21)	
Midwest	17,825	180 (23)	17,645 (23)	
South	25,089	124 (16)	24,965 (33)	
West	17,496	300 (39)	17,196 (23)	
Teaching hospital				0.29[a]
Rural	1,772	0	1,772 (2)	
Urban-nonteaching	7,858	49 (6)	7,809 (10)	
Urban-teaching	67,036	726 (93)	66,310 (87)	
Hospital bed size				0.03
Small	13,196	39 (5)	13,157 (17)	
Medium	20,067	361 (46)	19,706 (26)	
Large	43,402	374 (48)	43,028 (57)	
Length of stay (median, IQR)	1.8 (1.8)	1.0 (0.7)	1.8 (1.8)	<0.001
Total cost (median, IQR)	6,282 (4,129)	9,230 (7,577)	6,304 (4,138)	0.002

[a]Rao-Scott chi square for rural-teaching versus non-teaching.

Table 2

NSQIP postoperative complications by surgery type

NSQIP complications	Total *N*=76,756 (%)	MIS N=780(%)	Open N=75,976(%)
UTI	5,281 (6.88)	53 (6.79)	5,228 (6.88)
Urinary complications	827 (1.08)	21 (2.69)	806 (1.06)
All complications	6,955 (9.06)	80 (10.26)	6,875 (9.05)

Table 3

Bivariate/multivariate analysis of LOS and cost for MIS UNC

Economic outcomes[a]	Unadjusted RR (95% CI)	Adjusted RR[b] (95% CI) value[b]	*p*
LOS	0.74 (0.62–0.89)	0.80 (0.66–0.97)	0.02
Cost	1.47 (1.15–1.87)	1.40 (1.09–1.80)	0.01

[a] Using open UNC as reference.

[b] After adjusting for age, gender, insurance, year, comorbidity, teaching status, hospital region, and hospital bedsize.

Appendix 1

Complications	ICD-9 codes
SSI (superficial)	998.32
SSI (deep)	998.31
Peritoneal abscess	567.22
UTI	599
Urinary complications	997.5
ARF	584.x, 586.x
Resp complications	997.3
Pneumonia	481–487, 507
Post-OP resp. insufficiency	518.5
ARDS	518.82
Systemic Sepsis	790.7, 038.x
PE	415.1, 415.11, 415.19
Vent >96h	96.72
CVA	997.02
Cardiac complications	997.1
MI	410.x
Cardiac arrest	427.5
Bleeding	285.1, 998.11
DVT	453.4, 453.40, 453.9

Table

Bivariate/multivariate analysis of postoperative complications for MIS UNC

NSQIP complications[a]	Unadjusted OR (95% CI)	Adjusted OR[b] (95% CI)	*p* value[b]
UTI	1.00 (0.37–2.72)	0.99 (0.40–2.44)	0.98
Urinary complications	2.63 (1.00–6.91)	3.13 (1.17–8.40)	0.02
All complications	1.15 (0.48–2.78)	1.27 (0.57–2.85)	0.56

[a]Using open UNC as reference.

[b]After adjusting for age, gender, insurance, year, comorbidity, teaching status, hospital region, and hospital size.