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Robotic versus open pediatric ureteral reimplantation: Costs and complications from a nationwide sample

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Summary

Introduction
We sought to compare complications and direct costs for open ureteral reimplantation (OUR) versus robot-assisted laparoscopic ureteral reimplantation (RALUR) in a sample of hospitals performing both procedures. Anecdotal reports suggest that use of RALUR is increasing, but little is known of the outcomes and costs nationwide.

Objective
The aim was to determine the costs and 90-day complications (of any Clavien grade) in a nationwide cohort of pediatric patients undergoing OUR or RALUR.

Methods
Using the Premier Hospital Database we identified pediatric patients (age < 21 years) who underwent ureteral reimplantation from 2003 to 2013. We compared 90-day complication rates and cost data for RALUR versus OUR using descriptive statistics and hierarchical models.

Results
We identified 17 hospitals in which both RALUR and OURs were performed, resulting in a cohort of 1494 OUR and 108 RALUR cases. The median operative time was 232 min for RALUR vs. 180 min for OUR ($p = 0.0041$). Incidence of any 90-day complications was higher in the RALUR group: 13.0% of RALUR vs. 4.5% of OUR (OR = 3.17, 95% CI: 1.46–6.91, $p = 0.0037$). The difference remained significant in a multivariate model accounting for clustering among hospitals and surgeons (OR, 3.14; 95% CI, 1.46–6.75; $p = 0.0033$) (Figure). The median hospital cost for OUR was $7273 versus $9128 for RALUR ($p = 0.0499$), and the difference persisted in multivariate analysis ($p = 0.0043$). Fifty-one percent (55/108) of the RALUR cases occurred in 2012–2013.

Discussion
We present the first nationwide sample comparing RALUR and OUR in the pediatric population. There is currently wide variation in the probability of complication reported in the literature. Some variability may be due to differential uptake and experience among centers as they integrate a new procedure into their practice, while some may be due to reporting bias. A strength of the current study is that cost and 90-day postoperative complication data are collected at participating hospitals irrespective of outcomes, providing some immunity from the reporting bias to which individual center surgical series' may be susceptible.

Conclusions
Compared with OUR, RALUR was associated with a significantly higher rate of complications as well as higher direct costs even when adjusted for demographic and regional factors. These findings suggest that RALUR should be implemented with caution, particularly at sites with limited robotic experience, and that outcomes for these procedures should be carefully and systematically tracked.

90-day complications	Univariate analysis		Multivariate analyses*	
	Odds Ratio (95% CI)	*p*-value	Odds Ratio (95% CI)	*p*-value
RALUR vs OUR	3.17 (1.46, 6.91)	0.0037	3.14 (1.46, 6.75)	0.0033
Female gender	1.05 (0.69, 1.61)	0.8156	-	-
Age (years, increasing)	1.01 (0.94, 1.08)	0.7625	-	-
Absence of comorbidity	0.34 (0.18, 0.66)	0.0014	0.34 (0.19, 0.62)	0.0004

*Multivariate model is adjusted for propensity score

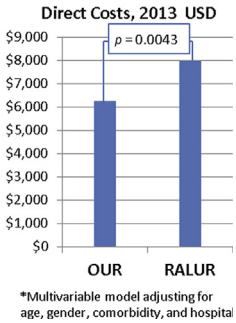

Figure Left: Univariate and multivariate odds of 90-day complication comparing open ureteral reimplantation (OUR) and robotic-assisted laparoscopic ureteral reimplantation (RALUR). Right: Comparison of OUR and RALUR direct costs in 2013 USD.

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Introduction

Although open ureteral reimplantation (OUR) has long been the gold standard for surgical correction of vesicoureteral reflux (VUR), laparoscopic approaches for VUR have been reported as far back as 1993 with a description of laparoscopic correction of VUR in a porcine model [1]. A robot-assisted approach was first described in 2004 [2,3], and subsequent reports suggest that robot-assisted laparoscopic ureteral reimplantation (RALUR) is rising in popularity [4,5]. While broad, multi-institutional data regarding outcome and cost have been reported for robotic pyeloplasty [6] the same is not true for ureteral reimplantation. Currently, the published data are conflicting regarding the complication profile of RALUR [7–10] with multi-institutional pooled data demonstrating high rates of persistent reflux and reoperation [10], whereas a large prospective single-surgeon series reported no complications [11]. This exists in comparison to OUR, which has a robust literature of favorable short and long-term outcomes and low complication rates [12,13]. Similarly, direct costs have increased with use of robot-assisted technology [6]. As such, we sought to compare 90-day complications and direct costs for OUR versus RALUR in a large national sample of hospitals performing both procedures. We hypothesize that RALUR would be associated with higher rates of complications and higher direct costs than OUR.

Materials and methods

Study cohort assembly

The Premier hospital database (Premier, Inc., Charlotte, NC, USA) is an inpatient dataset created for national quality and utilization benchmarking and includes approximately 20% of inpatient discharges from non-federal institutions in the United States comprising over 700 hospitals [14]. In addition, it provides a unique patient identifier key that allows tracking of an individual across encounters.

We extracted hospital discharge data for pediatric patients (age $<$ 21 years) with an International Classification of Diseases, Ninth Revision (ICD-9-CM) procedure code for ureteroneocystostomy (ICD-9 56.74) between January 1, 2003, and December 31, 2013, from the Premier Hospital Database. From these, we selected patients with ICD-9 diagnosis codes for VUR (593.7), and excluded patients with diagnosis codes indicative of secondary VUR (e.g., neurogenic bladder, exstrophy, ureterocele, posterior urethral valves), as previously described [15]. Absence of comorbidity was defined as a Charlson Comorbidity Score of zero [16]. This study was exempt from institutional review board approval, due to the de-identified nature of the data.

We further classified patients by surgical approach. Patients with code for a robot-assisted procedure (ICD-9 17.42 or 17.44 introduced in October 2008, Healthcare Common Procedure Coding System [HCPCS] Current Procedural Terminology [CPT] Code S2900 introduced in July 2005) or a recorded charge code for robotic instrumentation were classified as RALUR. The charge codes for robotic instrumentation were obtained through a thorough review of the charge description master for each patient specifically identifying supplies unique to robotic procedures, via a combination of flagging every item in the EndoWrist Instrument and Accessory Catalog from Intuitive Surgical and manual review, similar to the methodology described previously [17].

Perioperative outcomes

The primary outcome was 90-day complications after reimplantation. We identified all grades (I–V) of postoperative Clavien–Dindo complications using ICD-9 codes, as previously described [18,19]. Complications occurring during the index hospitalization and/or rehospitalization within 90 days were included, even if not occurring during the initial admission. Secondary outcomes included length of stay (LOS) and costs. LOS was determined by calculating the difference between admission and discharge dates and was reported in days.

Cost calculations

The Premier database enumerates both charges and direct costs (only costs were used in this analysis) of individual billing items for a hospitalization. Total direct cost was calculated by summing the cost of all individual billing items provided in the charge master for each procedure. Costs were tabulated for the 90 days following ureteral reimplantation to include the medical expenditures associated with postoperative complications requiring readmission to a Premier Hospital. These costs were further subdivided into operating room use, operating room supplies, room and board, and other (including laboratory, radiology, pharmacy, and miscellaneous non-categorizable items). The proportion of overall cost attributable to each category was calculated. Fixed costs, including capital costs, annual maintenance fees and professional fees for surgical assistants, were not included. All costs were adjusted to 2013 US dollars using the medical component of the Consumer Price Index. Costs were not available for 17 subjects and whose data was excluded from costs' comparisons.

Statistical analysis

Descriptive statistics were used to characterize the cohort. Continuous variables were expressed as median with interquartile range (IQR). Categorical variables were presented as counts and percentages. To account for RALUR versus OUR procedure type selection, a propensity score was built based on gender, age, and absence of any comorbidity. The association of complications with RALUR versus OUR, adjusting for comorbidity, was investigated. Associations of costs (total, OR, room and board, supply, pharmacy, and other) with procedure type, absence of comorbidities, age, and gender were investigated. All multivariate models were propensity score adjusted. All analyses were performed using generalized estimating equations with identical and logit links for continuous and binary outcome variables, respectively. All of the analyses accounted for clustering of the data by a physician within a