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Does de novo hydronephrosis after pediatric robot-assisted laparoscopic ureteral re-implantation behave similarly to open re-implantation?

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Keywords
Vesicoureteral reflux; Ureteral re-implantation; Bladder; Hydronephrosis; Robotic surgery

Abbreviations
RALUR-EV, robot-assisted laparoscopic ureteral re-implantation via an extravesical approach; VUR, vesicoureteral reflux; HN, hydronephrosis; SFU, Society for Fetal Urology

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Summary

Background
While open ureteral re-implantation surgery is the gold standard for surgical correction of vesicoureteral reflux (VUR), robot-assisted laparoscopic ureteral re-implantation via an extravesical approach (RALUR-EV) has become a minimally invasive alternative. Previous studies have shown that transient hydronephrosis after open re-implantation can occur in up to 28% of patients. However, previous studies have also shown that de novo hydronephrosis after open re-implantation is not predictive of final differential renal function.

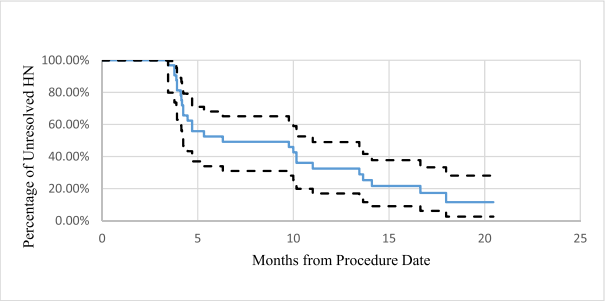
Objective
A retrospective review was performed to characterize the natural history of postoperative hydronephrosis after RALUR-EV for primary VUR in pediatric patients.

Study design
A retrospective chart review of a single-surgeon series was performed for pediatric patients who underwent RALUR-EV for primary VUR. The severity of de novo hydronephrosis was assessed using the Society for Fetal Urology (SFU) grading system via renal ultrasound at the 1-month postoperative follow-up. Renal ultrasound was performed at least every six months. Radiographic success was defined as complete resolution of VUR on the voiding cystourethrogram at the 4-month mark. Patient demographics, surgery duration, length of hospital stay, pre-operative and post-operative VUR grades, and follow-up time periods were collected. Patients with other associated urinary pathology and patients lost to follow-up were excluded from the study.

Results
A total of 87 patients (121 kidney units) with primary VUR who underwent RALUR-EV met the inclusion criteria. SFU grade 1–3 hydronephrosis was noted in 30.3% (36/119) of kidney units at the 1-month mark, but 83.9% (26/31) cases with hydronephrosis completely resolved in a median time of 7.9 months (range: 3.4–21.0 months), and all four cases with unresolved hydronephrosis were downgraded to SFU grade 1 without the need for intervention.

Discussion
A radiographic success rate of 96% was demonstrated in this cohort, which is comparable with that of historical open re-implantation series. A similar rate of de novo hydronephrosis was also noted in this cohort when compared with that of previous open re-implantation series, but de novo hydronephrosis after RALUR-EV had a similar or more rapid resolution rate than that previously reported after open intravesical and extravesical re-implantation series.

Conclusion
De novo hydronephrosis after RALUR-EV behaves similarly to de novo hydronephrosis after open ureteral re-implantation, where de novo hydronephrosis is present in up to 30% of pediatric patients who underwent RALUR-EV. The hydronephrosis self-resolves without the need for intervention in the overwhelming majority of cases and resolves at a median time of 7.9 months after surgery.



Summary Fig. Cumulative percentage of unresolved hydronephrosis with 95% confidence interval. This graph shows the cumulative percentage of unresolved hydronephrosis by months from the procedure date. HN, hydronephrosis; CI, confidence interval.

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Introduction

Open ureteral re-implantation via an intravesical or extravesical approach has been the gold standard for surgical correction of vesicoureteral reflux (VUR) in pediatric patients as this procedure is associated with high radiographic success rates of 95% or more in historical series [1]. Recently, the application of robot-assisted laparoscopic surgery has expanded the availability of minimally invasive techniques, such as robot-assisted laparoscopic ureteral re-implantation via an extravesical approach (RALUR-EV), to pediatric patients undergoing ureteral re-implantation [2–4]. The potential benefits of RALUR-EV have previously been reported as fewer and less intense bladder spasms, less hematuria, and shorter hospital stays [2,5–8].

Minimizing complication rates for ureteral re-implantation surgery is important for both open and minimally invasive approaches, and the appearance of de novo hydronephrosis postoperatively may indicate the possibility of complications such as urinary obstruction. Factors that contribute to de novo hydronephrosis include transient postoperative edema, ureteral ischemia, or kinking of the ureter by the new detrusor tunnel after re-implantation [9,10]. Because de novo hydronephrosis may indicate the possibility of asymptomatic ureteral obstruction, it is common practice to screen for postoperative hydronephrosis by renal ultrasound [10]. Some groups have even recommended the use of ureteral stents after extravesical open re-implantation for up to 3 weeks to reduce the risk of ureteral obstruction [11–13]. Other studies have shown that postoperative hydronephrosis in the absence of a stent is a benign and transient finding [12]. The authors previously described a top-down detrusor tunnel suturing technique without the use of ureteral stents for RALUR-EV, which is associated with high radiographic success rates and low complication rates [14].

Previous studies on postoperative hydronephrosis in pediatric patients undergoing open re-implantation via an extravesical approach have shown that de novo or increased postoperative hydronephrosis does not appear to be predictive of the need for postoperative intervention or final differential renal function [10,15]. Since the introduction of RALUR-EV, no previous study to date has examined the incidence and natural history of de novo hydronephrosis after RALUR-EV. The authors' hypothesis was that de novo hydronephrosis after RALUR-EV in pediatric patients behaves similarly to that in patients who underwent open re-implantation. In this study, the aim was to characterize the natural history of postoperative hydronephrosis after RALUR-EV for primary VUR and compare these findings to historical open re-implantation series.

Materials and methods

A retrospective chart review was performed for all pediatric patients who underwent RALUR-EV that was performed by a single surgeon for primary VUR between 2007 and 2016. During this period, a postoperative voiding cystourethrogram (VCUG) was routinely ordered as part of the care protocol.

RALUR-EV technique

All procedures were performed with the da Vinci S and Si Surgical Systems (Intuitive Surgical, Sunnyvale, CA) using 5-mm instruments. The patients were secured in a supine and Trendelenburg position. Dissection was carried out using the robotic DeBakey forceps and a hook cautery. After ureteral mobilization, a percutaneous hitch stitch was placed at the bladder dome to aid in retraction. Re-implantation by a Lich-Gregoir technique was performed in a top-down manner, where the first suture (4-0 polydioxanone) was placed at the superior aspect of the new detrusor tunnel. The rest of the detrusorraphy was performed in an interrupted fashion with 4-0 polydioxanone, as previously described by Silay et al [14]. All re-implantations were performed without an indwelling ureteral stent or catheter.

Patient selection

Indications for RALUR-EV included persistent or worsening primary VUR, breakthrough infections, and/or progressive renal scarring despite antibiotic prophylaxis. The severity of VUR was graded based on the International Reflux Study guidelines. Children undergoing a redo RALUR-EV for recurrent VUR and children with other associated urinary pathology, such as megaureter, ectopic ureter, and ureterovesical junction obstruction, or secondary VUR were excluded. Patients with pre-existing hydronephrosis that was detected on pre-operative renal ultrasound and those without postoperative imaging who were lost to follow-up were also excluded.

Data collection

The severity of de novo hydronephrosis was assessed using the Society for Fetal Urology (SFU) grading system with renal ultrasound at the 1-month mark after surgery. Renal ultrasound was then performed at least every six months. Radiographic success was defined as complete resolution of VUR on the VCUG at the 4-month postoperative follow-up. Temporary urinary retention was addressed with replacement of the indwelling Foley catheter before discharge, and then, the catheter was subsequently removed at the 2-week mark. Collected data included patient demographics, surgery duration, length of hospital stay, pre-operative and postoperative VUR grades, and follow-up length. Operative time was measured as time from incision to closure, and console time was measured as the duration in which the surgeon was using the console.

Continuous variables were summarized by means (standard deviations) and compared using the Wilcoxon rank test, whereas the categorical variables were summarized by counts and percentages and compared using the Fisher's exact test. VUR grade was treated as both a continuous and categorical variable. A Kaplan–Meier curve was generated to estimate the cumulative percentage of unresolved hydronephrosis by months from the procedure date with a 95% confidence interval.

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Results

A total of 87 patients (121 kidney units) with primary VUR who underwent RALUR-EV were included in this study. The median age at surgery was 5.0 years (range: 1.0–16.2). Seventeen patients (19.5%) were males, and 70 (80.5%) were females.

The overall median operative time was 175 min (range: 118–329), whereas the median operative time for unilateral operations was 161 min (range: 118–270), and for bilateral operations, the median operative time was 205 min (range: 164–329) (Table 1). The estimated blood loss was minimal in all cases, and there were no intra-operative or postoperative complications higher than Clavien grade II. The median length of hospital stay was 1.3 days (range: 0.8–3.1).

A total of 35 (40%) patients had left unilateral VUR, 18 (21%) had right unilateral VUR, and 34 (39%) had bilateral VUR. Pre-operatively, 11 ureters (9%) were associated with grade I VUR, 24 (20%), with grade II VUR, 48 (40%), with grade III VUR, 33 (27%), with grade IV VUR, and five (4%), with grade V VUR.

The postoperative VCUG was completed on 101 ureters (83%). Of these, 97 (96%) showed complete VUR resolution, and four (4%) showed persistent VUR. Three of the patients with persistent VUR had persistent grade I VUR, with two showing improvements from their previous VUR grades III and IV, respectively, and one patient with persistent VUR grade I after surgery. Another patient with pre-operative VUR grade IV had residual VUR grade II postoperatively. These patients were followed up for an average of 256.7 days (range: 134–304), and none had episodes of urinary tract infection (UTI) that warranted intervention and evidence of de novo hydronephrosis.

Table 1 Peri-operative parameters.

Parameters	N
Median total operative time (minutes)	
Overall (range)	175 (118–329)
Unilateral (range)	161 (118–270)
Bilateral (range)	205 (164–329)
Median console time (minutes)	
Overall (range)	130 (75–274)
Unilateral (range)	108 (75–221)
Bilateral (range)	154 (127–274)
Median length of stay in days (range)	1.3 (0.8–3.1)
Median follow-up in months (range)	10.8 (1.0–35.5)
Temporary urinary retention (%)	7 (6%)
Median retention in days (range)	14 (6–15)
Follow-up VCUG conducted (%)	101 (83%)
Complete VUR resolution (%)	97 (96%)
1st postoperative ultrasound conducted (%)	119 (98%)
De novo hydronephrosis (%)	36 (30%)
SFU grade 1 (%)	12 (33%)
SFU grade 2 (%)	18 (50%)
SFU grade 3 (%)	6 (17%)
HN resolution (%)	26 (84%)
Median time to HN resolution in months (range)	7.9 (3.4–21.0)
Median age—de novo HN in years (range)	4.8 (1.0–13.4)

VCUG, voiding cystourethrography; VUR, vesicoureteral reflux; SFU, Society for Fetal Urology; HN, hydronephrosis.

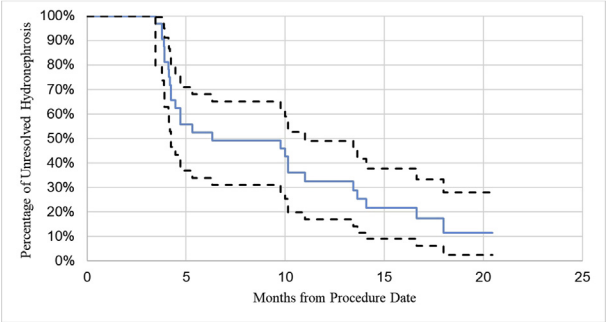

Fig. 1 Cumulative percentage of unresolved hydronephrosis with 95% confidence level. This graph shows the cumulative percentage of unresolved hydronephrosis by months from the procedure date.

Postoperatively, six patients (7%) developed temporary urinary retention and were discharged home with indwelling Foley catheters. The catheters were removed by the 2-week mark with resolution of urinary retention in all patients. Of these patients, three patients (50%) developed de novo hydronephrosis (10% of the hydronephrosis group).

Of the 121 ureters on which RALUR-EV was performed, three were associated with being lost to follow-up as no postoperative ultrasound was available for review. De novo hydronephrosis grade 1–3 was noted in 30.3% (36/119) of kidney units on 1-month postoperative renal ultrasound. Of these, 31 kidney units had follow-up ultrasounds, and 26 (83.9%) showed complete resolution of hydronephrosis at a median time of 7.9 months (range: 3.4–21.0). Of those with unresolved de novo hydronephrosis, four had improvement to grade 1, and none of these patients required intervention. One patient had grade 3 de novo hydronephrosis at 1-month postoperative renal ultrasound, which eventually resolved by the 21-month mark. The patient remained asymptomatic with no recurrent UTIs or other urinary complaints during that period. Fig. 1 shows the cumulative percentage of unresolved hydronephrosis with 95% confidence level, as measured by months from the procedure date.

In comparing the hydronephrosis and non-hydronephrosis groups, the average pre-operative VUR grade was 3.3 (standard deviation [SD]: 0.8) for patients with hydronephrosis and 2.8 (SD: 1.0) for the patients without hydronephrosis (Table 2), with 86% of the kidney units with hydronephrosis having pre-operative VUR at grade 3 or higher vs 65% of the non-hydronephrosis kidney units ($P = 0.03$). Logistic regression showed that an increase of one VUR grade increased the risk of developing de novo hydronephrosis by 81.4% ($P = 0.01$) (odds ratio of 1.81).

The percentage of female patients, laterality, average age, average console time, and average length of stay were not significantly different between the hydronephrosis and non-hydronephrosis groups ($P = 0.59$, 0.75, 0.39, 0.69, and

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Table 2 Comparison of the de novo hydronephrosis and non-de novo hydronephrosis groups.

	De novo	Non-de novo	*P*-Value
	HN (N = 30)	HN (N = 57)	
Age (years)	5.6 ± 3.3	6.1 ± 3.2	0.39
Gender, female	25 (83%)	45 (79%)	0.59
Laterality			0.75
Bilateral	11 (37%)	23 (42%)	
Left	13 (43%)	22 (39%)	
Right	6 (20%)	12 (21%)	
Pre-operative VUR grade[a]			0.02
1	1 (3%)	10 (12%)	
2	4 (11%)	20 (23%)	
3	12 (39%)	36 (43%)	
4	17 (44%)	16 (17%)	
5	1 (3%)	4 (5%)	
Console time (minutes)	128.8 ± 32.5	134.8 ± 40.9	0.69
Length of stay (days)	1.5 ± 0.5	1.6 ± 1.2	0.64
Temporary urinary retention	3 (10%)	3 (5%)	0.46

VUR, vesicoureteral reflux; HN, hydronephrosis.
[a] Numbers and percentages of pre-operative VUR grades were calculated among 35 kidney units with hydronephrosis and 86 kidney units without hydronephrosis.

0.63, respectively). Furthermore, 10% of the patients with hydronephrosis and 5% of the patients without hydronephrosis developed temporary urinary retention, but this difference also did not reach statistical significance ($P = 0.46$).

Discussion

Open surgical correction of VUR, either via an extravesical or intravesical approach, has similar resolution rates (>95%) [10,15,16]. The main advantages of performing extravesical ureteral re-implantation have been previously described as less reported pain, shorter hospital stays, and a decreased incidence of gross hematuria [6]. On the other hand, potential disadvantages of this approach are the known risk of urinary retention with bilateral cases and the new onset of hydronephrosis with concerns of urinary obstruction [11].

With the introduction of robot-assisted laparoscopic surgery into pediatric urology, there is continued discussion on its role in the surgical management of VUR. Smith et al. [6] and Shomburg et al. [17] compared RALUR-EV and open extravesical re-implantation, reporting longer operative time with RALUR-EV, but also reported shorter hospital stays and lower pain medications requirements. Previously reported success rates in RALUR-EV have varied from 81.9% to 100% [4,7,18], which may reflect differences in surgical techniques and surgeons' learning curves. For example, Grimsby et al. [18] reported a 10% complication rate with persistent VUR in 23% of their cohort patients, and Marchini et al. [7] reported a 30% complication rate including two postoperative ureteral leaks. In contrast, a multi-institutional study by Boysen et al. [4] examined the largest RALUR-EV cohort reported in the literature (260 patients from nine institutions) and concluded that although the overall complication rate was 9.6% in their cohort, only 2.7% had Clavien grade 3 complications with no reported grade 4 or 5 complications. A radiographic success rate of 96% was reported in the study cohort, which is comparable with that of historical open re-implantation series [10,15,16] and especially for previously reported robotic extravesical re-implantation series [2,4]. As a result, a VCUG is no longer routinely ordered for pediatric patients after RALUR-EV at the authors' institution, similar to the care protocol for patients who underwent open re-implantation.

The natural history of de novo hydronephrosis after RALUR-EV was described in pediatric patients, which have not been reported in the literature to date. De novo hydronephrosis in patients who underwent open re-implantation is likely secondary to ureteral edema from surgery and is thought to be a benign, self-limited process that resolves without intervention. Bomalaski et al. [19] identified dysfunctional voiding and postoperative UTI as factors associated with this type of hydronephrosis. However, in the study series, hydronephrosis was not associated with either of these variables. Rosman et al. [10] hypothesized that postoperative hydronephrosis might be related to (1) the degree and duration of pre-operative hydronephrosis and (2) temporary periods of obstruction during and after surgery [7]. Other potential peri-operative factors may be the prolonged hydrostatic pressures of pre-existing VUR, as well as ureteral edema, intramural hematomas, cessation of peristalsis in the operated ureter, and kinking of the ureter [10]. Because this study excluded any patients with pre-operative hydronephrosis, the findings most likely reflected transient obstruction that self-resolved.

While de novo hydronephrosis was seen in 30.3% of the patients in the RALUR-EV cohort, it is of note that previously published open re-implantation series have noted similar or lower rates. Barrieras et al. [20] noted an incidence of 12.6% for postoperative hydronephrosis after open extravesical re-implantation, while Rosman et al. [10] noted a 12% incidence after open intravesical re-implantation. On the other hand, Aboutaleb et al. [21] noted a 21.6% incidence after both open intravesical and extravesical re-implantation, and Lee et al. [15] noted a 28% incidence (de novo and aggravated combined) after open extravesical re-implantation.

However, de novo hydronephrosis was not associated with the need for intervention and usually self-resolved at a more rapid rate when than that previously reported after open intravesical and extravesical re-implantation series. Rosman et al. [10] noted an average of 35.2 months for de novo grade 1–2 hydronephrosis to resolve and 16.0 months for de novo grade 3 hydronephrosis to resolve in their cohort of 938 patients. They also concluded that de novo hydronephrosis was more likely to resolve spontaneously than aggravated hydronephrosis [10]. Lee et al. [15] showed improvement in 92% of de novo or aggravated hydronephrosis within six months after surgery but did not specify if the hydronephrosis was completely resolved. This

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study cohort had an average resolution time of 7.6 months in 83.9% of the patients. However, the reported resolution time may also be influenced by the timing and frequency of postoperative ultrasound. In the study by Rosman et al. [10], the first postoperative ultrasound was performed at the 1- to 3-month mark after surgery, and the second postoperative ultrasound was performed at the 6- to 12-month mark after surgery, whereas this cohort underwent the first postoperative ultrasound at the 1-month mark after surgery, with subsequent postoperative ultrasounds at least every 6 months until resolution.

This study also showed that a higher pre-operative VUR grade was a risk factor for de novo hydronephrosis, where each increase in the pre-operative VUR grade increased the risk of de novo hydronephrosis by 81.4%. This finding differs from that of the open extravesical re-implantation series of Lee et al. [15], which noted no correlation between the severity of pre-operative VUR and de novo hydronephrosis. Lee et al. [15] also showed that younger age (less than 2 years) was correlated with a higher incidence of hydronephrosis, but the authors in this study did not identify any significant relationship between the incidence of postoperative hydronephrosis and age in their RALUR-EV cohort.

To avoid postoperative ureteric obstruction, Peters [22] previously recommended placing a ureteral stent in patients after RALUR in an early report soon after the introduction of the robot to the pediatric urology field. Others have recommended the routine use of ureteral stents as a safety mechanism to facilitate ureteral identification and dissection [5—7]. Although no ureteral injuries were observed in this study, the incidence of ureteral injury cited in the literature during RALUR-EV has been reported to be as high as 10% [2,3,13]. Marchini et al. [7] noted that the risk of ureteral injury and obstruction can be minimized by leaving sufficient peri-ureteral tissue and limiting peri-ureteral cautery in accordance with standard open surgical principles. In this study, ureteral stents were not used in all cases that underwent RALUR-EV, as previously described [14]. However, stents may be needed for patients with complex anatomy or in redo cases. Ultimately, the decision of stent use is often based on the surgeon's preference and experience.

This study is not without limitations as it is a retrospective study involving a single surgeon. However, this study provides important information on the natural history of de novo hydronephrosis after RALUR-EV, which has not previously been described in the literature, and how it behaves similar to the open re-implantation experience. The present study also did not assess longitudinal renal growth or the effect on differential function as this will be the focus of future studies.

Conclusions

De novo hydronephrosis after RALUR-EV behaves similarly to de novo hydronephrosis after open ureteral re-implantation. Although de novo hydronephrosis can be present in up to 30% of pediatric patients who undergo RALUR-EV, the hydronephrosis typically self-resolves without the need for intervention in the overwhelming majority of cases at a median time of 7.9 months after surgery. Furthermore, the higher pre-operative VUR grade is correlated with a higher incidence of de novo hydronephrosis after surgery.

Author statements

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Ethical approval

Institutional review board approval was obtained for this retrospective study (protocol H-33575). This study was performed in accordance with the ethical standards of the Declaration of Helsinki and its later amendments.

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Competing interests

C.J.K. is a course director and consultant for Intuitive Surgical.

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