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Minimally invasive reimplantation of the ureter for obstructive megaureter in children: a multicenter study

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ABSTRACT

BACKGROUND: Open reimplantation has been considered the gold standard treatment for pathologies of the ureterovesical segment. In 2000, studies that presented results of the use of laparoscopic and vesicoscopic techniques for ureteral reimplantation in children began to emerge.

AIM: This study aimed to retrospectively analyze the results and complications of minimally invasive interventions in children with obstructive megaureter using various ureteral reimplantation techniques.

MATERIALS AND METHODS: Data from 369 patients (385 ureters) operated on in 12 clinics were included. The median age of the patients was 6 months (4; 7.8), and 39 (10.7%) patients had concomitant pathology of the ureter and bladder. Cohen's vesicoscopic operation, extravesical transverse reimplantation, Lich–Gregoir dissection, and psoas-hitch reimplantation were conducted on 189, 148, 27, and 21 ureters, respectively, and ureteral diameter remodeling was performed in 23.6% of patients. The Mann–Whitney U-test, Kruskal–Wallis test, Fisher's exact test, and binary logistic regression model were used to assess the statistical significance of the studied variables.

RESULTS: The median operation time was 140 minutes (110; 170). Obstruction was eliminated in 375 of 385 ureters (97.4%), regardless of the type of reimplantation, and vesicoureteral reflux developed in 35 (9.1%) ureters. Intraoperative (3) and postoperative complications (22) were present in 0.8% and 6% of cases, respectively. Reoperations were performed in 31 patients (8%). The statistically significant predictors of reimplantation outcome were tunnel orientation, infant age, and ureteral diameter.

CONCLUSIONS: Minimally invasive ureteral reimplantation for obstructive megaureter is safe for children, with efficacy comparable to open surgery, and with few complications.

Keywords: primary obstructive megaureter; minimally invasive reimplantation; laparoscopy; pneumovesicoscopy; children.

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Минимально инвазивная реимплантация мочеточника при обструктивном мегауретере у детей. Мультицентровое исследование

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АННОТАЦИЯ

Актуальность. До последнего времени открытая реимплантация при патологии уретеро-везикального сегмента считалась золотым стандартом. С начала 2000-х годов начали появляться публикации, в которых были представлены результаты применения лапароскопической и везикоскопической техники реимплантации мочеточника у детей.

Цель — провести ретроспективный анализ результатов и осложнений минимально инвазивных вмешательств у детей с обструктивным мегауретером при использовании различных техник реимплантации мочеточника.

Материалы и методы. В исследование были включены данные 369 пациентов (385 мочеточников), оперированных в 12 клиниках. Медиана возраста составила 6 мес. (4; 7,8), у 39 (10,7 %) пациентов имелась сопутствующая патология мочеточника и мочевого пузыря. Была применена везикоскопическая операция Коэна, экстравезикальная поперечная реимплантация, расчленяющая операция Лич–Грегуара и psoas-hitch-реимплантация (на 189, 148, 27 и 21 мочеточниках соответственно), ремоделирование диаметра мочеточника выполняли в 23,6 %. Для оценки статистической значимости изучаемых переменных использовали *U*-тест Манна–Уитни, тест Краскела–Уоллеса, точный критерий Фишера и бинарную логистическую регрессионную модель.

Результаты. Медиана длительности операция составила 140 мин (110; 170). Вне зависимости от вида реимплантации обструкция была устранена в 375 из 385 мочеточников (97,4 %), в 35 (9,1 %) мочеточниках развился пузырно-мочеточниковый рефлюкс. Интраоперационные (3) и послеоперационные осложнения (22) имелись в 0,8 и 6 % случаях соответственно. Повторные операции выполняли у 31 пациента (8 %). Статистически значимыми предикторами исхода реимплантации были ориентация туннеля, грудной возраст детей и диаметр мочеточника.

Заключение. Минимально инвазивная реимплантация мочеточника при обструктивном мегауретере у детей является безопасной с эффективностью, сравнимой с открытыми операциями, и сопровождающаяся небольшим количеством осложнений.

Ключевые слова: первичный обструктивный мегауретер; минимально инвазивная реимплантация; лапароскопия; пневмовезикоскопия; дети.

Как цитировать

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儿童阻塞性巨尿管的最小侵入性输尿管再植。多中心研究

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摘要

现实性。直到近期，开放式输尿管再植被认为是尿道膀胱段病变的金标准。从2000年代初开始，出现了一些关于腹腔镜和膀胱镜技术在儿童输尿管再植中应用的研究成果。

目的。对使用不同输尿管再植技术的儿童阻塞性巨尿管的最小侵入性手术结果和并发症进行回顾性分析。

材料和方法。研究纳入了369名患者（385个输尿管）的数据，这些患者在12个医院接受了手术。中位年龄为6个月（4；7.8），其中39名患者（10.7%）有合并的输尿管和膀胱病变。采用了Cohen膀胱镜手术、膀胱外横向再植、Lih-Gregoire分离手术和腰大肌悬吊再植（分别针对189、148、27和21个输尿管），在23.6%的情况下进行了输尿管直径重建。为评估所研究变量的统计显著性，使用了Mann-Whitney U检验、Kruskal-Wallis检验、Fisher精确检验和二元逻辑回归模型。

结果。140分钟（110；170）。无论再植类型如何，385个输尿管中有375个（97.4%）成功解除阻塞，35个（9.1%）输尿管出现了膀胱-输尿管反流。术中并发症（3例）和术后并发症（22例）分别占0.8%和6%。31名患者（8%）进行了重复手术。统计学上显著的再植结果预测因素包括通道的方向、儿童的年龄和输尿管的直径。

结论。儿童阻塞性巨尿管的最小侵入性输尿管再植是一种安全的手术，其有效性与开放手术相当，并且并发症较少。

关键词：原发性阻塞性巨尿管；最小侵入性再植；腹腔镜；气囊膀胱镜；儿童。

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BACKGROUND

Open ureteral reimplantation has an approximately 90% success rate rate and is the gold standard for the surgical treatment of obstructive megaureter (OM), even in infants [1, 2], despite its invasiveness and long recovery period. However, in recent years, minimally invasive reimplantation using laparoscopic or vesicoscopic approaches has become a prevalent treatment option for children with OM. These approaches are primarily used in pediatric patients aged ⩾1 year, considering the technical complexities associated with reimplantation of an enlarged ureter in infants with a limited bladder volume. Accordingly, reflux reimplantation has been proposed as a preliminary procedure, to be followed by should be followed by anti-reflux reimplantation at an older age [3, 4].

This study aimed to retrospectively analyze the outcomes and complications of minimally invasive procedures in children with OM using different ureteral reimplantation techniques to identify factors that influence their effectiveness.

MATERIALS AND METHODS

A multicenter retrospective controlled non-randomized study was conducted using data from patients who underwent surgical treatment of OM with minimally invasive techniques in 12 centers in Russia and the Republic of Belarus between 2007 and 2022. Of the 369 children enrolled in the study, 366 were included in the analysis, as 3 patients required conversion and were therefore excluded. Additionally, 122 children (33.3%) were diagnosed with intrauterine. Table 1 summarizes the clinical characteristics of the patients.

Urinary tract pathology was identified in 39 (1.1%) children. In nine cases of ectopia of the duplicated ureter and eight instances of ureterovesical segment (UVS) obstruction of one or both ureters, separate reimplantation was performed. In these instances, reimplantation was performed as a single unit. In cases where bladder diverticulum was present, reimplantation was preceded by diverticular resection. Of the 366 patients (385 ureters) included in the study, 25 (6.7%) developed secondary ureteral obstruction. The obstruction occurred in 10 patients after open Lich–Gregoir reimplantation, in 4 patients after open Cohen procedure, in 10 patients after administration of a endoscopic injection of bulking agent for vesicoureteral reflux (VUR), and in 1 patient after attempted ureteral stent placement for pelvic-ureteral segment obstruction. Ureteral stent placement was performed as the initial surgical intervention in 22 cases, whereas puncture nephrostomy was conducted in 12 patients during the preoperative period. Moreover, 99 infants (105 ureters) underwent surgical intervention at a median age of 6 months (range: 4–7.8 months). The indications for ureteral reimplantation were hydronephrosis of Grade III to IV, irrespective of ureter diameter (Fig. 1), and the absence of a beneficial effect of dynamic monitoring with declining renal function or symptomatic obstruction (pain or urinary tract infection).

Ureteral reimplantation was carried out in six children with congenital posterior urethral valve due to the absence of dynamics following transurethral electroresection over a follow-up period of 1–2 years. Table 2 presents the characteristics of ureteral reimplantation methods.

The geometric characteristics of the submucosal tunnel were found to be a significant factor in the classification of the reimplantation techniques. Two distinct groups were identified based on this factor: vertical tunnel orientation (Lich–Gregoir and psoas hitch reimplantation) and transverse (Cohen's and extravesical transverse reimplantation). In 91 cases (23.6%), ureteral diameter reduction was achieved through resection in 40 ureters (40.9%) and Starr ureteral plication in 51 ureters (59.1%). Extracorporeal ureteral remodeling was performed in 13 (14.3%) children. In 72.7% of cases, the reimplanted ureter was stented.

The Mann–Whitney U test and nonparametric Kruskal–Wallis one-factor variance test were used to assess the

Table 1. Patient demographics

Таблица 1. Характеристика пациентов

Parameters	Values
Total number of patients, *n*	366
Total number of ureters	385
Number of patients with bilateral obstructive megoureteritis	19 (5.2 %)
Males	282 (77 %)
Females	84 (23 %)
Age, months	19.7 (10; 48)
Infants	105 (28,4 %)
Ureteral diameter, mm	17 (14; 20)
Number of patients with ureteral doubling	17 (4.4 %)
Number of patients with bladder diverticulum	16 (4,4 %)
Number of patients with congenital posterior urethral valve	6 (1.6 %)

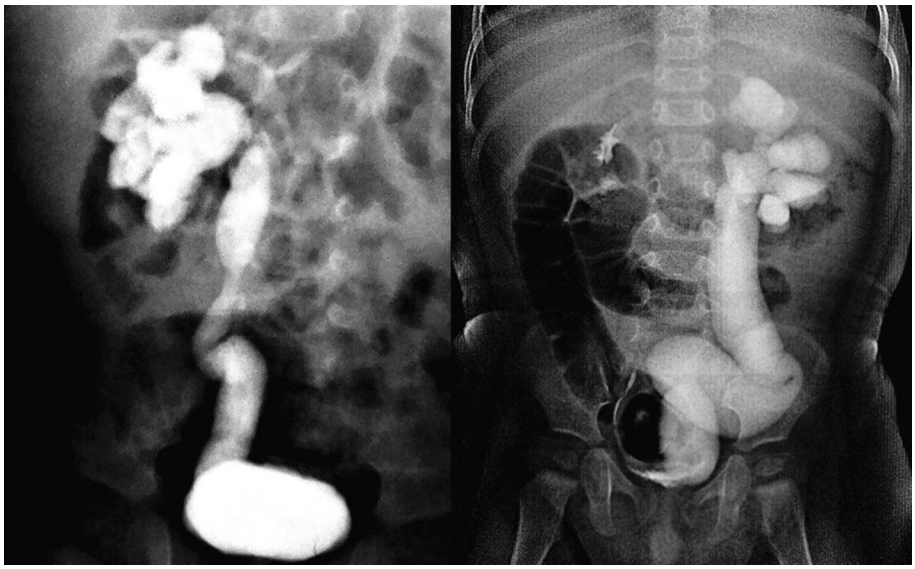

Fig. 1. Urogram images of patients with obstructive megaureter. Grade IV hydronephrosis; ureter diameter: 10 mm on the left and 22 mm on the right
Рис. 1. Урограммы пациентов с обструктивным мегауретером. Гидронефроз IV степени, диаметр мочеточника 10 мм слева и 22 мм справа

statistical significance of the variables studied in the case of continuous variables with a distribution other than normal. A binary logistic regression model with odds ratio (OR) and confidence interval (CI) was used to study the factors that could influence the outcome of reimplantation. The Fisher's exact test (two-sided significance) was employed to evaluate discrepancies in binary qualitative variables. For comparative analysis of reimplantation efficacy, the results were coded as 1 (positive result, indicating a decrease in the degree of hydronephrosis and ureter diameter) and 0 (negative result, indicating postoperative VUR or ureter restenosis).

RESULTS

A comparative analysis of the association between the age of patients and minimally invasive reimplantation methods revealed that intravesical reimplantation was employed less frequently in infants than other methods (RR: 0.3; CI: 0.2–0.5; $p < 0.001$). No significant differences were observed in the duration of surgery between infants (130 [100; 160]) and patients older than 1 year (140 [110; 180], $p = 0.7$). Ureteral diameter modeling was performed in 23.6% of patients, which is significantly lower than vesicoscopic reimplantation

Table 2. Characteristic of the minimally invasive reimplantation
Таблица 2. Характеристика минимально инвазивных реимплантаций

Parameters	Reimplantation method			
	Cohen's intravesical	Transverse extravesical	Lich–Gregoir's method	Psoas hitch
Number of ureters	189	148	27	21
Age, months	30 (14; 60)	13,4 (6; 36)	12 (6; 60)	12 (3; 42)
Proportion of patients aged ⩽12 months, %	16.4	41.6	36	42.9
Ureteral diameter, mm	14 (11.8; 16,5)	17 (14; 20)	16 (12; 20)	18 (13; 20)
Number of ureters remodeled	20	46	16	9
Surgery time, minutes	135 (110; 170)	140 (111; 180)	150 (140; 175)	139 (109.3; 182)
Associated pathologies				
Number of patients with posterior urethral valve	6	–	–	–
Number of patients with ureteral doubling	5	10	–	2
Number of patients with bladder diverticulum	14	2	–	–

(10.5% vs. 36.6%; OR: 0.2; CI: 0.1–0.4; $p < 0.001$). Furthermore, the diameter of remodeled ureters (18 mm [15; 20]) was significantly greater than that of ureters reimplanted without remodeling (15 mm [11; 19], $p = 0.001$). The use of oblation was more prevalent in infants (33.7% vs. 20%; OR: 2.0; CI: 1.2–3.7; $p = 0.009$), although no significant difference was found in ureteral diameters between infants and children older than 1 year [16 mm (12; 20) and 17 mm (13.3; 20.0), respectively, $p = 0.8$]. This resulted in a significant increase in the duration of surgery compared to reimplantation without modeling (150 min [125; 179] and 135 min [108.8; 170], respectively; $p = 0.017$).

The overall efficiency of minimally invasive reimplantations was 87.8%. Table 3 presents the comparative efficiency of reimplantations depending on the methods used.

As shown in Table 3, Cohen's reimplantation and extravesical transverse reimplantation had higher frequency of positive results. In the group of patients, regardless of the type of reimplantation, 36 (9.4%) cases of VUR and 10 (2.6%) cases of UVS restenosis were detected post-surgery. Stenosis was localized at the site of detrusor defect suture in the Cohen procedure and at the ureteral entry into the tunnel in the Lich–Gregoir and extravesical transverse reimplantation procedures (Fig. 2).

A binary logistic regression model was used to determine factors influencing reimplantation performance and showed that tunnel orientation, infant age, and ureteral diameter were significant predictors of reimplantation outcome (Table 4).

Thus, the transversely oriented tunnel resulted in 89.8% positive results compared to 74.5% for the vertical orientation. Regardless of surgical technique, reimplantation was more effective in older children (91.8%) than in infants (80.8%) (Table 5).

Comparative analysis of the efficacy of transverse tunnel orientation in infants revealed that the positive results (86%) were not significantly different from that in older children (92%, Fisher's exact test, $p = 0.1$). When the ureter was severely dilated (diameter > 10 mm), the efficacy of reimplantation was lower (89.8%) compared to when the ureter diameter was <10 mm (93.9%). However, this relationship was only evident in infants, in whom the efficacy was significantly lower with marked dilatation (69.6% vs. 95.7%, $p = 0.02$). In infants, ureteral diameter did not affect the outcome of reimplantation when remodeling was performed ($p = 0.37$, Fisher's exact test). A similar pattern was observed in children older than 1 year ($p = 0.22$, Fisher's exact test).

Intraoperative complications were determined in three patients (0.8%), two of whom underwent psoas hitch and one underwent Cohen's procedure and experienced a divergence of the bladder mucosa during the formation of the submucosal tunnel. In all cases, the defect was sutured with knotted sutures. Postoperative complications were detected in 22 patients (6%). Of these, 12 were after Cohen's reimplantation (6.4%), 6 (4.1%) after extravesical transverse reimplantation, 3 (14.3%) after psoas hitch reimplantation, and 1 (3.7%) after Lich–Gregoir dissecting reimplantation. The incidence of postoperative complications was not significantly associated with the method of surgery ($p = 0.39$, Kruskal–Wallis test). Transient ureteral obstruction was diagnosed in nine ureters (2.3% of cases),

Table 3. Effectiveness of minimally invasive reimplantation depending on the method of the surgery

Таблица 3. Эффективность минимально инвазивных реимплантаций в зависимости от метода операции

Type of reimplantation	Number of ureters, *n*	Postoperative complications, *n*		Efficiency, %
		Vesicoureteral reflux	Restenosis	
Cohen's intravesical reimplantation	189	8 (2.1 %)	5 (2.7 %)	93.1
Extravesical transverse reimplantation	148	19 (12.8 %)	2 (1.4 %)	85.8
Lich–Gregoir's surgery	27	3 (11.1 %)	3 (11.1 %)	77.8
Psoas hitch reimplantation	21	5 (23.8 %)	0	76.2

Table 4. Logistic regression of factors associated with minimally invasive reimplantation

Таблица 4. Логистический регрессионный анализ факторов, влияющих на результат минимально инвазивной реимплантации

Independent variables	Odds ratio	Confidence interval	*p*
Reimplantation method	1.3	0.8–1.9	0.5
Tunnel orientation	3.9	1.4–11.3	0.012
Ureteral remodeling	0.9	0.4–2.0	0.79
Infants	0.4	0.2–0.8	0.018
Ureteral diameter	3.6	1.2–11.0	0.025
Associated pathologies	1.4	0.39–4.7	0.8

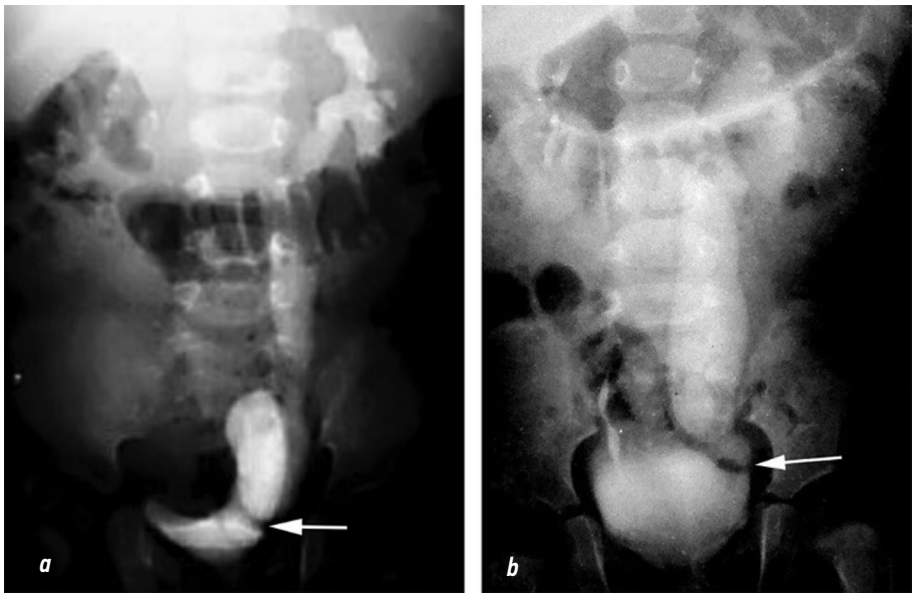

Fig. 2. Obstruction site (arrows) after Cohen reimplantation (*a*) and Lich–Gregoir reimplantation (*b*)
Рис. 2. Зона стеноза (указана стрелками) после реимплантации по Коэну (*a*) и после операции Лич–Грегуара (*b*)

six of which had been stented intraoperatively and three had been reimplanted using the drainless method. In five cases, stent reinsertion was required, whereas puncture nephrostomy was performed in one case. The obstruction resolved spontaneously in three patients. Seven patients (1.8%) experienced postoperative complications in the form of febrile infection. Antibacterial therapy was unsuccessful in two cases, necessitating puncture nephrostomy and ureteral stenting, respectively, to ensure permanent urine diversion and control the inflammatory process. Two patients were diagnosed with dynamic ileus, and two cases involved suture material encrustation and one case presented with macrohematuria with urinary leakage into the Retzius space and formation of a vesicoureteral fistula. In 8% of cases (n = 31), multiple surgical procedures were performed. Table 6 presents the details of these interventions.

In 24 cases of postoperative VUR, correction was performed with the introduction of a volume-forming drug, which successfully eliminated the condition in 94% of cases, while in 6%, there was a decrease in the degree of VUR. In six patients (six ureters), minimally invasive reimplantation was performed in one case and open reimplantation in was performed the other five cases. The remaining 11 patients did not require further intervention due to the resolution of first-degree VUR or the absence of recurrent episodes without urinary tract infection. In 10 cases of postoperative UVS obstruction, two patients underwent nephroureterectomy because of the progression of nephrosclerosis and a decline in renal function to below 10%. The remaining pediatric patients underwent repeated reconstructive surgeries, six of which were performed using minimally invasive techniques. Two cases of ureteral obstruction in the area of ureteral tunnel entry were treated with partial detrusorrhaphy (ureterolysis),

Table 5. Results of minimally invasive reimplantation depending on the age and surgery method
Таблица 5. Результаты минимально инвазивных реимплантаций в зависимости от возраста и метода операции

Type of reimplantation	Age, months	*n*	Vesicoureteral reflux, *n*	Restenosis, *n*
Cohen's intravesical reimplantation	⩽12	29	4 (13.8 %)	1 (3.5 %)
	>12	160	4 (2.5 %)	5 (3.1 %)
Extravesical transverse reimplantation	⩽12	58	9 (15.5 %)	1 (1.7 %)
	>12	90	9 (10 %)	0
Lich–Gregoir's procedure	⩽12	9	1 (11.1 %)	2 (22.2 %)
	>12	18	3 (16.7 %)	1 (5.6 %)
Psoas hitch reimplantation	⩽12	9	3 (33.3 %)	0
	>12	12	2 (16.7 %)	0
Total	⩽12	105	17 (16.2 %)	3 (2.9 %)
	>12	280	18 (6,4 %)	7 (2.5 %)

Table 6. Characteristics of the repeat surgery
Таблица 6. Характеристика повторных операций

Surgeries	*n*	Positive results, *n*
Surgeries for vesicoureteral reflux		
Injection of volumizing material	17	16
Psoas hitch reimplantation	4	3
Extravesical transverse reimplantation	1	1
Lich–Gregoir tunnel extension	1	1
Open reimplantation	1	1
Total	24	22
Surgeries for ureterovesical segment restenosis		
Cohen's procedure	2	2
Nephrectomy	2	2
Ureterolysis	2	2
Psoas hitch reimplantation	1	1
Open reimplantation	2	2
Transureteroureterostomy	1	1
Total	10	8

whereas one patient underwent transureteroureterostomy because of a significant ureteral length deficit.

DISCUSSION

In 2006, Ansari et al. [5] published the inaugural account of laparoscopic correction of OM in a pediatric patient, wherein the ureter width was intracorporeally modeled and subsequently reimplanted using the Lich–Gregoir method. Vesicoscopic reimplantation in OM was first employed by Kutikov et al. in 2006. One of two patients who underwent surgery developed neoureteral stenosis. The authors concluded that vesicoscopic reimplantation is a technically challenging procedure in young children with small bladder volumes. In 2012, Abraham et al. [7] presented their experience with laparoscopic reimplantation of 13 ureters using intracorporeal modeling and reimplantation using the Lich–Gregoir method. The mean age of the pediatric participants was 8 years, and the mean ureteral diameter was 14–22 mm. One patient was diagnosed with first-degree VUR during follow-up examination. In 2013, Bondarenko [8] reported a case series of extravesical transverse reimplantation with intracorporeal ureteral modeling. The cases of 10 patients with OM were presented, four of whom were infants with ureter diameters of 25–30 mm. One patient developed VUR as evidenced by follow-up studies. In subsequent years, studies in which a robot-assisted technique was employed for minimally invasive reimplantation began to emerge. In 2014, Fu et al. [9] published the results of a case series involving the use of a robotic technique in four patients with OM. They employed the Lich–Gregoir technique and Ricardo nipple technique, rejecting the formation of a submucosal tunnel. Irrespective of the surgical technique employed, no evidence of VUR development was noted following surgery. In a separate study, Rappaport et al. [10] used robotic extravesical transverse reimplantation in 48 pediatric patients, achieving a 97% positive outcome rate. The theoretical model of anti-reflux mechanism proposed by Villanueva et al. [11] demonstrated that the orifice configuration plays a more significant role in anti-reflux protection than the submucosal tunnel. In 2023, Babu [12] proposed the laparoscopic extravesical invagination of the ureter as a treatment option for UVS obstruction, which may result in the formation of a Ricardo "papilla" prolapsing into the bladder lumen. Eleven patients who did not exhibit VUR on control cystograms underwent surgical intervention. Gander et al. [13] and He et al. [14] distinguished between the classical technique and invaginated distal ureter, which was first described by Shanfield [15] in the upper or lower part of a vertically formed tunnel by Lich–Gregoir. In all cases, obstruction was resolved without the presence of VUR following surgical intervention. The authors highlight the simplicity and reliability of the proposed technique. As indicated by several studies [7, 16, 17], laparoscopic extravesical ureteral reimplantation using the Lich–Gregoir method in children with OM aged over 1 year yields positive results in 86%–92% of cases. Pirogov and Sisonov [18] used vesicoscopic reimplantation with Cohen's technique without ureteral modeling in children with OM, which had a positive result in 95.8% of cases. Analysis of results of other studies showed that vesicoscopic reimplantation using Cohen's technique with ureteral modeling in OM induces 95%–100% positive outcomes [19–22].

In most of these studies, the children who underwent surgery were older than 1 year. The feasibility of minimally invasive reimplantation in infants with OM has not been studied; however, there are studies showing successful open reimplantation in infants. For example, Jude et al. [1] presented data on successful reimplantation using the Cohen method in infants with OM in 97% of cases. One patient experienced restenosis, and 15% had postoperative complications, such as urinary tract infections. Unfortunately, the present study does not include data on on follow-up voiding cystograms. In a sample of children with OM who underwent surgery across 12 centers using different reimplantation methods, restenosis was reported in 2.6% of cases, indicating that it is an unlikely or rare event in a single trial. Postoperative complications occurred in 6% of patients, with 2.3% experiencing transient ureteral obstruction, which can also occur after open reimplantation. In a stusdy by Babajide et al. [23], transient obstruction was observed in 30.8% of cases following open reimplantation and 27.6% following robot-assisted reimplantation. The average recovery time for the upper urinary tract was 7 months following open reimplantation and 3.7 months after robot-assisted reimplantation. It is well-established that adjusting ureter diameter during OM surgeries is a standard procedure to ensure a 5:1 ratio of tunnel length to ureter diameter, as per the Paquin rule. Notably, while the results were worse in infants in the total sample, in cases of reimplantation using transverse tunnel orientation, the positive results in both age groups were comparable and not significantly different. It is well-established that modeling of ureter diameter in OM surgeries is a standard procedure to ensure a 5:1 ratio of tunnel length to ureter diameter, according to the Paquin rule. The results of the present study indicate that ureteral shoeing has no effect on the outcome of reimplantations in all age groups. The retrospective nature of our study represents a limitation, underscoring the need for further investigation through a randomized study design. This approach would more accurately ascertain the causal relationship between the factors influencing the outcomes of minimally invasive reimplantation.

CONCLUSIONS

Minimally invasive reimplantation is a safe and effective surgical treatment for OM in pediatric patients. Additionally, it is technically feasible in young children, even in the presence of concomitant bladder and ureteral pathology.

ADDITIONAL INFO

Authors' contribution. All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study. Personal contribution of each author: N.R. Akramov — concept development, research design development, surgical interventions, article editing; Yu.V. Baranov — conducting surgical interventions, editing the article; S.G. Bondarenko — concept development, research design development, surgical interventions, evaluation of results, collection and analysis of literary sources, statistical data processing, preparation and writing of the text of the article, editing of the article; V.I. Dubrov — research design development, surgical interventions, article editing; I.M. Kagantsov — concept development, research design development, surgical interventions, article editing; S.A. Karpachev — conducting surgical interventions, editing the article; M.I. Kogan — scientific consultant of the study, editing the text of the article; G.I. Kuzovleva — literature review, collection and analysis of literary sources, conducting surgical interventions, writing the text of the article and preparing the article for publication; A.V. Pirogov, D.E. Sablin, O.S. Shmyrov — performing surgical interventions, editing the article; Yu.E. Rudin — concept development, surgical interventions, editing of the article; V.V. Sizonov — conducting surgical interventions, preparing and writing the text of the article, editing the article.

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Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией. Личный вклад каждого автора: Н.Р. Акрамов — разработка концепции и дизайна исследования, проведение оперативных вмешательств, редактирование статьи; Ю.В. Баранов — проведение оперативных вмешательств, редактирование статьи; С.Г. Бондаренко — разработка концепции и дизайна исследования, проведение оперативных вмешательств, оценка результатов, сбор и анализ литературных источников, статистическая обработка данных, подготовка и написание текста статьи, редактирование статьи; В.И. Дубров — разработка дизайна исследования, проведение оперативных вмешательств, редактирование статьи; И.М. Каганцов — разработка концепции и дизайна исследования, проведение оперативных вмешательств, редактирование статьи; С.А. Карпачев — проведение оперативных вмешательств, редактирование статьи; М.И. Коган — научный консультант исследования, редактирование текста статьи; Г.И. Кузовлева — обзор литературы, сбор и анализ литературных источников, проведение оперативных вмешательств, написание текста статьи и подготовка статьи к публикации; А.В. Пирогов, Д.Е. Саблин, О.С. Шмыров — проведение оперативных вмешательств, редактирование статьи; Ю.Э. Рудин — разработка концепции, проведение оперативных вмешательств, редактирование статьи; В.В. Сизонов — проведение оперативных вмешательств, подготовка и написание текста статьи, редактирование статьи.

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