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ORIGINAL ARTICLE

Laparoscopic and robotic-assisted repair of retrocaval ureter in children: a multi-institutional comparative study with open repair

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Abstract

Purpose This retrospective study aimed to report a multi-institutional experience with laparoscopic and robotic-assisted repair of retrocaval ureter in children and to compare outcome of minimally invasive surgery (MIS) with open repair.

Methods The records of all children, who underwent MIS and open repair of retrocaval ureters in six international pediatric urology units over a 5-year period, were retrospectively collected. Data were grouped according to the operative approach: a laparoscopic group (G1) included five patients, a robotic-assisted group (G2) included four patients, and an open group (G3) included three patients. The groups were compared in regard to operative and postoperative outcomes.

Results At follow-up, all patients (one G1 patient after redo-surgery) reported complete resolution of symptoms and radiologic improvement of hydronephrosis and obstruction. In regard to postoperative complications, one G1 patient developed stenosis of anastomosis and needed re-operation with no further recurrence (IIIb Clavien). G2 reported the lowest average operative time (135 min) compared to G1 (178.3 min) and G3 (210 min). MIS (G1–G2) reported a significantly better postoperative outcome compared to open repair (G3) in terms of analgesic requirements, hospitalization, and cosmetic results.

Conclusions The study outcomes suggest that MIS should be the first choice for retrocaval ureter because of the minimal invasiveness and the better cosmetic outcome compared to open surgery. Furthermore, our results showed that robotic-assisted reconstruction was technically easier, safer, and quicker compared to laparoscopic repair, and for these reasons, it should be preferentially adopted, when available.

Keywords Retrocaval ureter · Robotics · Laparoscopy · Children · Complications

Introduction

Retrocaval ureter is a rare congenital anomaly secondary to the abnormal persistence of the right subcardinal vein positioned ventral to ureter in the definitive inferior vena cava (IVC) [1, 2]. The abnormality usually presents in the third or fourth decade of live with lumbar pain, urinary tract infections, or secondary urolithiasis due to low-grade obstruction from the retrocaval part of the ureter. Reports have suggested that this abnormality can also present in the pediatric age with similar symptoms [1, 2]. Two types of the anomaly have been described, based on radiologic appearance. In type I or "low loop" form, the dilated proximal ureter descends normally to the level of the third or fourth lumbar vertebra, and then curves back in the shape of a reverse "J" to pass behind the IVC. This type is more common and usually causes moderate-to-severe hydronephrosis. Type II or "high loop" form has a sickle-shaped ureteral curve, as

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the renal pelvis and upper ureter pass behind the IVC at the level of, or just above the uretero-pelvic junction, and are almost horizontal. This type is rare and generally does not cause obstruction [3, 4]. Patients with symptoms and/or with moderate-to-severe hydronephrosis resulting from ureteral obstruction are recommended to have surgical correction, which involves transection and relocation of the ureter anterior to the IVC [5]. The Anderson–Hynes dismembered pyeloplasty with transposition of the ureter in front of the vena cava was originally described for treatment of this anomaly [6]. In the last years, minimally invasive surgical management has emerged as the method of choice for repair of retrocaval ureter. The correction of this anomaly with a laparoscopic approach has been described. Variations in the reported laparoscopic techniques include transperitoneal laparoscopic repair, retroperitoneal laparoscopic repair, and single-port laparoscopic repair [7, 8]. More recently, the use of robotic-assisted surgery has been described for a number of urological procedures in children, including correction of retrocaval ureter [9, 10]. The use of the surgical robot facilitates the most challenging part of the procedure, which is intra-corporeal suturing and knotting. However, there is no agreement among pediatric urologists about the best surgical approach to be adopted for repair of symptomatic cases.

This retrospective study aimed to report a multi-institutional experience with laparoscopic and robotic-assisted repair of retrocaval ureter in children and to compare outcome of minimally invasive surgery (MIS) with conventional open repair.

Materials and methods

The records of all children, who underwent repair of retrocaval ureters using MIS and open approach in six international pediatric urology units over a 5-year period (January 2011–January 2016), were retrospectively collected. A total of 12 patients (11 boys and 1 girl) from all participating centers were included in the study. The average patients' age at presentation was 10.3 years (range 3–16), and the average weight was 31.6 kg (range 20–45). The main presentation symptom was right flank pain in all patients excluded one who was asymptomatic, and the pathology was incidentally discovered during an abdominal ultrasound performed for other indications. Preoperative work-up included abdominal ultrasound (US) followed by uro-magnetic resonance imaging (MRI), and Mag3 renogram in all patients, whereas retrograde ureteropyelogram was performed in only three patients (Fig. 1). Postoperative follow-up was performed with renal ultrasound (US) 1 month, 6 months after surgery, and then every 6 months for 2 years. A Mag3 renogram was performed 3 months after surgery in all patients.

Fig. 1 Right retrograde ureteropyelogram, showing a reverse "J"-shaped right uretero-pelvic region, suggestive for a type I retrocaval ureter

Table 1 Patients' demographics in G1–G2–G3

Patients' demographics	G1 Laparoscopic group ($n=5$)	G2 Robotic-assisted group ($n=4$)	G3 Open group ($n=3$)
Male ($n=$)	5	4	2
Female ($n=$)	0	0	1
Average age (years)	7.5	15.5	8.1
Average weight (kg)	25.4	42	27.6

Data were grouped according to the operative approach: a laparoscopic group (G1) included five patients (average age 7.5 years), a robotic-assisted group (G2) included four patients (average age 15.5 years), and an open group (G3) included three patients (average age 8.1 years). Patients' demographics are reported in Table 1. In laparoscopic group (G1), 4/5 procedures were accomplished using transperitoneal route and 1 procedure using retroperitoneal approach. The surgical procedures were performed by a single expert surgeon in each participating center. The choice of robotic-assisted over laparoscopic approach was first determined by availability of the robot. However, the indications for robotic-assisted repair were restricted to patients older than 2 years of age and of a weight > 20 kg. The three groups were compared in regard to operative and postoperative outcome. Primary outcome parameters measured included operative success rate, intra-operative and postoperative complications and re-operations. The success of surgery was defined by postoperative resolution of symptoms, reduction of anterior–posterior pelvic diameter (APD) on ultrasound and relief of obstruction on Mag3 renogram. Secondary outcome parameters included operative time, length of hospital stay, cosmetic results, analgesic requirements during inpatient stay, time to full oral feeding, time of bladder catheterization and time of ureteral stenting. The cosmetic outcome was evaluated using the Vancouver Scar Scale (VSS). This scale has four separate domains: vascularity, pigmentation, pliability, and height. The maximum score possible was 14, indicating the worst possible scar result, with a score of 0 indicating normal skin. The cosmetic outcome was scored by the same surgeon at each center at the last follow-up appointment, and these data were collected prospective. The protocol envisaged for postoperative analgesia included Paracetamol (<10 kg: 7.5 mg/kg; >10 kg: 15 mg/kg) and Tramadol (1 mg/kg/dose) intravenous. In case of vomiting, Zofran 0.2 mg/kg was administered. The drugs were administered every 8 h and with a 2-h interval between Paracetamol and Tramadol in the first 48 h.

The study received the appropriate Institute Review Board (IRB) approval at each participating center.

Surgical technique

Open repair

An extraperitoneal incision was made at the 12th rib and on exploration a dilated right renal pelvis and proximal ureter was found. The dilated proximal ureter curved medially and then passed behind the IVC with distal ureter appearing of normal caliber. The ureter was divided and brought anterior to IVC and an end-to-end ureteroureterostomy was fashioned over a JJ stent using running suture. A suction drain was left at the end of surgery.

Laparoscopic repair

Laparoscopic repair was performed via transperitoneal or retroperitoneal route.

In the transperitoneal approach, after positioning of an indwelling bladder Foley catheter, patients were placed in semilateral position. Three trocars were used: one 5- or 10-mm port placed umbilically for the 30° optic and other two 5-mm working ports, one at right fossae and the other supraumbilical. The ureter was completely freed by mobilizing the entire ascending colon and sectioned at the retrocaval segment. The retrocaval segment was excised in 3/4 patients and incorporated into the repair in 1/4 patients, according to the surgeon's preference. Then, an end-to-end ureteroureterostomy was performed using a 5/0 resorbable interrupted suturing anterior to the vena cava over a JJ stent. A suction drain was left at the end of surgery.

In the retroperitoneal approach, after positioning of an indwelling bladder Foley catheter, patients were placed in a full lateral decubitus position. Three trocars were used: one 5- or 10-mm port placed below the 12th rib in the posterior axillary line for the 30° optic and other two 5-mm working ports, one inserted below the costal margin in the anterior axillary line and the other inserted 2-cm above the superior border of the iliac crest in the midaxillary line. After the Gerota's fascia was incised longitudinally and the perirenal fat was dissected to reveal the posterior surface of the mid and lower pole of the kidney, the dilated renal pelvis and the upper ureter were fully mobilized. Dissection proceeded downward along the proximal dilated ureter and then the IVC was identified. The upper ureter changed its way and passed behind the IVC, and then followed the lower ureter. The lower ureter was mobilized enough to facilitate a tension-free ureteroureteral anastomosis. The upper ureter was transected at the level of the retrocaval segment that was incorporated into the repair. Then, an end-to-end ureteroureterostomy was performed using a 5/0 resorbable interrupted suturing anterior to the vena cava over a JJ stent. A suction drain was left at the end of surgery.

Robotic-assisted repair

Robotic-assisted repair was performed via transperitoneal route in all cases. After a bladder Foley catheter was inserted, the child was secured in a lateral decubitus position exposing the affected side. An infraumbilical 12-mm camera port was placed using a Hasson technique to obtain the pneumoperitoneum. A 30° camera was introduced into the peritoneal cavity. Under direct vision, two 8-mm working ports were placed in the midclavicular line triangulating approximately 7 cm apart from the umbilical port and 10 cm apart from each other. A fourth 5-mm laparoscopic trocar was placed for the bedside assistant surgeon. The da Vinci Robot system was then docked in the standard fashion. After mobilization of the colon and incision of Gerota's fascia, the ureteral defect was meticulously isolated with minimal devascularization and sectioned at the retrocaval segment. The retrocaval segment was excised in all patients. Then, an end-to-end ureteroureterostomy was performed using a 5/0 resorbable running suturing anterior to the vena cava over a JJ stent. A suction drain was left at the end of surgery.

Operative details of the different groups are reported in Table 2.

Results

The average length of follow-up was 44 months in G1, 56 months in G2, and 58 months in G3. At follow-up evaluation, all patients (one G1 patient after redo-surgery) reported

Table 2 Operative details in G1–G2–G3

Operative details	G1 Laparoscopic group ($n=5$)	G2 Robotic-assisted group ($n=4$)	G3 Open group ($n=3$)
Excision of the retrocaval segment ($n=$)	3/5 (60%)	4/4 (100%)	3/3 (100%)
Inclusion of the retrocaval segment into the repair ($n=$)	2/5 (40%)	0	0
Use of interrupted stitches for ureteral anastomosis ($n=$)	5/5 (100%)	0	0
Use of running suture for ureteral anastomosis ($n=$)	0	4/4 (100%)	3/3 (100%)

complete resolution of symptoms, significant improvement of hydronephrosis on postoperative US controls and relief of obstruction on postoperative Mag3 renogram. No intra-operative complications occurred in all cases. In regard to postoperative complications, one G1 patient, who underwent laparoscopic retroperitoneal repair, developed postoperatively stenosis of the retrocaval segment incorporated into the primary ureteroureterostomy and needed re-operation with no further recurrence (IIIb Clavien).

All laparoscopic and robotic-assisted procedures were completed in MIS without conversions to open surgery. The robotic-assisted repair (G2) reported the lowest average operative time (135 min) compared to laparoscopic (G1) (178.3 min) and open repair (G3) (210 min). The ureteral JJ stent was removed under a short-duration anesthesia at mean 26 days postoperatively. Postoperative outcome was significantly better following MIS compared to open repair in terms of analgesic requirements (G1 = 40 min and G2 = 36 min vs G3 = 66 min), hospital stay (G1 = 3.6 days and G2 = 3 days vs G3 = 5.5 days), and cosmetic results (average VSS score G1 = 0.8 and G2 = 1.5 vs G3 = 3.2). No significant difference between the three groups was found in regard to: average time to full oral feeding (G1 = 24 h; G2 = 24 h; G3 = 26 h), average time of bladder catheterization (G1 = 40 h; G2 = 48 h; G3 = 48 h), and average time of ureteral stenting (G1 = 20 days; G2 = 28 days; G3 = 30 days).

All outcome parameters are reported in Table 3.

A chart showcasing each case variables, including type of retrocaval ureter, indications for surgery, type of surgical approach, type of anastomosis, excision of the retrocaval segment, pathology of the excised segment, stenting duration, and follow-up is reported in Table 4. The patient with failed laparoscopic repair presented pre-operatively with recurrent colicky flank pain, and he was diagnosed a type I retrocaval ureter. At primary surgery, the retrocaval segment of the ureter was preserved, since it had a grossly normal appearance without obvious stenosis under laparoscopic magnification and it was incorporated into the primary ureteroureterostomy. The first US control, performed at 1 month postoperatively, showed a mild reduction of hydronephrosis compared to preoperative US (15 mm vs 22 mm). The child presented, at 2 months postoperatively, with the same flank pain reported before surgery, the repeated US showed a marked right hydronephrosis (APD 32 mm), and the Mag3 renogram confirmed an obstructive pattern. Therefore, he was re-operated in laparoscopy, the anastomotic tract appeared markedly stenotic, and it was removed; then, an end-to-end ureteroureterostomy was fashioned over a JJ stent. The postoperative course was uneventful, the JJ stent was removed after 4 weeks, and at the follow-up, the patient is being symptom-free and with no signs of obstruction at radiologic evaluation until now. Pathology processing of the excised portion of the ureter at the time of redo-surgery revealed signs of chronic inflammation and fibrosis.

Discussion

This retrospective study reported a multi-institutional experience with laparoscopic and robotic-assisted repair of retrocaval ureter in children and compared the outcome of minimally invasive surgery (MIS) with conventional open repair. The main study's findings demonstrated that the success rate was excellent for all approaches, since, at follow-up, all patients (one patient of laparoscopic group after redo-surgery) reported complete resolution of symptoms and radiologic improvement of hydronephrosis and obstruction. However, MIS reported a significantly better postoperative outcome in terms of lower analgesic requirements, shorter hospitalization, and better cosmetic results compared to open approach. In addition, MIS resulted significantly faster compared to open approach with the lowest operative time reported by robotic-assisted repair.

Open retroperitoneal ureterostomy has been the treatment of choice for many years for the surgical repair of a retrocaval ureter [5, 11]. With advances and increasing experience in laparoscopic technique and associated technology, the laparoscopic correction of retrocaval ureter has become

Table 3 Outcome parameters in G1–G2–G3

Outcome parameters	G1 Laparoscopic group ($n=5$)	G2 Robotic-assisted group ($n=4$)	G3 Open group ($n=3$)
Postoperative resolution of clinical symptoms ($n=$)	5/5 (100%)	4/4 (100%)	3/3 (100%)
Postoperative reduction of APD on US ($n=$)	5/5 (100%)	4/4 (100%)	3/3 (100%)
Postoperative relief of obstruction on Mag3 renogram ($n=$)	5/5 (100%)	4/4 (100%)	3/3 (100%)
Average preoperative APD (mm)	24.9	25.5	23.8
Average postoperative APD (mm)	8.5	9.7	10.1
Intra-operative complications ($n=$)	0	0	0
Postoperative complications ($n=$)	1/5 (20%)	0	0
Re-operations ($n=$)	1/5 (20%)	0	0
Average operative time (min)	178.3	135	210
Average time to full oral feeding (h)	24	24	26
Average analgesic requirement (h)	40	36	66
Average time of bladder catheterization (h)	40	48	48
Average time of ureteral stenting (days)	20	28	30
Average length of hospital stay (days)	3.6	3	5.5
Average Vancouver Scar Scale (VSS) score	0.8	1.5	3.2

APD anterior–posterior pelvic diameter, *US* ultrasound

a safe and effective alternative to open techniques [12, 13]. Regarding the operative approach, the transperitoneal route was the method of choice in most published cases [8, 12–14] and the retroperitoneal approach was used less [7, 15, 16]. Some authors reported that transperitoneal laparoscopic management was less time-consuming and relatively easier than retroperitoneoscopic suturing, due to a larger working space and a better exposure of the ureter [4, 8]. On the contrary, other authors reported that retroperitoneal approach has more advantages compared to laparoscopic technique, since it requires little dissection and affords rapid and direct access to the renal pelvis and ureter without violating the peritoneal cavity [17]. However, each approach has its own advantages and disadvantages and surgeons may have their own preferences [18]. In our personal experience, we prefer transperitoneal approach, as it provides good working space for intra-corporeal suturing. Laparoscopic ureteroureterostomy is a technically challenging and lengthy surgical procedure, with a proficiency required for intra-corporeal suturing and knotting [17, 19]. More recently, robotic-assisted repair has been reported for treatment of retrocaval ureter [9, 10]. With its inherent advantages over conventional laparoscopy, robotic surgery provides an excellent three-dimensional view of the operative field, increases manual dexterity for the dissection, and improves intra-corporeal suturing and knotting [20]. These advantages have been confirmed by our results: in fact, the robotic-assisted repair reported the lowest average operative time (135 min) compared to laparoscopic (178.3 min) and open repair (210 min). However, considering the rarity of the pathology and the steep learning curve of MIS due to the high technical challenge of the procedure, we believe that results can be optimized referring the patients with this rare pathology in pediatric centers with a strong experience in MIS. The better outcome in terms of operative time reported by MIS over open repair in our series was mainly related to the high experience of participating centers. In fact, all procedures were performed by a single expert surgeon in each participating center. Each expert surgeon had more than 20 years of experience in laparoscopic surgery and at least 5 years of experience in robotic surgery and performed over 500 MIS procedures per year.

Analyzing the current literature, there is no consensus about the best management of the retrocaval segment [21]. In a recent paper focused on laparoscopic retroperitoneal approach, the authors reported that the retrocaval segment of the ureter was preserved when it had a grossly normal appearance without obvious stenosis under laparoscopic magnification, whereas an obvious stenotic retrocaval segment of the ureter was excised [17]. However, in their series, the strategy used for management of the retrocaval segment of the ureter did not show any impact on the postoperative outcome [17]. In our series, only one stenotic complication was reported in laparoscopic group. Analyzing the variables of the failed laparoscopic case (Table 4), we noticed

Table 4 Chart showcasing each case variables

Patient number	Type of retrocaval ureter	Indication for surgery	Approach	Anastomosis	Excision of retrocaval segment	Pathology of the excised segment	Stenting duration (days)	Follow-up
1	Type I	Recurrent colicky pain	Laparoscopic Transperitoneal	Interrupted 5-0 polyglactin	Yes	Chronic inflammation Fibrosis	22	No obstruction
2	Type I	Loss of renal function	Laparoscopic Transperitoneal	Interrupted 5-0 polyglactin	No	N/A	25	No obstruction
3	Type I	Recurrent colicky pain	Laparoscopic Transperitoneal	Interrupted 5-0 polyglactin	Yes	Chronic inflammation	28	No obstruction
4	Type I	Worsening hydronephrosis	Laparoscopic Transperitoneal	Interrupted 5-0 polyglactin	Yes	Chronic inflammation	26	No obstruction
5	Type I	Recurrent colicky pain	Laparoscopic Retroperitoneal	Interrupted 5-0 polyglactin	No (primary) Yes (re-operation)	Chronic inflammation Fibrosis	17	Stenosis of anastomosis Re-operation
6	Type I	Recurrent colicky pain	Robotic Transperitoneal	Running 5-0 polyglactin	Yes	Chronic inflammation Fibrosis	29	No obstruction
7	Type I	Recurrent colicky pain	Robotic Transperitoneal	Running 5-0 polyglactin	Yes	Chronic inflammation Fibrosis	30	No obstruction
8	Type II	Worsening hydronephrosis	Robotic Transperitoneal	Running 5-0 polyglactin	Yes	Chronic inflammation Fibrosis	27	No obstruction
9	Type I	Loss of renal function	Robotic Transperitoneal	Running 5-0 polyglactin	Yes	Chronic inflammation Fibrosis	26	No obstruction
10	Type I	Recurrent colicky pain	Open	Running 4-0 polyglactin	Yes	Chronic inflammation Fibrosis	27	No obstruction
11	Type I	Worsening hydronephrosis	Open	Running 4-0 polyglactin	Yes	Chronic inflammation	34	No obstruction
12	Type II	Recurrent colicky pain	Open	Running 4-0 polyglactin	Yes	Chronic inflammation	29	No obstruction

two factors that may be related to the anastomotic stricture. The first one was that the retrocaval segment of the ureter was not excised neither bypassed, but it was left in situ and incorporated into the primary repair. The second factor was that the JJ stent was removed after only 17 days from the primary surgery, due to the presence of stent-related irritative symptoms. Probably, the premature removal of the ureteral stenting in association with the incorporation of the retrocaval segment into the repair could justify the stricture at the level of the primary anastomosis. Pathology processing of the excised portion of the ureter at the time of redo-surgery revealed signs of chronic inflammation and fibrosis that were similar to the pathology's findings of the other cases underwent primary excision of the retrocaval segment. Our experience would suggest that the retrocaval segment should not be incorporated into the primary ureteroureterostomy repair. Whether the retrocaval segment is simply bypassed and left in place or excised remains a matter of surgeon's preference and surgical circumstances. In addition, we also recommend the ureteral stenting for at least 3–4 weeks postoperatively to prevent anastomotic stricture.

Limitations of this study include its retrospective nature and the small number of included patients that made the groups hardly comparable using statistical analysis; however, this limitation is due to the high rarity of this pathology in the pediatric population. For this reason, we collected the data from several pediatric centers with the efforts to achieve a more objective evidence regarding the treatment of this pathology.

In conclusion, the study outcomes suggest that MIS should be the first choice for retrocaval ureter because of the minimal invasiveness and the better cosmetic outcome compared to open surgery. Furthermore, our results showed that robotic-assisted reconstruction was technically easier, safer, and quicker compared to laparoscopic repair, due to the known advantages of ergonomics ease for the surgeon and higher precision and facility of intra-corporeal suturing, and for these reasons, it should be preferentially adopted, when available.

Author contributions ME: project development, data collection, manuscript writing, and manuscript editing. LM: data collection, data analysis, and manuscript editing. JSV: data collection, data analysis, and manuscript editing. PJL: data collection, data analysis, and manuscript editing. BT: data collection, data analysis, and manuscript editing. IM: data collection, data analysis, and manuscript editing. CE: project development, data analysis, manuscript writing, and manuscript editing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest or financial ties to disclose.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required. This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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