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TOPIC PAPER

Robotic surgery in infants and children: an argument for smaller and fewer incisions

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Abstract

Purpose Robotic-assisted laparoscopic (RAL) surgery has gained momentum in pediatric urology. Technological adaptations such as the development of 5 mm instruments have led to robotic procedures being performed on younger children and those having smaller body habitus, with improved cosmesis. However, concerns have been raised regarding decreased intra-abdominal working space and the absence of monopolar curved scissors (hot endoshears®) when using 5 mm instruments. The aim of this study is to examine the overall experience at a single pediatric urology center using 5 mm instruments with no planned additional assistant ports during common robotic procedures. We hypothesized this approach is safe and feasible for a variety of pediatric urologic reconstructive procedures.

Methods We retrospectively reviewed all major robotic procedures entered into an IRB approved data registry. The analysis was performed only for procedures in which 5 mm instruments were used exclusively with hook diathermy. Procedures that utilized 8 mm instrumentation were excluded from the study. Data were abstracted according to patient age, weight and robotic surgery performed. Outcomes included post-operative complications (Clavien–Dindo classification), operative time, operative blood loss, need for assistant port placement and conversion rates to open or pure laparoscopic surgery.

Results From 2012 to 2016, 220 consecutive pediatric RAL urological surgical cases were performed on 201 patients. These comprised pyeloplasty ($n=102$) 46.4%, ureteral reimplants ($n=84$) 38.2% and ipsilateral ureteroureterostomy ($n=34$) 15.5%. Median age at surgery was 4 years (3 months to 18 years). There were no conversions to open or laparoscopic surgery. Placement of an additional Assist port was documented in seven cases. Severe (Clavien grade 4) complications occurred in two patients requiring ICU admission: one for sepsis and one ventilator-dependent patient having increased work of breathing post-op. Intra-operative blood loss was minimal (<50 ml) in 97% of cases. Patients ≤ 1 year of age comprised 28.6% of the study population. Univariate analysis revealed no association between age and occurrence of complications ($p=0.957$)

Conclusions This study represents one of the largest series of consecutive RAL surgery using 5 mm instruments in pediatric urology. Acceptable complication rates, OR times and blood loss were achieved using this technique. We conclude that the use of 5 mm instruments gives excellent operative outcomes in pediatric reconstructive procedures.

Keywords Robot-assisted surgery · Pediatric urologic reconstructive procedures · Minimally invasive surgery · 5 mm robotic instruments

Introduction

Robot-assisted laparoscopic (RAL) surgery is now an established surgical adjunct in pediatric urology. Trends in the United States over the last 10 years show pyeloplasty is now the most commonly performed robotic reconstructive urological procedure in children and has surpassed open surgery as the preferred approach [1–4]. Other commonly performed procedures include the robot-assisted ureteral reimplant (RALUR) and the robot-assisted ipsilateral ureteroureterostomy (RALIUU)—for duplex anomalies—and more complex procedures such as the robot-assisted appendicovesicostomy, bladder neck reconstruction and bladder augmentation [5, 6]. Despite this trend in high-volume pediatric centers, closer examination reveals that the majority

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of pediatric RAL is being performed in older children and adolescents (65% of all the RALPs were done in patients between 11 and 18 years, while it was only 2.7% utilization for patients under 2 years) [2], while younger infants do not avail the benefits of minimally invasive surgery due to presumed difficulties and a bias towards open surgery [7]. Also, the slow adoption of RALP in the infant population has been attributed to relatively large instruments [8].

The development of smaller, 5 mm instruments facilitated the use of RAL procedures in younger children and those with a smaller body habitus, with improved cosmesis [9]. Scientific data supporting the safety and feasibility of RAL in infants is growing, with several contemporary cohorts demonstrating acceptable success rates with a low complication profile [2, 3]. However, concerns have been raised regarding decreased intra-abdominal working space [10] and the absence of monopolar curved scissors (EndoShear® monopolar scissors, Intuitive Surgical®, Sunnyvale, CA) adapted for 5 mm instruments, propelling the popularity of 8 mm trocars in pediatric urology. Indeed, Intuitive's® latest iteration of the surgical robot, the Xi® system, does not accommodate 5 mm trocars and is exclusively adapted to 8 mm trocars. But Blinman demonstrated that since the tension created across an incision—affecting healing and scarring—is actually proportional to the square of an incision, multiple smaller incisions are preferable even to a single larger incision [11]. Therefore, the length of an incision matters, and smaller incision sizes should be preferred and utilized whenever feasible.

At our institution, we have prioritized use of the smallest available trocar size for RAL—5 mm. We also strive to obviate placement of an assistant port or robotic fourth arm to limit oft-performed RAL cases to a cumulative of three incisions. The aim of this study is to examine the overall RAL experience at a single pediatric urology center using 5 mm trocars with no planned additional assistant ports during commonly performed RAL procedures. We hypothesize that this minimization of incision size and number, along with the consequent wound tension reduction, offers the well-described cosmetic and analgesic benefits of minimally invasive surgery without compromising safety or visibility for a variety of pediatric urologic reconstructive RAL procedures.

Methods

We retrospectively reviewed all major robotic procedures entered into an Institutional Review Board approved data registry between August 2012 and December 2016. The three most commonly performed robotic reconstructive procedures were chosen for inclusion. These were: robot-assisted laparoscopic pyeloplasty (RALP), RALUR, and RALIUU. The *da Vinci*® Si robotic platform (Intuitive Surgical, Sunnyvale, CA) was utilized in all cases. The analysis was performed for procedures in which 5 mm instruments were used exclusively. Procedures that utilized 8 mm trocars and instruments were excluded. The incisions were placed in accordance to planned surgical intervention with an 8.5 or 10 mm camera port placed in the umbilicus.

For the RALP, we placed an 8.5 mm camera port just inside the umbilical crease, followed by one 5 mm port in the lower abdomen either close to the midline or the ipsilateral lower quadrant, and another 5 mm working port just below the xiphoid process. These anatomical landmarks can be utilized universally, even for small infants (Fig. 1). For infants and small children, a 4 or 4.7-French nephroureteral Salle stent (Cook Medical, Bloomington, IN) was utilized as a drainage stent to decrease the risk for additional anesthesia (Fig. 1). An internal, indwelling double J stent was used in all other cases. The technical details were previously described [7].

For the RALUR and RALIUU, the two 5 mm trocars are placed in the mid-clavicular line, just below the umbilicus, bilaterally. If the planned pelvic procedure is bilateral, then the ports are placed parallel across the abdomen from each other. For unilateral and RALUR and RALIUU, the ipsilateral port is placed more superior on the ipsilateral side to allow for triangulation of the operative field. More recently, in select cases, we incorporate the Hidden Incision Endoscopic Surgery (HIdES) modification for improved outcomes. With this approach, the skin incisions are placed on the lower abdominal crease, but a with tunneling maneuver the ports enter into the abdomen in a more cephalad location, which provides a comfortable working distance. If an assist port was required, we placed a 5 mm Step™ bladeless trocars (Medtronic, Minneapolis, MN). Our standard surgical techniques have been described in previous reports

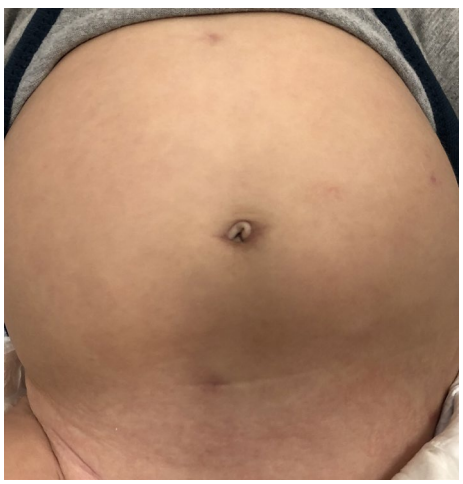

Fig. 1 Near-term appearance in 6 month old infant after RALP. Five millimeter ports placed in midline

[7, 12–14]. Due to utilization of 5 mm sized instruments, hook diathermy was used exclusively in place of monopolar curved scissors.

Data abstracted included patient demographics such as patient age, weight, gender, laterality of the procedure, and the type of robotic surgery performed. Outcomes included post-operative complications stratified based on the Clavien–Dindo classification, operative time, operative blood loss, the need for assist port placement, and conversion rates to open or pure laparoscopic surgery.

Comparison between two groups was made between Mann Whitney *U* test. Statistical analysis was performed using SPSS® version 20.

Results

From 2012 to 2016, 220 consecutive pediatric RAL urological surgical cases were performed on 201 patients. Pyeloplasty was performed in 102/220 (46.4%), ureteral reimplantation in 84/220 (38.2%), and ipsilateral ureteroureterostomy in 34/220 (15.5%) of cases. Patient demographics and perioperative parameters are summarized in Table 1. All the cases were performed by fellowship-trained pediatric urologists. Median patient age at surgery was 4 years (range 3 months to 18 years). Patients ≤ 1 year of age comprised 28.6% of the study population. The median OR time was 192 and 220 min for unilateral and bilateral surgeries, respectively. Intra-operative blood loss was minimal (< 50 ml) in 97% of cases. There were no conversions to open surgery. Placement of an additional assist port was required in 7/220 (3%) of cases due to technical limitations of the two working ports. Clavien grade 4 complications occurred in two patients, both of whom required ICU admission: one for sepsis and one ventilator-dependent patient who had increased work of breathing in the immediate post-operative period. None of these complications were due to concerns related to utilization of 5 mm instruments. Univariate analysis revealed no association between age at surgical intervention and occurrence of complications ($p = 0.957$).

Table 1 Patient characteristics, intra-operative and post-operative parameters of RAL surgeries

Variable	Value
Age at surgery, years [Med (IQR)]	4 (1.6, 9.1)
Weight at surgery, kg [Med (IQR)]	16.3 (11.3, 24.6)
Gender	
Male (%)	86 (41%)
Female (%)	124 (59%)
Procedure (%)	
RALP	102 (46%)
RALIUU	34 (15.5%)
RALUR	84 (38%)
Unilateral vs bilateral (%)	
Unilateral	187 (85%)
Bilateral	33 (15%)
Blood loss (%)	
Minimal < 50 ml	182 (97%)
50–100 ml	1 (0.53%)
> 100 ml	3 (1.6%)
OR time, min [Med (IQR)]	
Unilateral surgery	192 (155, 230)
Bilateral surgery	220 (192, 250)
Complications (%)	50 (22.7%)
Clavien 1	21 (9%)
Clavien 2	16 (7%)
Clavien 3	11 (5%)
Clavien 4	2 (0.91%)

RALP robotic-assisted laparoscopic pyeloplasty, *RALIUU* robotic-assisted laparoscopic ureteroureterostomy, *RALUR* robotic-assisted laparoscopic ureteral reimplant, *Med (IQR)* median (interquartile range)

Discussion

In pediatric urology, the robotic approach for reconstructive surgery has emerged as the preferred option at many centers with outcomes on par with the open approach [1, 4]. Examples of this include equivalent success rates of RALP and open pyeloplasty in children, with parent satisfaction regarding the cosmesis and recovery greater with RALP than open surgery [9]. With the established role of minimally invasive surgery (MIS) in adults, extension of robotic surgery to the pediatric population was a logical step. As in adults, it confers the well-known benefits of MIS including shorter hospital stay, more rapid return to work or normal daily activity, and improved cosmesis.

In the pediatric population, RAL was first performed in older children and adolescents, due to concerns for the small working space in the abdomen of younger children. Objective parameters include a threshold of absolute weight > 10 kg of the patient, as well as the distance between the anterior superior iliac spine and the rib cage [15]. In recent years, however, several contemporary series have reported good outcomes of robotic reconstructive surgery in younger children and infants independent of their size [16, 17]. In our series, although the median patient weight was 16 kg, 11.9% ($n = 24$) patients were ≤ 10 kg. There was no compromise of patient outcomes in these patients.

One technical simulation study proposed that 5 mm instruments were less effective than 8 mm instruments in small working spaces [18]. The range of motion profile of the 8 mm instrument is smaller than that of the 5 mm instruments, theoretically making it a better option in a small body

habitus. To this end, instrument collision occurred more frequently and more damage to the training box occurred when 5 mm instruments were used in this trial [18]. Our experience contrasts with these conclusions. As reported above, we did not identify any technical limitations of the 5 mm instruments, such as a higher complication rate, longer operative times, or increased rate of assistant port utilization. The three-port technique, including the camera port and two working ports were used exclusively, and was successful in 97% of cases which did not require an assistant port. In an another pre-clinical randomized crossover study, Cundy et al. compared 3 mm non-robotic instrument, 5 mm and 8 mm robotic instruments to perform suturing tasks by 23 participants in different workspace simulators. Median performance scores were statistically not different, although scores are better with 5 mm robot instruments as compared to 8 mm, favoring smaller instruments [19].

Since monopolar curved scissors are not available for use with 5 mm ports, monopolar hook diathermy was used instead. In our experience, the hook provides equivalent dissection and coagulation and is not a limitation to this approach. This is also reflected in the operative times and EBL. In a similar fashion, comparison of RALP in infants to older children using 5 mm instruments have shown similar perioperative outcomes in the two groups [7]. Specifically, one series found no statistical difference in time to dissection of the ureteropelvic junction (UPJ) or the time spent completion of the anastomosis [16]. This study confirms our findings that there is no technical disadvantage to 5 mm instrument utilization for RAL surgery in the pediatric population, regardless of body habitus or patient age.

Young children do present a unique challenge to RAL surgery due to their small body habitus. To counteract this, technological adaptation as mentioned above has allowed the use of smaller instruments. The use of 5 mm rather than 8 mm instruments optimizes the available working space to operate in these patients. Thus, a smaller incision can be performed, leading to less wound tension compared to the incision that must be made for an 8 mm instrument (Fig. 1).

Some have utilized assist ports for suture passage, surrounding organ retraction, and for suction to improve visualization. This is not a routine practice for us and instead we reserve the assistant port for challenging situations wherein visibility can be improved by regular suction/irrigation or better traction/positioning. We routinely insert suture material into the abdomen using the 3 mm laparoscopic needle driver via 5 mm ports without any manipulation of the needle. Traction sutures such as hitch stitch to renal pelvis in RALP or to bladder dome in RALUR have helped replace the necessity for assist ports and maximize the utility of 5 mm ports. MiniLap instruments (Teleflex® Inc) can be used to provide additional traction or for cutting purposes without the use of additional trocars; with their slim 2.3 mm shaft diameters instruments can be percutaneously inserted using an integrated needle tip.

We find that the 5 mm port sizes are well suited for our own adaptation of the HIdES concept [20]. As opposed to exclusively utilizing the standard incision approach, we used with parallel mid-clavicular line incisions (Fig. 2a), we find no compromise in working space or instrument versatility by placing the skin incision in the inguinal crease and then tunneling cephalad prior to inserting the 5 mm trocar through the fascia. This approach provides cosmetically superior incision placement easily hidden below clothing (Fig. 2b).

Surgeons today accept the principle that the length of any incision occupies a place of importance in pediatric surgery. For long, the widely held view that laparoscopy had no role in the care of small infants—since, for example, three 5 mm incisions are additively greater than a single 12 mm incision through which, perhaps, a pyeloplasty could be accomplished. Not only did the enhanced visualization and magnification of laparoscopy and rising facility with laparoscopy and robotics dismiss that argument, but mathematics and concepts of wound tension, too, favor multiple smaller incisions than a single, longer incision [11]. Intuitive's® Xi® platform, despite its multitude of technological offerings and advancements, simply does not offer adaptability to 5 mm instrumentation, and incorporating 5 mm instruments is not currently planned (personal communication). Pediatric surgeons and urologists must join voices in urging not only Intuitive®, but even those manufacturers planning to introduce competitor models into the marketplace, to pursue the technology inherent in miniaturizing trocar sizes and affording the advantages of smaller incisions to the youngest consumers.

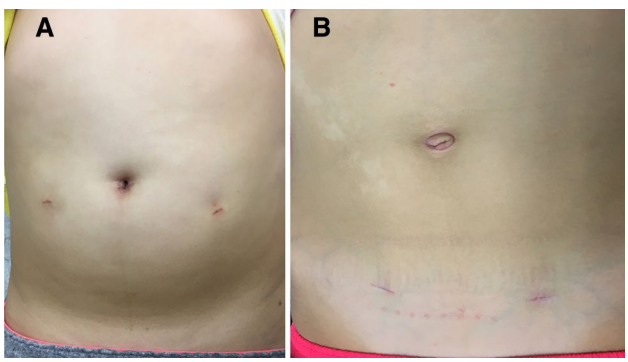

Fig. 2 Appearance of port sites after RALUR and RALIUU. **a** After conventional port placement. **b** After modified hidden incisions placed within the inguinal crease and tunneled cranially prior to entering fascia

Limitations

This study was done in a retrospective fashion and carries with it the inherent limitations of a retrospective study. Additionally, although it investigates the safety and advantages of a three-port procedure employing 5 mm instruments exclusively, no comparison was made to a similar patient cohort undergoing surgery with 8 mm instruments. However, the authors believe that given the large number of subjects investigated, these findings show that this technique is safe and feasible, with a low rate of intra- and post-operative complications.

Conclusion

This study represents one of the largest contemporary series of consecutive robotic-assisted laparoscopic surgery using solely 5 mm instruments in pediatric urology. We demonstrate, herein, that utilizing 5 mm instrumentation and obviating an assistant port may be accomplished without compromising movement and articulation within the abdominal space. A total of 97% of our consecutive cases did not require an assistant port and the Clavien 3 complication rate was 5%—on par with the published literature for the three reconstructive procedures that are the focus of this study. Since the physics of wound tension favor smaller incision sizes, we argue that this should be a focus, rather than just a byproduct of technological innovations and evolutions in robotic surgery platforms. Surgeons should insist, in their dialogs with the robotic system manufacturing industry, that robotic platforms prioritize miniaturization of trocars and advance the technology in this regard. We conclude that the use of 5 mm instruments using a three-port approach yields excellent cosmesis and equivalent operative outcomes in pediatric reconstructive urologic procedures.

Author contributions TK: data collection, data analysis, and manuscript writing. RS: data collection and manuscript writing. AKS: project design/development and manuscript review. DC: data analysis/review. DW: project development and manuscript review. CL: project development and manuscript review. JVB: project development and manuscript review. YB: data management/collection. JS: data management/collection. ARS: project design/development, manuscript editing and review.

Compliance with ethical standards

Conflict of interest The authors declare they have no conflict of interest.

Ethical approval for research Data were collected/analyzed in an approved institutional review board data registry (12-009259). Data were de-identified before analysis.

Informed consent Additional informed consent was not required as only de-identified data were used for analysis. Informed consent was obtained for the pictures used

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