Robotics in Pediatric Urology

Evolution and the Future

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KEYWORDS

• Minimally invasive surgery • Pediatric robotic surgery • Pediatric urologic reconstruction
• Ureteropelvic junction obstruction • Vesicoureteral reflux • Bladder augmentation

KEY POINTS

- Robotic-assisted surgery in children is increasing in utilization for common reconstructive procedures such as pyeloplasty and ureteral reimplantation.
- Similar to open surgery, careful attention to surgical technique and outcomes allows robotic-assisted surgery to be a safe and effective alternative treatment option.
- Further complex reconstructions are being reported with encouraging preliminary results.

Video content accompanies this article at http://www.urologic.theclinics.com.

INTRODUCTION

Pediatric urologists were early adopters of laparoscopy and subsequently robotic-assisted (RA) surgery. The first reported pediatric urologic surgery performed robotically was performed in 2002 by Dr Craig Peters at Boston Children's Hospital.[1] As is discussed, robot utilization in pediatric urology has been ubiquitous with most major academic institutions offering access to this technology. As surgeon comfort, access, and indications for robotic surgery in children expand, utilization will likely continue to increase. Here we review the current state of robotic surgery in pediatric urology, including utilization and general and case-specific technical considerations.

UTILIZATION AND LEARNING CURVE OF ROBOTIC-ASSISTED SURGERY IN PEDIATRIC UROLOGY

Between 2000 and 2010, the number of pediatric urology cases published increased gradually with rapid increases seen after 2010.[2,3] The most common cases performed robotically are pyeloplasty and ureteral reimplantation which combined account for 80% of RA procedures performed?[4] Recent studies have shown that from 2003 to 2015, the overall number of pyeloplasty cases and open pyeloplasty cases has declined 7% and 10% annually, respectively, while RA pyeloplasty increased by 29% annually, accounting for 40% of pyeloplasties in 2015.[5] Currently at our own institution, the Children's Hospital of Philadelphia, more than 75% of pyeloplasties and reimplants are performed robotically.

As in other surgical procedures, adoption of new technology is dependent on many factors and a major component is its reproducibility and the associated learning curve. Within pediatric urology, Tasian and colleagues[6] initially reported attempts to understand the learning curve in performing robotic pyeloplasty and showed that via multivariate linear regression, fellow trainees were projected to achieve the median operative time of the attending surgeon after 37 cases. Other studies have shown similar findings of in the

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relatively quick learning curve of this common procedure,[7,8] but studies have been limited in investigating the other types of cases. As RA surgical experience and comfort increases in urologic residencies nationwide, we are likely to see decreased learning curves in pediatric urology trainees with further increased utilization.

IMPORTANT PRINCIPLES IN PEDIATRIC ROBOT-ASSISTED SURGERY

Anesthesia considerations for robotic surgery are very similar compared with other minimal invasive approaches that involve pneumoperitoneum. Efforts to minimize insufflation pressure (<10 mm Hg) and reduce flow-rate are necessary in children as the ratio to peritoneal surface is larger relative to body weight, the systemic absorption of carbon dioxide may be higher. In addition, increased intraperitoneal pressure can lead to increased peak inspiratory pressure and decreased pulmonary compliance as well as decreases cardiac output and renal perfusion and increased renal vascular resistance. Bradyarrhythmias have also been documented during insufflation possibly secondary to vagal stimulation. Immediate reversal of pneumoperitoneum is generally enough to reverse these arrhythmias.

PORTS: CHOICE, PLACEMENT, AND REMOVAL

The most common robotic port size used across the country is 8 mm but for the Si version of the da Vinci, 5 mm is an option. The differences between the 8 mm and 5 mm instrumentation are that the 5 mm lacks a wrist joint and lacks surgical shears as an instrument option. Hence, the hook is the dissecting tool of choice with the 5-mm instruments. More recently, the single-port version of the Xi has been introduced although not specifically approved for pediatric use. Whether a single 25-mm incision is beneficial in children is unclear.

Port Placement

There are a number of techniques for robotic port placement and we will define the basic principles of safe port placement and some strategies to consider in this population. It is important to emphasize that a child's abdomen is very pliable and hence provides little, if any counter resistance when a port is pushed through an incision. This process has to be taken into consideration to ensure safe port placement.

1. Adequate skin incision: in our experience smaller incisions have been the most common reason excessive force used during port placement.
2. Place port under vision whenever possible. If in doubt, use a visual obturator during port placement. We also prefer to incise the fascia and peritoneum and use blunt obturators for robotic port placement.
3. Laparoscopic literature has not demonstrated any clear difference in outcome between an open technique (Hasson) versus Veress needle for initial access into the peritoneum.[9] Surgeons should pursue the technique he or she is most comfortable with. Our preference is to use the Veress needle but dissect partially through the abdominal fascia before we introduce the needle.
4. It is ideal to have 4 finger breadths between ports, although this not uniformly available during infant cases.
5. Ensure adequate distance from the point of port entry to the surgical field to allow for adequate mobility and safety during instrument exchange.

Literature on incision site aesthetics and patient preferences have trended toward incisions below the umbilicus, preferably at the level of the Pfannenstiel incision, which can be covered easily. The development of "hidden incision endoscopic surgery (HIdES)" has gained some momentum in this regard.[10] Skin incisions are made lower in the abdomen and the camera is placed above the pubic symphysis with trocars triangulating on the organ of interest (**Fig. 1**). Similarly, making skin incisions in the inguinal crease and tunneling the robotic trocars subcutaneously while entering the abdomen in their standard location has also

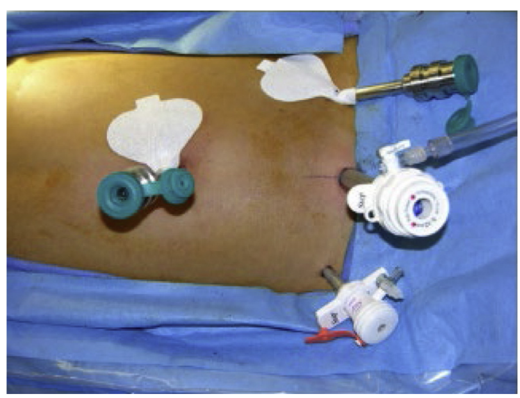

Fig. 1. Figuration of port placement during hidden incision ("HIdES") technique. (*From* Gargollo PC. Hidden incision endoscopic surgery: description of technique, parental satisfaction and applications. J Urol. 2011;185(4):1425-1431.)

been described (Fig. 2). Early reports are encouraging but long-term and aesthetic outcomes including patient preferences remain unknown.

Although port site hernia in children is an infrequent complication, we routinely close fascia at port sites, including the 5-mm ports. We perform this, because unlike adults, children have much less abdominal wall muscle mass and subcutaneous tissue, which could allow for port site hernias.

ROBOTIC-ASSISTED RECONSTRUCTION FOR UPPER TRACT PATHOLOGY

Ureteropelvic Junction Obstruction (UPJO)

Indications and technique

RA pyeloplasty remains the most common robotic procedure performed in pediatric urology. The indications for RA pyeloplasty are the same as those for open surgery. Declines in the overall number of pyeloplasty cases performed nationally likely reflect judicious selection of patients being recommended for surgery who exhibit even severe degrees of upper tract dilation.

The steps of RA pyeloplasty are shown in Box 1. We give patients a broad-spectrum, intravenous antibiotic based on previous urine culture data or empiric cefazolin. A Foley catheter is placed. After peritoneal insufflation is obtained, ports are placed and the robot is docked. Our practice is to begin the procedure by medially reflecting the bowel, although others have used a transmesenteric window to gain access to the ureteropelvic junction (UPJ). A hitch stitch is used to bring the renal pelvis closer to the abdominal wall to allow for suturing without using a third-arm or assistant port (Fig. 3). We use 5 to 0 monocryl for the anastomosis with 1 to 3 interrupted sutures placed at the most dependent portion of the UPJ followed by continuous suture. The use of interrupted sutures throughout and knotless self-anchoring barbed suture[11] have also been reported. We generally do not place a drain, except in more challenging cases (eg, redo cases or ureterocalicostomy).

Utilization of stents and their method of effective placement is a topic of continued debate in the field. Traditional placement of pigtail stents requires an additional anesthetic for their removal, which contributes to additional morbidity and cost. To mitigate this, groups have popularized the utilization of a ureteral stent secured to the patient via a string placed at the beginning of the procedure and removal within 7 to 10 days or utilization of a percutaneous pyeloureteral stent (Salle stent; Cook Urologic, Spencer, Indiana).[12,13] Furthermore, groups have shown comparable perioperative outcomes in stentless reconstructions in small case series with relatively short follow-up.[14,15] In our practice, stents are placed antegrade while the bladder is filled with a methylene blue/saline mix. This allows for confirmation of appropriate placement in the bladder, via visualization of blue fluid effluxing through the stent, and avoids the potential complication of the stent deploying in the distal ureter.

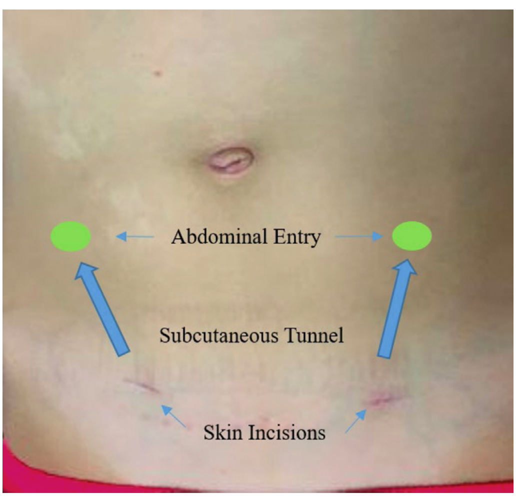

Fig. 2. Tunneled Trocar placement for pelvic surgery. (*Courtesy of* Aseem Shukla MD, Philadelphia, PA.)

Box 1
Operative steps for robotic-assisted pyeloplasty

1. Position patient in modified flank at the edge of operative table
2. Port placement
   - Camera placed in umbilicus
   - 5-mm working ports in the midline above umbilicus and ipsilateral to midline 4 fingers below the umbilicus
3. Dock robot over kidney
4. Medial reflection of colon to expose UPJ
5. Mobilization of ureter and renal pelvis
   - Identification and mobilization of UPJ from possible crossing vessel
6. Percutaneous hitch stitch placed to anchor renal pelvis
7. Incision of dilated renal pelvis and lateral spatulation of ureter
8. Anastomosis of ureter to renal pelvis with continuous monofilament suture
   - Percutaneous placement of double pigtail stent antegrade across UPJO

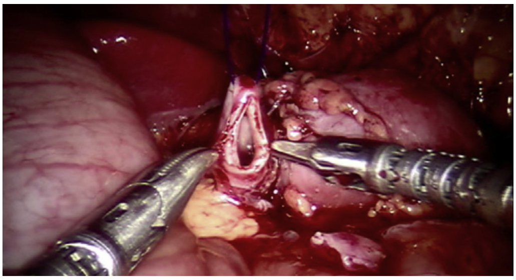

Fig. 3. Demonstration of utility of percutaneous hitch stitch on renal pelvis during pyeloplasty to avoid use of an assistant port and stabilization during reanastomosis.

Outcomes, costs, and complications

Most series show a success rate, defined as improvement of hydronephrosis, resolution of symptoms, and/or improved T1/2 on diuretic renogram of robotic pyeloplasty of greater than 92% to 98%,[16–23] which is equivalent to that of the open experience. Benefits of RA pyeloplasty include decreased narcotic requirements[24] and shorter length of stay. Despite this, RA is associated with increased operating room (OR) time and equipment costs[5] with an absolute difference of $1060 per case. Efforts to identify areas of cost-saving during the procedure have shown areas such as OR turnover, positioning, and increasing overall utilization,[25] as well as efforts to quantify downstream costs such as decreased lost parental wages and lower hospitalization expenses[26] associated with the RA approach. In addition, patient-/family-centered outcomes have shown higher parent satisfaction noted after RA than open surgery.[27] Comparable to the open experience, complications have been reported to occur in 10% of cases and most are Clavien-Dindo 1 to 2 grade complications.[28]

Special considerations: infant robotic pyeloplasty

The first reported case series of patients younger than 1 year undergoing RA pyeloplasty was in 2006 and offered encouraging results.[20] Despite this, the appropriate approach to UPJO in this patient population continues to be debated due to the decreased working space and increased robotic arm collisions. Finkelstein and colleagues[29] proposed the distance between both anterior superior iliac spines and the puboxyphoid distance of 13 cm and 15 cm,[30] respectively, decreased collisions and operative time, although adoption of this metric is unreported. As groups report positive outcomes in this patient population,[29,31] we expect further adoption in approaching this unique group robotically.

Special considerations: bilateral ureteropelvic junction obstruction

In rare instances of bilateral UPJO, the RA approach has been used with simultaneous bilateral repair with good short-term results.[32] Both sides can be repaired if midline port placement is used without the need to place additional ports. We use an iodine impregnated drape over the port sites during repositioning and draping of the patient.

Special considerations: Reobstruction after initial repair

Persistent obstruction occurs in ∼5% of patients and management of these cases can be difficult. Initially, endopyelotomy was shown to be a viable option in small case series with short-term follow-up.[33,34] As the minimally invasive surgery experience was further adopted, reports of laparoscopic salvage pyeloplasty showed promise in adults[35] and that experience has been mirrored in the pediatric population. Multiple groups have shown good success rates with RA redo pyeloplasty.[36–40] It our institutional preference to address these cases with this approach. In cases in which significant renal pelvis reduction was performed at the initial procedure, significant intrarenal pelvis dilation is present, or if the UPJ is unable to be safely mobilized, an RA ureterocalicostomy has proven an effective method to overcome these challenges and relieve the obstruction.[41] [Video 1]

Duplex anomalies: ureteroceles, ureteral ectopia, single-moiety ureteral reflux

Patients presenting with ureteroceles or ureteral ectopia historically presented with febrile urinary tract infections, but contemporarily are identified via antenatal ultrasonography. This shift in presentation has changed the natural history and treatment recommendations for these diseases. Despite this, the goals are the same: relief of obstruction, reduction in infection and preservation of renal function. The RA platform has allowed for decreased morbidity when correcting these anomalies.

Robot-assisted ureteroureterostomy (Video 2)

The ipsilateral ureteroureterostomy is a common procedure to address this pathology. Laparoscopic ureteroureterostomy initially gained momentum in the late 2000s.[42] This was quickly replaced with the RA approach as access to the technology increased[43,44] and it offers superior visualization and more delicate handling of the ureters. The procedure is completed by performing an end-to-side anastomosis between the donor and recipient ureters.[45] [**Fig. 4**] At our institution, a ureteral stent is placed in the recipient ureter with no

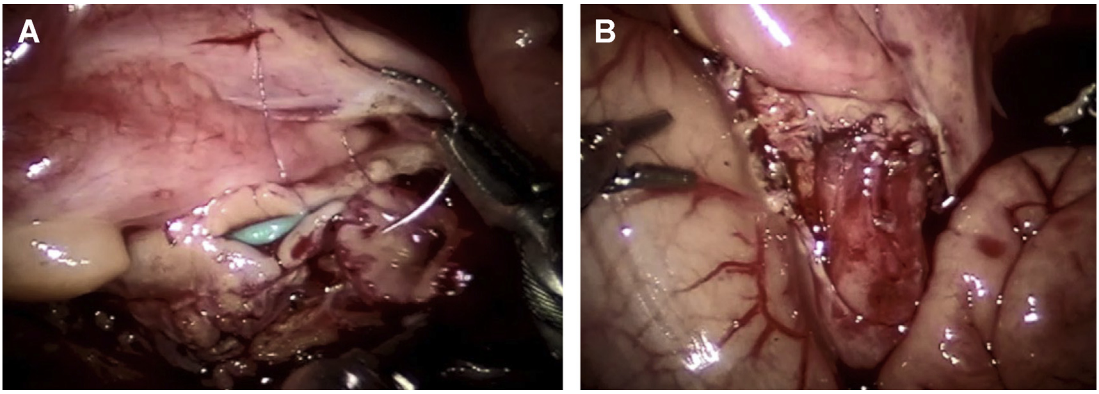

Fig. 4. (*A*) Example of upper-to-lower pole ureteroureterostomy reanastomosis. (*B*) Final end-to-side anastomosis after ureteroureterostomy.

stent across the anastomosis and is removed ~6 weeks after the procedure. One group has reported good short-term outcomes after external ureteral stent removal on postoperative day 1,[46] which may offset further costs associated with subsequent indwelling ureteral stent removal. The overall success rate in resolving the obstruction is greater than 90% with rare complications noted. Further surgical management of the infected residual donor ureteral stump may be required in up to 12% of cases.[47] During the initial procedure, we aim to excise this ureteral stump as far distally as possible, generally to the area where the ureters cross close the ureterovesical junction. This procedure is used most often at our institution to address these cases.

Robot-assisted heminephroureterectomy with partial ureterectomy

In the hopes of leaving the unaffected renal moiety undisturbed, many advocate for heminephrectomy and partial ureterectomy in cases of obstructed duplex systems. This approach allows for removal of the poorly functioning unit that is, associated with recurrent infections and/or symptomatology. In the open approach, during excision of the upper pole, the associated ureter is mobilized from a posterior to superior position along the renal vessels, which allows for its complete removal. Unfortunately, this technique as well as complete kidney mobilization is associated with a 5% incidence of vascular injury or vasospasm affecting the functional moiety. This risk is decreased via a minimally invasive approach by allowing for decreased manipulation of the entire kidney and an in situ dissection.[48] Comparison between the open and robotic approach have shown similar complication rates, success, need for additional interventions but with decreased length of stay.[49]

Minimally invasive techniques have been reported by using a variety of approaches including both intraperitoneal[50,51] and retroperitoneal approaches.[52] Regardless, the robotic approach with its increase magnification will allow for accurate distinction between the upper and lower pole moieties and further preservation of the unaffected moiety vasculature. In addition, using advanced imaging with near infrared fluorescence and indocyanine green (ICG) to perform intraoperative selective arterial mapping[53] theoretically may further decrease the risk of injury to the vasculature. The RA approach has also allowed for reconstruction/closure of the renal capsule after excision, which has been shown to decrease the formation of postoperative fluid collections from 42% to 11% when performed.[50]

ROBOTIC-ASSISTED RECONSTRUCTION FOR LOWER TRACT PATHOLOGY

Vesicoureteral Reflux

Ureteral reimplantation is performed for vesicoureteral reflux with recurrent febrile urinary tract infections with or without evidence of renal scarring. Open ureteral reimplantation, either via an intravesical or extravesical approach, is considered the gold standard for this procedure and the robotic approach is being perfected to achieve the same standards.

Patient selection and optimization

Children with recurrent febrile urinary tract infections despite continuous antibiotic prophylaxis in the setting of vesicoureteral reflux are ideal candidates for this procedure. Other indications, although controversial, are patients with renal scarring, worsening reflux, or unresolved high-grade reflux particularly in girls. Pre-procedure evaluation and optimization should include treatment directed toward bladder and bowel dysfunction. We recommend all children who are toilet trained have a uroflowmetry and estimation of post void residual to objectively evaluate bladder function. Bladder habits should be quizzed in terms of frequency of voiding, continence issues, and adequacy of hydration. Stooling frequency and consistency should be optimized before surgery. If problems with bladder and bowel dysfunction persist despite treatment, consideration should be given for neurologic evaluation of the spine and/or additional medical/ behavioral therapy.

Technique

RA ureteral reimplantation can be done both intravesically or extravesically, with the latter more commonly used. The surgical technique in both mimics the open approach. The intravesical replicates a Cohen cross-trigonal reimplantation, whereas the extravesical replicates the Lich-Gregoir technique.

Patient positioning

Patients younger than 2 years are positioned supine on the operating table, whereas older children are positioned in dorsal lithotomy with stirrups. In addition, we have found that the robot can be brought in the midline stopping at the patient's feet or alternatively side docked. We have found no difference between these 2 approaches. The patient is secured to the operating table with silk tape across their chest with extreme care to avoid compromising ventilation, especially in smaller children. As the patient is in steep Trendelenburg position, we place a heavy gel bolster secured to the operating table above their head to prevent intraoperative sliding in a cranial direction (Fig. 5). We place a soft thick cushion over the patient's face and the endotracheal tube to protect both from the robotic arms. Special attention is paid to appropriate padding of pressure points and neutral positioning of the joints.

Intravesical technique

The anterior abdominal wall from the xiphoid to pubis including external genitalia is included in the sterile field. Cystoscopy is performed and the bladder is distended with fluid. Under direct visual guidance of cystoscopy, port placement sites are selected and "box stitches" are placed. These are full-thickness sutures from the fascia through the bladder and back out through the fascia. These sutures allow for traction anchoring the bladder to the abdominal wall during port placement and to allow for easy closure at the conclusion of the procedure. Pneumovesicum is achieved after draining the bladder. Similar to a Cohen cross-trigonal reimplantation, feeding tubes are used to intubate the ureters and secured. Using this tube for traction, periureteral dissection is performed to mobilize the ureter(s) further into the bladder. A mucosal tunnel is then created with a natural shallow angle to the old hiatus across the trigone. The ureter is then passed through the tunnel and the neo-orifice is created with interrupted monofilament suture. Dissected mucosa over the old orifice is closed. Continuous drainage via Foley catheter is used for 3 to 5 days, at which point a cystogram is performed before trial of void.

Extravesical technique

After draping the patient, a Foley is placed. A camera port in the inferior border of the umbilicus, 2 working arm ports on either side at the mid clavicular line are placed and either hook or endoshears in the working arm and a Maryland dissector are used. In girls, the dissection is started between the fallopian tube and broad ligament on one side and the bladder on the other. In boys, the peritoneum is opened on the ureter distal to the vas which is visualized and protected throughout the procedure. Proximal dissection of the ureter in the retroperitoneum is performed to gain adequate length at avoid tension during tunneling. Dissection distal to the ureterovesical junction is then performed. Avoiding the use of traction sutures, directly handling, crushing or the use of cautery on the ureter during dissection to avoid injury or compromising vascularity is important.

A traction suture is placed near the posterior dome of the bladder to aid visualization of the ureterovesical junction and to aid detrussorotomy. The detrussorotomy should be performed to allow for a tunnel length approximately 4 times the diameter of the ureter and in a trajectory to avoid kinking as it enters the bladder. The indwelling urethral

Fig. 5. Patient positioned for robotic-assisted reimplantation.

catheter is used to fill the bladder about one-third full with sterile water/saline. Using cautery and blunt dissection, the detrussorotomy is then created down to the mucosal layer. Filling the bladder allows for early identification of the mucosal layer, which bulges out like a blue dome and allows for efficient dissection. If the mucosal layer is breeched, we recommend simple closure to avoid subsequent leak. The detrussorotomy is extended distally in a Y-shaped configuration around the ureterovesical junction on either side with sparing use of cautery in this area. The bladder is then deflated and the ureter is placed in this tunnel and the detrusor closed behind it in an interrupted fashion. The Foley is left overnight and removed the following day.

Outcomes and success in a modern cohort

The robotic approach to ureteral reimplantation has been controversial as institutions with varying degrees of experience reported varying initial success rates. Understanding factors such as the technique used and surgeon experience as well as patient-specific factors including the age of the child, if the child is toilet trained or not, presence and treatment of bowel-bladder dysfunction, baseline bladder dynamics, the grade of reflux, and gender of child all play an important role in success. Furthermore, there is significant controversy in how we define success. If the goal of surgery is to reduce the risk of urinary tract infections, should that be the primary end point rather than radiologic success? **Table 1** provides the results from studies evaluating the efficacy of RA ureteral reimplantation for primary vesicoureteral reflux. We believe these encouraging results show this approach leading to greater than 90% success rate.

Pediatric urologists have modified the diagnostic patterns and treatment recommendations of this disease notably over the past 2 decades. This has led to a significant decline in the number of patients undergoing surgery.[54,55] When critically evaluating the patients with vesicoureteral reflux undergoing surgery, historical cohorts are different by age at surgery, grades of reflux and other confounders like the presence of bowel-bladder dysfunction. Studies comparing the 2 approaches in a modern cohort with a controlled research design are lacking.

Grimsby and colleagues[56] also reported a multi-institutional experience that provides a cautionary tale when implementing a novel surgical technique and the importance of recognizing areas for improvement and sharing experiences. We acknowledge that the technique for reimplantation at our institution has evolved and improved over time. To this point, Boysen and colleagues[57] reported on a multi-institutional effort that demonstrated how institutions vary in technique, success and benefit from this type of collaboration, which continues to develop and expand.

Complications

Table 1 shows that complications after robotic ureteral extravesical ureteral reimplantation are few and infrequent. Transient urinary retention has been reported and in our experience, is self-limited and resolves spontaneously. There is a general belief that this occurs more common in bilateral procedures, but Kawal and colleagues[58] showed that this did not appear to be a risk factor. Ureteral injury and ureteral obstruction are other possible complications reported in about 1.0% to 2.5% of patients. Careful use of cautery during the ureteral dissection, discontinued use of traction sutures on the ureters and avoiding traction injuries to the ureter are critical to decrease the likelihood of these complications. In addition, avoiding pressure on the ureter during detrusorrhaphy is essential. Transient hydronephrosis has also been reported after ureteral reimplantation in about 30% of patients and typically resolves within 1 year,[59] which is similar to open surgery.[60]

ADVANCED ROBOTIC-ASSISTED PROCEDURES

As pediatric robotic surgeons gained more experience with the procedures discussed previously, centers began to apply these techniques to more complex operations such as augmentation cystoplasty and appendicovesicostomy creation. The first robotic case was reported in 2008 by Dr Mohan Gundeti and colleagues[61] and provided the framework to approaching this operation in the pediatric population. The open approach continues to be the most common technique to for these cases, but as experience is further published and disseminated, the authors feel adoption will continue to increase.

Robot-Assisted Augmentation Cystoplasty and Mitrofanoff Appendicovesicostomy

Indications for this surgery include diseases that leads to impaired bladder function with reduced capacity and decreased compliance. Commonly, patients with diseases such as spina bifida, neurogenic bladder, posterior urethral valves, and prune belly syndrome may benefit from these reconstructions. In addition to the contraindications noted in open surgery, such as history of inflammatory bowel diseases, inability to perform catheterization and poor access to care, the minimally

Table 1
Results from studies evaluating efficacy of robotic-assisted ureteral reimplantation

Study	Technique	Patients, n/Ureters, n	Median Age, y	Bowel-Bladder Dysfunction: Yes/No, %	Complications, %	Success, %
Marchini et al,[74] 2011	RALUR-IV and EV OR-IV and EV	RALUR-IV – 19 RALUR-EV – 20 OR-IV – 22 OR-EV - 17	RALUR IV-9.9 RALUR EV – 8.6 OR-IV -8.8 OR – EV -6.0	No	RALUR IV- 5 (retention = 1, leak = 4) RALUR EV – 4 (retention = 2, ureteral leak = 2)	RALUR IV-92.2 RALUR EV – 100 OR – IV -93.2 OR – EV – 94.2
Casale,[75] 2008	RALUR-EV	41(82)	3.2	Addressed preoperatively but numbers not included	0	97.6
Smith et al,[76] 2011	RALUR-EV OR IV	RALUR-EV-25(33) OR-IV – 25(46)	RALUR IV- 5.8 OR IV – 4.2	Addressed preoperatively but numbers not included	RALUR EV – 3 (urinary retention) OR IV – 1 (bladder leak)	RALUR EV- 97 OR IV - 100
Kasturi et al, 2012[77]	RALUR-EV	150 (300)	3.55	Addressed preoperatively but numbers not included	0	99.3
Chalmers et al,[78] 2012	RALUR-EV	17(23)	6.23	No	0	90.9
Schomburg et al,[79] 2014	RALUR-EV OR EV	RALUR 20 OR 20	RALUR 6.2 OR4.3	No	RALUR 2 OR 7	RALUR 100 OR 95
Akhavan et al,[80] 2014	RALUR-EV	50(78)	6.2	No	6: ileus = 2, obstruction = 2, ureteral injury = 1, perinephric fluid = 1	92.3

Boysen et al,[57] 2018 – Multi-institutional	RALUR-EV	143 (199)	6.6	Yes: 45, of those 35.4% dysfunction resolved completely before surgery	12: obstruction = 2, urine leak = 3, port site hernia = 1, catheter and drain complications = 2, transient urinary retention = 4	93.8–1 had redo surgery
Grimsby et al,[56] 2015 – Multi-institutional	RALUR-EV	61(93)	6.7	Addressed preoperatively, included in a multivariate analysis but numbers and outcomes not provided	6: obstruction = 3, urine leak = 2, readmission = 1	72–4 had redo surgery

Abbreviations: EV, extravesical; IV, intravesical; OR, open ureteral reimplant; RALUR-EV, robot-assisted laparoscopic extravesical ureteral reimplantation.
Data from Refs.[56,57,74–80]

invasive approach may be hampered in patients with history of multiple prior abdominal surgeries or severe spinal abnormalities that may affect appropriate positioning. Many of these patients have a history of ventriculo-peritoneal shunt placement, which may benefit from isolation by using an Endopouch bag (Ethicon Endo-Surgery, Cincinnati, OH)[62] during surgery, although our practice does not commonly use this approach.

Technique and outcomes

The steps of the procedure have been reported in great detail in previous publications.[63,64] Differing slightly from these techniques, it has been our preference to perform the bowel mobilization by using a conventional laparoscopic approach. Reports have shown success with RA intracorporeal hand-sewn bowel anastomosis,[65] but we prefer to perform the bowel reanastomosis by using surgical stapling devices.

Interim studies have shown RA procedures had longer operative time (623 vs 287 mins; $P<.01$) and a decreased length of stay compared with open surgery, but comparable increases in measured bladder capacity, narcotic use, and complication rates.[66] We believe these initial results are optimistic and encourage further implantation of these procedures.

Additional Procedures in Pediatric Urology

A number of additional complex procedures have been performed robotically, including bladder neck repair,[67] bladder diverticulectomy,[68] and excision of prostatic utricles.[69] Unlike the adult experience, RA technology being applied to pediatric urologic oncology is just beginning to be reported both in cases of renal tumors[70,71] as well as retroperitoneal lymph node dissections[72] with good initial results. Further adoption of these techniques is likely to continue as these cases are managed at high-volume centers and in collaboration with adult urologic oncologists.

THE FUTURE IN PEDIATRIC UROLOGY

As discussed previously and likely in many of the articles reported herein, in an era of rising health care expenditures, aside from outcomes, procedural costs will continue to play a role in deciding appropriate treatment of disease. With the development and approval of competing robotic platforms,[73] the authors hope that industry will consider application of their technologies on pediatric patients and their procedures. This competition will hopefully decrease cost as well as provide further diversity and specificity in instrumentation that may be further tailored to pediatric urology. RA procedures within pediatric urology will continue to play a major part of the care provided and training opportunities for our next generation of trainees. Pediatric urologists, in conjunction with their adult counterparts, will continue to champion this technology in hopes of providing good results with less morbidity in this population.

DISCLOSURE

The author has nothing to disclose.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.ucl.2020.09.008.

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