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REVIEW ARTICLE

# Current status of robotic surgery in pediatric urology

**Asif Muneer · Manit Arya · Iqbal S. Shergill · Dev Sharma · Mohammed Y. Hammadeh · Imran Mushtaq**



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**Abstract** Robotic-assisted pediatric urological surgery has emerged as a valid and reliable surgical therapy, which maintains the advantages of the minimally invasive approach but avoids the restrictions of laparoscopic surgery. The ideal application of the robot in the Pediatric population is in procedures requiring delicate suturing such as pyeloplasty or partial nephrectomy although the use of robotic surgery has been reported in a wide range of other procedures, particularly the diverse reconstructive pediatric operations. In this article, we review the current indications and results of robotics in the management of pediatric pathology.

**Keywords** Pediatric · Urology · Pyeloplasty · Minimally invasive · Robotic

## Introduction

The advances in minimally invasive surgery have inevitably improved periooperative outcomes. The superior visual field, reduction in the stress response to surgery combined with a shorter postoperative recovery time with a superior cosmetic result has led to patients electing for the minimally invasive option where available.

Since 1988 the da Vinci robot (Intuitive Surgical, Sunnyvale, CA) has been instrumental in the clinical development of robotic surgery in adults. Successful outcomes have been reported in adult surgery mainly in the specialties of cardiothoracic, gastrointestinal and urological surgery. Although the Zeus system (Computer Motion, Goleta, CA) was originally available as a separate system, the merger of the da Vinci and Zeus system has resulted in the da Vinci robot being exclusive for clinical use. The da Vinci robot is a master slave device approved for use in humans. The surgeon sits at a console which provides an ergonomic environment to perform surgery and has a view of the surgical field from the console using a fully stereoscopic binocular visual system. The hand movements from the console are digitalized allowing movements of the robotic arm in real time with seven degrees of freedom (DOF) with the advent of EndoWrist technology. The tactile and force feedback otherwise known as haptic feedback can provide useful feedback to the surgeon. The robotic software eliminates fine tremors to allow precise suturing. Currently the robotic device utilized in the Pediatric and adult population is identical utilizing 12-mm camera ports and 8-mm working ports.

The uptake of robotic surgery in pediatric urology has been restricted to a few international centers. Pediatric surgeons have evaluated the potential for robotic surgery since the beginning of the decade in procedures such as fundoplication and pyeloplasty. Compared to robotic surgery, minimally invasive laparoscopic surgery allows four DOF and therefore intracorporeal suturing during reconstructive procedures is particularly demanding. The diverse reconstructive procedures undertaken in Pediatric urology makes this specialty amenable to robotic surgery with the additional benefits of precise suturing, enhanced stereoscopic visualization with magnification and increased dexterity during suturing provided by the multi-jointed robotic instruments.

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Factors which have limited the uptake of robotic surgery in the pediatric population include the initial capital outlay and maintenance costs, the lack of pediatric sized ports and the smaller working space compared to the adult population. The smaller working space in children is overcome by using the transperitoneal route where possible. In addition to this, the thin abdominal wall in pediatric patients presents a problem with anchoring the trocars particularly during instrument exchange. Despite these limitations, centers which have embarked on a robotic surgery program have shown good outcomes with comparable morbidity rates in procedures such as pyeloplasty [1]. However, there is a clear lack of randomized controlled trials comparing robotic surgery to conventional procedures providing evidence of improved outcome.

The ideal application of the robot in the pediatric population is in procedures requiring delicate suturing such as pyeloplasty although the use of robotic surgery has been reported in a wide range of other pediatric procedures.

## Pediatric upper tract surgery

### Robot assisted pyeloplasty

Pediatric pyeloplasty is by far the commonest procedure performed using the da Vinci robot. The procedure can be performed retroperitoneally based on the same concepts as laparoscopic pyeloplasty. The transperitoneal route with transmesenteric or retrocolic exposure of the renal pelvis has also been performed. The port placements utilized in a pyeloplasty are illustrated in Fig. 1. The surgical steps following port placement are similar to those performed during minimally invasive laparoscopic surgery (Fig. 2) with 6-0 monofilament sutures used for the anastomosis.

Olsen et al. [1] published the first report on robot assisted retroperitoneoscopic pyeloplasty. A total of 15 pyeloplasties were performed in a series comprising 13 children using the da Vinci Surgical System with 4 ports. The results reported no perioperative complications and a median post-operative hospital stay of 2 days (range, 1–3). A total of two patients had post-operative complications, which were related to the JJ stent (one occlusion and one displacement). A follow-up period of up to 7 months showed that there was no obstruction based on MAG3 diuretic renography. This group concluded that the operating time was comparable to laparoscopic pyeloplasty with similar morbidity rates. A 5-year follow-up study [2] from the same group involving 67 pyeloplasties in a total of 65 children reported a median operative time of 143 min with complications occurring in 12 of the 67 procedures (18%). Only one case in this series required conversion to an open procedure. The reoperation rate was reported to be 6%. This group concluded that robot assisted retroperitoneoscopic pyeloplasty allowed direct access to the ureteropelvic junction with comparable outcomes to transperitoneal robot assisted pyeloplasty as well as both the laparoscopic and open techniques employed in the pediatric surgery.

**Fig. 1** Illustration of port placement during a robot assisted pyeloplasty

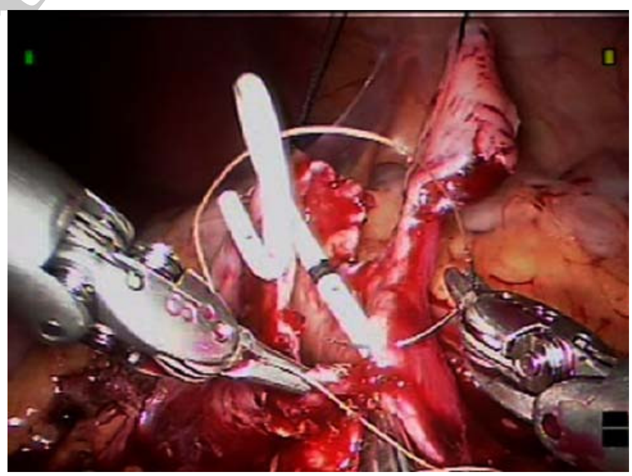

**Fig. 2** Anastomosis of the renal pelvis to the spatulated ureter performed over a JJ stent during robot assisted pyeloplasty





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The transperitoneal approach in children has recently been compared to open pyeloplasty in two series [3, 4]. Lee et al. [3] compared 33 age matched children undergoing open and robot assisted laparoscopic pyeloplasty for safety, efficacy, operative time, blood loss, in-hospital narcotic use and length of stay. Robotic pyeloplasty was deemed safe and efficacious with the added advantages of decreased hospital stay, decreased narcotic use and operative times approaching those of open surgery. In a smaller study by Yee et al. [4] the da Vinci robotic-assisted laparoscopic pyeloplasty was compared to a standard open Anderson–Hynes pyeloplasty in eight children matched by age group. This study found that although robotic-assisted laparoscopic pyeloplasty appeared to reduce the length of hospitalization and analgesic requirements, it was associated with a longer mean operative time in the robot assisted group. (363 min compared to 248 min in the open group). More recently, Kutikov et al. [5] reported on their experience of robotically assisted pyeloplasty in infants (mean age 5.6 months). This series of nine patients reported a mean operative time of 122.8 min. Post-operatively, seven patients were reported to have a resolution or improvement in the pre-operative hydronephrosis and two had no evidence of obstruction on follow-up diuretic renography.

From these initial studies and those listed in Table 1, robotic-assisted pyeloplasty is technically feasible with no significant increase in morbidity rates. Long-term follow-up of these patients is required in order to compare the recurrence rates with laparoscopic and open procedures before robot assisted pyeloplasty becomes the treatment option of choice.

## Robot assisted pyelolithotomy

Robot assisted pyelolithotomy has been reported in a limited number of patients with complex stones. The procedure uses a transperitoneal approach to the renal pelvis. The renal pelvis is incised using non electrified scissors and robotic graspers are used to remove the stone. Peters et al. [6] retrospectively reviewed their experience with robotic pyelolithotomy in five patients (mean age 16.6 years), and mean follow-up of 15.4 months. The mean operative time was 315 min (range, 165–462) with a mean hospital stay of 3.8 days (range, 2.3–5.7). Of the four cases completed robotically three were rendered stone-free and one had a residual 6-mm lower pole stone. One patient with a staghorn calculus composed of cystine required conversion to an open procedure because of the inability to remove the stone. When successful, this procedure avoided the need for pediatric patients to undergo multiple procedures such as repeated ESWL or multitrack PCNL in order to render them stone-free. However, this type of surgery is still in the early stages of development and still requires prospective studies to establish the long-term benefits compared to alternative minimally invasive procedures.

## Partial nephrectomy

The management of duplex anomalies together with the associated complications is universal in pediatric urological practice. Laparoscopic partial nephrectomy for non-functioning upper or lower pole moieties has been shown to shorten the post-operative recovery period and hospital stay with comparable operative times to open surgery [7]. Robot assisted heminephrectomy is particularly appealing as it allows precise dissection of the moiety followed by reconstruction. Currently, the clinical experience is limited to case reports or small series. Pedraza et al. [8] performed bilateral robot assisted heminephroureterectomy, in a 4-year-old girl using the da Vinci system. Excision of the upper moiety was performed using a Harmonic scalpel followed by argon beam fulguration of the base. The operating time was 7.5 h reflecting the complexity of the case which involved a bilateral procedure, with a total blood loss of 15 ml and no perioperative complications were reported. A further series consisting of 14 patients utilized a retroperitoneal approach to perform an upper pole heminephrectomy [9]. The technique involved excision of the upper pole by either diathermy or ultrasonic scissors. The median operative time was 176 min (range, 120–360 min) with two cases requiring open conversion, one for hemorrhage and the other due to a lack of progress.



**Table 1** Comparison of robot assisted pyeloplasty in the pediatric population

| Study | No of cases | Mean/median age (years) | Operative time (mins) | Complications |
|---|---|---|---|---|
| Yee et al. [4] | 8 | 11.5(6.4–16.5) | 363 (255–522) | Ileus[1] |
| Kutikov et al. [5] | 9 | 0.5 (0.3–0.7) | 123 | |
| Atug et al. [17] | 7 | 13 (6–15) | 184 | Prolonged drainage [2] |
| Olsen et al. [2] | 67 | 7.9 (1.7–17.3) | 146 (92–300) | UTI [2], hematuria [2], nephrostomy [4], displaced JJ stent [3] |
| Lee et al. [3] | 33 | 7.9 (0.2–19.6) | 219 (133–401) | |
| Najmaldin and Antao [10] | 13 | Not available | 214 (180–280) | |



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This group concluded that although the robot offered advantages such as accurate visualization of the moieties and precise vascular control, further development of the instruments is required before the resection of a non-functioning upper pole could be firmly included in the spectrum of indications for robotic surgery.

Orchidopexy

Orchidopexy does not utilize the precise suturing available using the robot. However, the increased dexterity available using the robot can enable surgeons to perform a minimally invasive procedure without having laparoscopic experience. A single case of bilateral orchidopexy combined with excision of a Mullerian remnant has been reported by Najmaldin and Antao [10] in their series of 50 procedures. The robotic operating time was 105 mins and the total hospital stay was 5 days. At present there does not appear to be a major benefit over the laparoscopic approach for performing orchidopexy.

## Pediatric pelvic surgery

Antireflux surgery

The development and progress of laparoscopic antireflux surgery has been slow mainly due to the antireflux procedures requiring difficult dissection followed by suturing of the bladder. Robot assisted antireflux surgery provides an excellent view of the pelvis with the added benefit of precise suturing of the bladder, ureters and urethra Olsen et al. [11] initially described a successful transvesical robotic-assisted approach for the Cohen transtrigonal ureteric reimplantation using a pig model.

Recent reports have described both extra- and intravesical approaches for antireflux surgery in children [12]. With appropriate instrumentation, the pediatric urologist has the ability to angle the instruments during the development of the submucosal tunnel and the suturing of the vesico-ureteral anastomosis. A robotically assisted Lich–Gregoir procedure has also been described [13]. Although technically feasible, the results showed that 2 of 17 patients had persisting reflux thus raising the question as to whether an adequate submucosal tunnel can be developed with the use of the robot. This is a lower success rate than that of open extravesical ureteroplasty, which should have a close to 100% success. The current working instruments of the da Vinci system with a diameter of 8 mm and a camera port of 12 mm give rise to concerns about proper bladder closure at the end of the procedure, especially in younger children with a small bladder capacity. The new and smaller 5-mm instruments may remove some of these drawbacks.

Mitrofanoff procedure

Technically complex procedures such as the Mitrofanoff procedure [9] have also been reported [14]. The procedure performed in a 7-year-old boy involved a total operating time of 6 h with a total blood loss of 10 ml. Passerotti et al. [15] have also reported their experience of performing two Mitrofanoff procedures using appendix together with one revision. Robot assisted Mitrofanoff procedures are technically very challenging but avoid the larger abdominal incisions traditionally employed.

Miscellaneous procedures

Further procedures which have been performed in the pediatric population using robot assisted techniques include the correction of a retrocaval ureter [16], bladder neck sling [15], pyelo-ureterostomy [15] but larger series have yet to be reported in order to allow comparison with open or laparoscopic techniques for these procedures.

## Conclusions

Robotic technology in pediatric urological surgery is currently in its infancy. The early available results with robotically assisted surgery are encouraging and there appears to be a rapidly growing body of evidence to support that this type of surgery is technically possible and safe. The reconstructive nature of pediatric urology lends itself to the advantages of robotic technology particularly pyeloplasty procedures. The advantage in other areas may not be as good as the current "gold standards", particularly due to cost effectiveness issues.

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