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Authors: Asif Muneer · Mani 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 (separated by '-') Pediatric - Urology - Pyeloplasty - Minimally invasive - Robotic

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2 Current status of robotic surgery in pediatric urology

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4 Dev Sharma · Mohammed Y. Hammadeh ·
5 Imran Mushtaq

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8 **Abstract** Robotic-assisted pediatric urological surgery
9 has emerged as a valid and reliable surgical therapy, which
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15 robotic surgery has been reported in a wide range of other
16 procedures, particularly the diverse reconstructive pediatric
17 operations. In this article, we review the current indications
18 and results of robotics in the management of pediatric
19 pathology.

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

24 Introduction

25 The advances in minimally invasive surgery have inevita-
26 bly improved perioperative outcomes. The superior visual
27 field, reduction in the stress response to surgery combined
28 with a shorter postoperative recovery time with a superior
29 cosmetic result has led to patients electing for the mini-
30 mally invasive option where available.

31 Since 1988 the da Vinci robot (Intuitive Surgical,
32 Sunnyvale, CA) has been instrumental in the clinical
33 development of robotic surgery in adults. Successful

outcomes have been reported in adult surgery mainly in 34
the specialties of cardiothoracic, gastrointestinal and 35
urological surgery. Although the Zeus system (Computer 36
Motion, Goleta, CA) was originally available as a sepa- 37
rate system, the merger of the da Vinci and Zeus system 38
has resulted in the da Vinci robot being exclusive for 39
clinical use. The da Vinci robot is a master slave device 40
approved for use in humans. The surgeon sits at a console 41
which provides an ergonomic environment to perform 42
surgery and has a view of the surgical field from the 43
console using a fully stereoscopic binocular visual system. 44
The hand movements from the console are digitalized 45
allowing movements of the robotic arm in real time with 46
seven degrees of freedom (DOF) with the advent of En- 47
doWrist technology. The tactile and force feedback 48
otherwise known as haptic feedback can provide useful 49
feedback to the surgeon. The robotic software eliminates 50
fine tremors to allow precise suturing. Currently the 51
robotic device utilized in the Pediatric and adult popula- 52
tion is identical utilizing 12-mm camera ports and 8-mm 53
working ports. 54

The uptake of robotic surgery in pediatric urology has 55
been restricted to a few international centers. Pediatric 56
surgeons have evaluated the potential for robotic surgery 57
since the beginning of the decade in procedures such as 58
fundoplication and pyeloplasty. Compared to robotic sur- 59
gery, minimally invasive laparoscopic surgery allows four 60
DOF and therefore intracorporeal suturing during recon- 61
structive procedures is particularly demanding. The diverse 62
reconstructive procedures undertaken in Pediatric urology 63
makes this specialty amenable to robotic surgery with the 64
additional benefits of precise suturing, enhanced stereo- 65
scopic visualization with magnification and increased 66
dexterity during suturing provided by the multi-jointed 67
robotic instruments. 68

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69 Factors which have limited the uptake of robotic surgery
 70 in the pediatric population include the initial capital outlay
 71 and maintenance costs, the lack of pediatric sized ports and
 72 the smaller working space compared to the adult popula-
 73 tion. The smaller working space in children is overcome by
 74 using the transperitoneal route where possible. In addition
 75 to this, the thin abdominal wall in pediatric patients pre-
 76 sents a problem with anchoring the trocars particularly
 77 during instrument exchange. Despite these limitations,
 78 centers which have embarked on a robotic surgery program
 79 have shown good outcomes with comparable morbidity
 80 rates in procedures such as pyeloplasty [1]. However, there
 81 is a clear lack of randomized controlled trials comparing
 82 robotic surgery to conventional procedures providing evi-
 83 dence of improved outcome.

84 The ideal application of the robot in the pediatric popu-
 85 lation is in procedures requiring delicate suturing such as
 86 pyeloplasty although the use of robotic surgery has been
 87 reported in a wide range of other pediatric procedures.

88 **Pediatric upper tract surgery**

89 Robot assisted pyeloplasty

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

100 Olsen et al. [1] published the first report on robot
 101 assisted retroperitoneoscopic pyeloplasty. A total of 15
 102 pyeloplasties were performed in a series comprising 13
 103 children using the da Vinci Surgical System with 4 ports.
 104 The results reported no perioperative complications and a
 105 median post-operative hospital stay of 2 days (range, 1–3).
 106 A total of two patients had post-operative complications,
 107 which were related to the JJ stent (one occlusion and one
 108 displacement). A follow-up period of up to 7 months
 109 showed that there was no obstruction based on MAG3
 110 diuretic renography. This group concluded that the oper-
 111 ating time was comparable to laparoscopic pyeloplasty
 112 with similar morbidity rates. A 5-year follow-up study [2]
 113 from the same group involving 67 pyeloplasties in a total of
 114 65 children reported a median operative time of 143 min
 115 with complications occurring in 12 of the 67 procedures
 116 (18%). Only one case in this series required conversion to
 117 an open procedure. The reoperation rate was reported to be

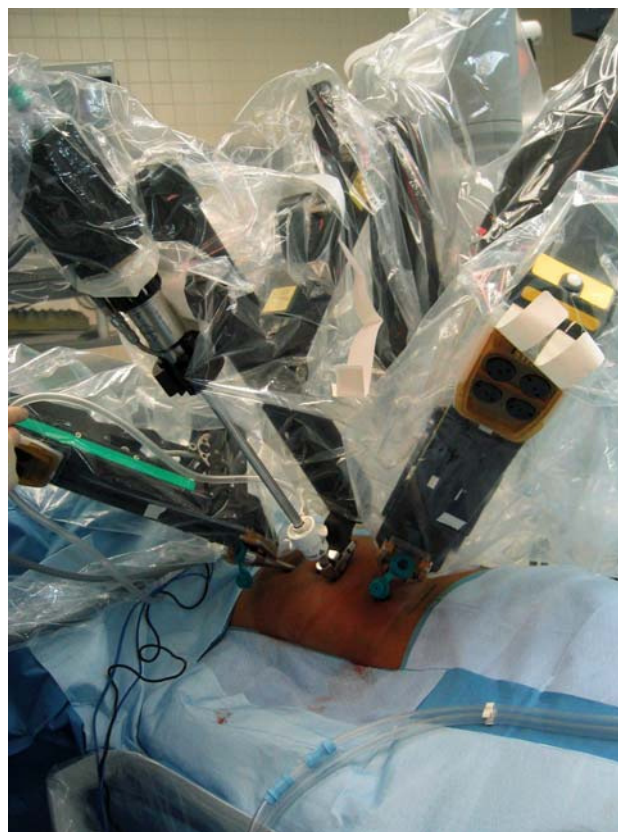


Fig. 1 Illustration of port placement during a robot assisted pyeloplasty

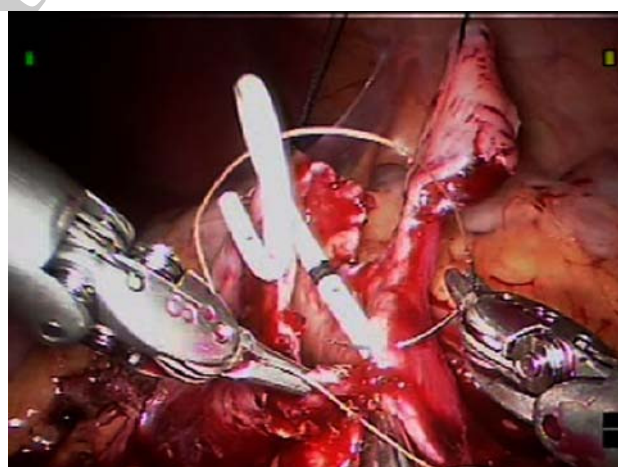


Fig. 2 Anastomosis of the renal pelvis to the spatulated ureter performed over a JJ stent during robot assisted pyeloplasty

6%. This group concluded that robot assisted retroperito- 118
 neoscopic pyeloplasty allowed direct access to the 119
 ureteropelvic junction with comparable outcomes to 120
 transperitoneal robot assisted pyeloplasty as well as both 121
 the laparoscopic and open techniques employed in the 122
 pediatric surgery. 123

124 The transperitoneal approach in children has recently
 125 been compared to open pyeloplasty in two series [3, 4]. Lee
 126 et al. [3] compared 33 age matched children undergoing
 127 open and robot assisted laparoscopic pyeloplasty for safety,
 128 efficacy, operative time, blood loss, in-hospital narcotic use
 129 and length of stay. Robotic pyeloplasty was deemed safe
 130 and efficacious with the added advantages of decreased
 131 hospital stay, decreased narcotic use and operative times
 132 approaching those of open surgery. In a smaller study by
 133 Yee et al. [4] the da Vinci robotic-assisted laparoscopic
 134 pyeloplasty was compared to a standard open Anderson–
 135 Hynes pyeloplasty in eight children matched by age group.
 136 This study found that although robotic-assisted laparo-
 137 scopic pyeloplasty appeared to reduce the length of
 138 hospitalization and analgesic requirements, it was associ-
 139 ated with a longer mean operative time in the robot assisted
 140 group. (363 min compared to 248 min in the open group).
 141 More recently, Kutikov et al. [5] reported on their experi-
 142 ence of robotically assisted pyeloplasty in infants (mean
 143 age 5.6 months). This series of nine patients reported a
 144 mean operative time of 122.8 min. Post-operatively, seven
 145 patients were reported to have a resolution or improvement
 146 in the pre-operative hydronephrosis and two had no evi-
 147 dence of obstruction on follow-up diuretic renography.

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

155 Robot assisted pyelolithotomy

156 Robot assisted pyelolithotomy has been reported in a lim-
 157 ited number of patients with complex stones. The
 158 procedure uses a transperitoneal approach to the renal
 159 pelvis. The renal pelvis is incised using non electrified
 160 scissors and robotic graspers are used to remove the stone.
 161 Peters et al. [6] retrospectively reviewed their experience
 162 with robotic pyelolithotomy in five patients (mean age

16.6 years), and mean follow-up of 15.4 months. The mean
 163 operative time was 315 min (range, 165–462) with a mean
 164 hospital stay of 3.8 days (range, 2.3–5.7). Of the four cases
 165 completed robotically three were rendered stone-free and
 166 one had a residual 6-mm lower pole stone. One patient with
 167 a staghorn calculus composed of cystine required conver-
 168 sion to an open procedure because of the inability to
 169 remove the stone. When successful, this procedure avoided
 170 the need for pediatric patients to undergo multiple proce-
 171 dures such as repeated ESWL or multitrack PCNL in order
 172 to render them stone-free. However, this type of surgery is
 173 still in the early stages of development and still requires
 174 prospective studies to establish the long-term benefits
 175 compared to alternative minimally invasive procedures. 176

177 Partial nephrectomy

178 The management of duplex anomalies together with the
 179 associated complications is universal in pediatric urologi-
 180 cal practice. Laparoscopic partial nephrectomy for non-
 181 functioning upper or lower pole moieties has been shown
 182 to shorten the post-operative recovery period and hospital
 183 stay with comparable operative times to open surgery [7].
 184 Robot assisted heminephrectomy is particularly appealing
 185 as it allows precise dissection of the moiety followed by
 186 reconstruction. Currently, the clinical experience is limited
 187 to case reports or small series. Pedraza et al. [8] performed
 188 bilateral robot assisted heminephroureterectomy, in a
 189 4-year-old girl using the da Vinci system. Excision of the
 190 upper moiety was performed using a Harmonic scalpel
 191 followed by argon beam fulguration of the base. The
 192 operating time was 7.5 h reflecting the complexity of the
 193 case which involved a bilateral procedure, with a total
 194 blood loss of 15 ml and no perioperative complications
 195 were reported. A further series consisting of 14 patients
 196 utilized a retroperitoneal approach to perform an upper
 197 pole heminephrectomy [9]. The technique involved exci-
 198 sion of the upper pole by either diathermy or ultrasonic
 199 scissors. The median operative time was 176 min (range,
 200 120–360 min) with two cases requiring open conversion,
 201 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) | |

| | | | |
|-----|--|---|-----|
| 202 | This group concluded that although the robot offered | smaller 5-mm instruments may remove some of these | 248 |
| 203 | advantages such as accurate visualization of the moieties | drawbacks. | 249 |
| 204 | and precise vascular control, further development of the | | |
| 205 | instruments is required before the resection of a non- | | |
| 206 | functioning upper pole could be firmly included in the | | |
| 207 | spectrum of indications for robotic surgery. | | |
| 208 | Orchidopexy | | |
| 209 | Orchidopexy does not utilize the precise suturing available | | |
| 210 | using the robot. However, the increased dexterity available | | |
| 211 | using the robot can enable surgeons to perform a minimally | | |
| 212 | invasive procedure without having laparoscopic experi- | | |
| 213 | ence. A single case of bilateral orchidopexy combined with | | |
| 214 | excision of a Mullerian remnant has been reported by | | |
| 215 | Najmaldin and Antao [10] in their series of 50 procedures. | | |
| 216 | The robotic operating time was 105 mins and the total | | |
| 217 | hospital stay was 5 days. At present there does not appear | | |
| 218 | to be a major benefit over the laparoscopic approach for | | |
| 219 | performing orchidopexy. | | |
| 220 | Pediatric pelvic surgery | | |
| 221 | Antireflux surgery | | |
| 222 | The development and progress of laparoscopic antireflux | | |
| 223 | surgery has been slow mainly due to the antireflux proce- | | |
| 224 | dures requiring difficult dissection followed by suturing of | | |
| 225 | the bladder. Robot assisted antireflux surgery provides an | | |
| 226 | excellent view of the pelvis with the added benefit of | | |
| 227 | precise suturing of the bladder, ureters and urethra Olsen | | |
| 228 | et al. [11] initially described a successful transvesical | | |
| 229 | robotic-assisted approach for the Cohen transtrigonal ure- | | |
| 230 | teric reimplantation using a pig model. | | |
| 231 | Recent reports have described both extra- and intra- | | |
| 232 | vesical approaches for antireflux surgery in children [12]. | | |
| 233 | With appropriate instrumentation, the pediatric urologist | | |
| 234 | has the ability to angle the instruments during the devel- | | |
| 235 | opment of the submucosal tunnel and the suturing of the | | |
| 236 | vesico-ureteral anastomosis. A robotically assisted Lich- | | |
| 237 | Gregoir procedure has also been described [13]. Although | | |
| 238 | technically feasible, the results showed that 2 of 17 patients | | |
| 239 | had persisting reflux thus raising the question as to whether | | |
| 240 | an adequate submucosal tunnel can be developed with the | | |
| 241 | use of the robot. This is a lower success rate than that of | | |
| 242 | open extravesical ureteroplasty, which should have a close | | |
| 243 | to 100% success. The current working instruments of the | | |
| 244 | da Vinci system with a diameter of 8 mm and a camera | | |
| 245 | port of 12 mm give rise to concerns about proper bladder | | |
| 246 | closure at the end of the procedure, especially in younger | | |
| 247 | children with a small bladder capacity. The new and | | |
| | | Mitrofanoff procedure | 250 |
| | | Technically complex procedures such as the Mitrofanoff | 251 |
| | | procedure [9] have also been reported [14]. The procedure | 252 |
| | | performed in a 7-year-old boy involved a total operating | 253 |
| | | time of 6 h with a total blood loss of 10 ml. Passerotti et al. | 254 |
| | | [15] have also reported their experience of performing two | 255 |
| | | Mitrofanoff procedures using appendix together with one | 256 |
| | | revision. Robot assisted Mitrofanoff procedures are tech- | 257 |
| | | nically very challenging but avoid the larger abdominal | 258 |
| | | incisions traditionally employed. | 259 |
| | | Miscellaneous procedures | 260 |
| | | Further procedures which have been performed in the | 261 |
| | | pediatric population using robot assisted techniques | 262 |
| | | include the correction of a retrocaval ureter [16], bladder | 263 |
| | | neck sling [15], pyelo-ureterostomy [15] but larger series | 264 |
| | | have yet to be reported in order to allow comparison with | 265 |
| | | open or laparoscopic techniques for these procedures. | 266 |
| | | Conclusions | 267 |
| | | Robotic technology in pediatric urological surgery is cur- | 268 |
| | | rently in its infancy. The early available results with | 269 |
| | | robotically assisted surgery are encouraging and there | 270 |
| | | appears to be a rapidly growing body of evidence to sup- | 271 |
| | | port that this type of surgery is technically possible and | 272 |
| | | safe. The reconstructive nature of pediatric urology lends | 273 |
| | | itself to the advantages of robotic technology particularly | 274 |
| | | pyeloplasty procedures. The advantage in other areas may | 275 |
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