7 Robotic Surgery in Pediatric Urology: State of the Art and Future Horizons

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7.1 Background and History

Robotic surgery has been clinically available for surgeons since 2000 with the approval in the USA of the da Vinci (Intuitive Surgical Corp., Sunnyvale, CA) and Zeus Systems (Computer Motion-now defunct). Two robotic surgical systems emerged from research at the Stanford University and the Stanford Research Institute (now SRI). While the definition of robot can vary, with some feeling it must include some degree of programmable automation; others consider any electromechanical device including a computer that can perform some physical function to be a robot. The term has certainly moved into common usage, and classification systems are in process.

Early pediatric uses were in general surgery and urology, using the Zeus System and the da Vinci beginning in 2002 [1–5]. At this time, complex *laparoscopic surgery* in children was uncommon, although well described. This limited use, while adult applications were developing rapidly, was in part due to the complexity of the technique and the difficulty in developing sufficient skill to perform a reliable procedure that involved reconstructive elements. The potential to have the ability to use minimally invasive techniques to perform common operations with ease and general proficiency was appealing. The cost, however, limited access to the system to mainstream pediatric surgical subspecialists, except in a few institutions. A slow progression of reports demonstrated that the da Vinci System could be used in children safely and successfully. The Zeus System faded from use due to purchase of Computer Motion by Intuitive Surgical to halt several intellectual property lawsuits. The Zeus System had several features that made it more adaptable to children, however, including 5 mm instruments, a smaller footprint, and a lower price. Nonetheless, the da Vinci System became the only commercially available surgical robotic system by 2004.

As more children's hospitals acquired the da Vinci and more pediatric surgical specialists partnered with their adult colleagues in general hospitals, the use of the system in children steadily grew. This growth was nearly all in *pediatric urology*, however, as pediatric general surgery did not actively explore its utility except for isolated anecdotal cases [6, 7]. With increasing usage came increasing complexity and a wider range of ages being operated on, as well as the development of several instructional courses.

7.2 Current Technology

At present the da Vinci Surgical System, model Si, is the available technology. It consist of a *four-arm surgical unit* that includes one robotic

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arm for the binocular endoscope, which is available in a 12 and 8.5 mm size and adapts to an Intuitive metal cannula or one of several plastic cannulae. Three arms are available for working instruments, but the fourth arm utilization can be difficult in smaller children, and it is not used regularly by many surgeons.

Working instruments are available in 8 and 5 mm sizes, each with a size-appropriate cannula that must be utilized. The 8 mm instruments are the original design and articulate smoothly by way of hinge joints very close to the tips of the instruments. In contrast, the 5 mm instruments were subsequently introduced and articulate by means of a series of partially articulated vertebra-like components. The articulation is less smooth and responsive and requires more room to turn. This can challenge their use in small spaces.

The 8 mm working instruments most commonly used include a *needle driver* that is rather blunt, a Maryland dissector that has bipolar cautery capacity, a curved scissor with monopolar cautery, and several different graspers for larger tissues or objects. A monopolar *hook cautery* instrument was the original cauterized instrument and continues to be a very useful tool for dissection, cutting, and hemostasis. There is also a very fine tip needle driver (diamond-tipped forceps) that can be used for very fine needles, although it is not very useful for tissue handling. A recent addition is the 8 mm *suction irrigator* with an articulated blunt tip that is very good for dissection. A needle driver with a scissor is available but can be difficult to use without inadvertently cutting the suture as it is being used to tie knots.

The 5 mm instruments include a needle driver that is blunt, a non-cautery curved scissor, a non-cautery Maryland dissector, and the hook cautery.

The 8 mm instrument *cannulae* include a reducing adapter to permit passage of smaller (5 mm) instruments without causing a gas leak as well as a plastic pointed but non-cutting obturator for introduction. The *obturator* is attached to the metal cannula with snaps to permit introduction and easy removal of the obturator. The 5 mm cannulae are not as well designed and have a rigid valve system that can snap off too easily, and the only obturator is metal, blunt tipped, and non-clipped. This makes introduction challenging and potentially dangerous as too much force may be applied in the absence of a pointed tip.

7.3 Basic Methods

7.3.1 Patient Positioning

Positioning is the first critical step in any robotic procedure. Renal procedures require the use of gravity to facilitate retraction and exposure. The method preferred by the author is to permit rotation of the patient with the endoscope in place to adjust the degree of lateral angulation. For *pyeloplasty*, this facilitates using the transmesenteric approach rather than having to mobilize the colon.

Patients are placed on an ipsilateral roll or wedge to raise the side and secured on the table with several straps, and the arms are placed along the sides and held in place by a strap or folded towel running behind the lumbar region and over each arm which is padded. A chest and thigh strap keeps the patient from moving. The operating table can be rotated to position the abdomen flat with the floor for access and then rotated to raise the ipsilateral side to the degree needed. This position is quick to set up, will hold infants to large adolescents securely, and is easily adjusted. It can permit rapid access to the abdomen in an emergency as well [8].

For bladder procedures, the patient is supine, and for larger children, a chest strap is used, as the *Trendelenburg position* is useful for exposure. Tall patients should be positioned with the legs split and carefully supported to allow the robotic surgical cart to fit between.

7.3.2 Port Placement

Many early users found challenges with the introduction of the working ports, although this can be simple with a systematic approach. *Open technique* is recommended for the initial port, although some use the *Veress technique*. The author's preferred method is to use an inferior intra-umbilical incision with stepwise cutting down to the peritoneum.

Once the peritoneum is entered and the field is visually clear, the size is stretched to accommodate the size of the cannula to be used. A fascial suture of 3-0 polyglycolic acid is placed in a *box stitch* manner using a CT-2 needle that has been curved to make it resemble a UR-6 needle or a 2-0 polyglycolic acid suture on a UR-6 is used in children over age 7 [9]. The box stitch then facilitates introducing the cannula into the peritoneum and will be used to close the fascia at the end of the procedure. The abdomen is insufflated, and the two or three working ports are placed under vision with a pre-placed fascial box stitch as with the initial port. The stitch facilitates placement and closure. It should be seen passing through the peritoneum to ensure a secure closure. Any assistant ports are placed at this time. Port placement should not take more than 10 or 15 min in most cases.

7.3.3 Dissection and Exposure

Dissection with the da Vinci System is similar to that used in conventional laparoscopy with a combination of sharp and blunt dissection, the sharp utilizing the hook cautery or the scissors. The surgeon should be aware that overly aggressive blunt dissection without *cautery* could cause bleeding that may obscure the field. The use of traction and countertraction greatly facilitates dissection. The advantage of the 3-D visualization and the articulation of the instruments is a subjective advantage over conventional laparoscopy, even in skilled hands. This is particularly the case with delicate exposure of renal vasculature and the ureter. At the same time, the absence of tactile feedback (*haptics*) can be troublesome if the surgeon is not carefully visualizing the tissues at all times. Excessive traction can be damaging, and overly aggressive dissection of delicate structures such as the ureter may risk devascularization. Similarly, great care needs to be paid to use of cautery, and all surrounding tissues should be away from the current, and awareness of the "hot" parts of the instrument should be constant. It is probably unwise to use a passive instrument such as a dissector to apply cautery by touching, as this risks contacting adjacent structures inadvertently.

Retraction is also a challenge, and the most effective tools are *hitch stitches*. These may be used by passing a suture through the body wall, through the object to be hitched, and then back out the body wall (Fig. 7.1). This permits adjustment of tension but is limited in its position. Intracorporeal hitches can be used for children with very thick abdominal walls, or a hook device can be rigged for adjustable and moveable hitching.

Passing *suture needles* into the field can slow down any procedure. The most efficient approach is to use small needles and make sure that the instrument being used to take the needle and suture inside is smaller than the cannula (i.e., 3.5 mm grasper for 5 mm cannula and a 5 mm grasper or needle driver for the 8 mm cannula). The suture should be grasped and not the needle to prevent the needle from pulling off.

7.3.4 Ureteral Stenting

Placing a double J stent for ureteral reconstruction may be accomplished either retrograde or antegrade. Retrograde placement is typically prior to the start of the robotic portion of the procedure in the usual fashion. This does require extra time but permits the use of an extraction string for stent removal without cystoscopy.

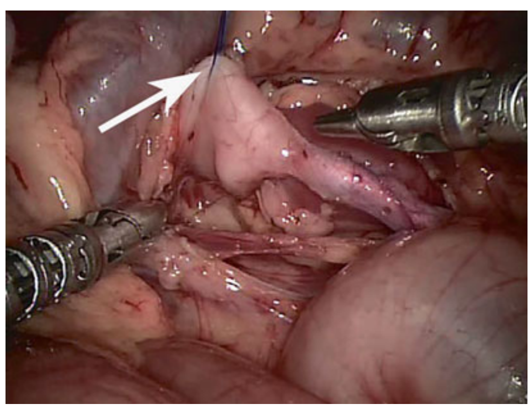

Fig. 7.1 Hitch stitch in place during robotic pyeloplasty. The renal pelvis is elevated and stabilized by the stitch (*arrow*), which is passed through the abdominal wall, through the medial aspect of the pelvis and out the abdominal wall

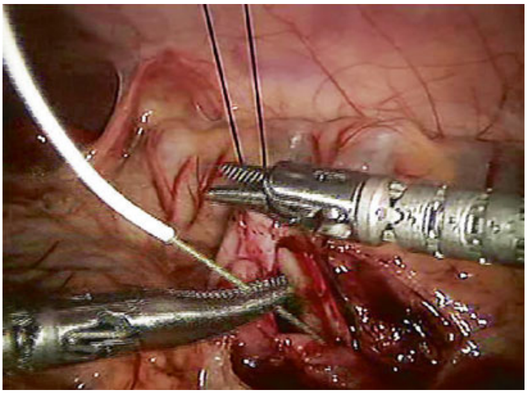

Fig. 7.2 Antegrade passage of a double J ureteral stent during pyeloplasty. The guidewire has been passed through a percutaneous angiocatheter and then down the ureter with the stent passed over the guidewire and directed into the ureter

Alternatively, *antegrade stent placement* can be very efficient. This is best performed by passing a 14 G angiocatheter through the abdominal wall at a location in line with the direction of the course of the stent and removing the needle. For smaller stents that can pass through a 14G angiocatheter (3.7 Fr and 4.8 Fr), the stent is pre-loaded on a guidewire with the flexible tip leading. This is passed through the angiocatheter then guided into the ureter (Fig. 7.2). The wire and stent are passed slowly down the ureter, watching for recoiling or excessive tension on the *ureter*. Usually this will pass very easily but can occasionally hang up. Using a smaller wire may help. The appropriate length can be estimated by the formula 10 cm plus age in years, and an extra 2 cm is useful. Some surgeons will fill the bladder with blue dye (indigo carmine or methylene blue) to signal when the bladder is entered, but this has not always been successful. Some have suggested an intraoperative US to identify the curl of the stent in the bladder, or a can be obtained in the operating room to confirm placement. Postoperative drainage is dependent upon the procedure and the surgeon's preferences.

7.3.5 Completion

Completion of the procedure should include a brief inspection of the operative field and the *peritoneum* to look for pooling of blood or irrigation or any inadvertent injury to an adjacent structure. This is usually done after the robot is disengaged and withdrawn. If significant dissection was undertaken, it can be useful to lower the intraperitoneal pressure for 2 or 3 min and reinspect for venous bleeding that was limited by the insufflation pressure. The working ports are removed under vision with the *pneumoperitoneum* in place to prevent catching any structures in the closure. The fascial sutures are tied, which closes the defect, and if there is no gas leak, this indicates a secure closure. The remainder of the insufflation gas is evacuated through the umbilical port, which is then removed, and the fascial suture is tied. Skin incisions are closed with a subcutaneous stitch followed by a subcuticular stitch if needed.

7.4 Principal Procedures

7.4.1 Pyeloplasty

The most common procedure in pediatric urology for which the da Vinci System has been used is *pyeloplasty*, and it is readily accomplished at all ages [10–12]. Three ports are used, with the endoscope and two *working ports*. Placement is typically umbilical for the endoscope and midline between the umbilicus and xiphoid for the first working port. The patient is then tilted to reveal the kidney and locate the UPJ to guide placement of the third port in the ipsilateral lower quadrant. It should not be too close to the site of the UPJ, or the instrument may not have enough room to maneuver. We have used a midline port placement in small children or those undergoing bilateral pyeloplasties, and this is very acceptable as long as the bladder is avoided. An alternative port placement strategy has been presented to limit any visible port site scars [13].

The left UPJ can be exposed *transmesenterically* in most cases, while on the right the hepatic flexure needs to be mobilized. Once the pelvis and ureter are identified, the ureter is lifted, the UPJ and pelvis further exposed, and the site of the hitch stitch identified. It should be

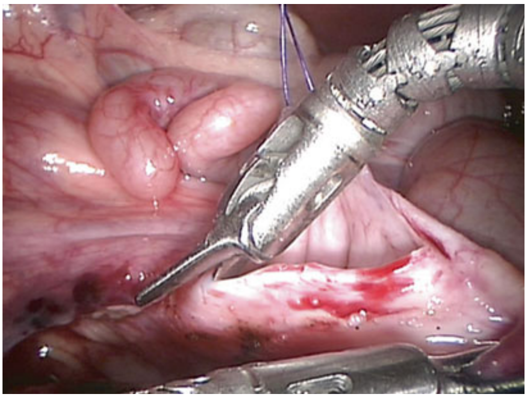

Fig. 7.3 Opening of the renal pelvis on a right-sided pyeloplasty. The hitch stitch is visible lateral to the pyelotomy. The UPJ is relatively low as seen by the presence of the appendix just lateral to the UPJ

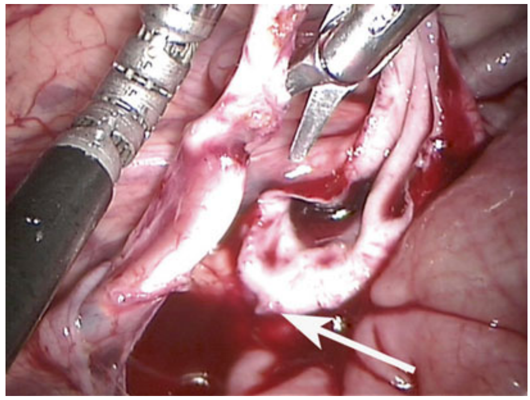

Fig. 7.4 Spatulation of the lateral aspect of the dismembered ureter using the 5 mm straight scissors. The open renal pelvis is visible with the most dependent portion indicated by the *arrow*

at the most medial aspect of the pelvis at the top of the planned pyelotomy. This provides orientation to the pelvis and what will be the most dependent portion of the pelvis. The *ureter* is not mobilized excessively. The pelvis is incised from either top down or bottom up and left on the ureter to serve as a handle (Fig. 7.3). The ureter is then spatulated on its lateral aspect, either by cutting through the UPJ or into the upper ureter. The length of the *spatulation* is best indicated by the visual opening of the ureter, which should admit the tips of the scissors (Fig. 7.4). If a stent has been pre-placed, it should be avoided.

The *anastomosis* is begun, usually on the dependent or posterior wall, starting with the inferior-most apex stitch (Fig. 7.5). Suture used depends on age and preference. Because it moves smoothly through tissues, an absorbable *monofilament* is favored in most cases, with 6-0 for infants and 5-0 for older children. This may be placed in a continuous manner, which is preferred due to uniform tension and watertightness (Fig. 7.6a, b). The anastomosis may be performed with interrupted suture as well, but this requires more time. If a stent is to be placed antegrade, this is done after the first side of the anastomosis. Otherwise, the anterior side of the pelvi-ureteric anastomosis is closed (Fig. 7.7). No other drains are usually used, and a bladder catheter is left in place overnight. Most children can be discharged home the next morning.

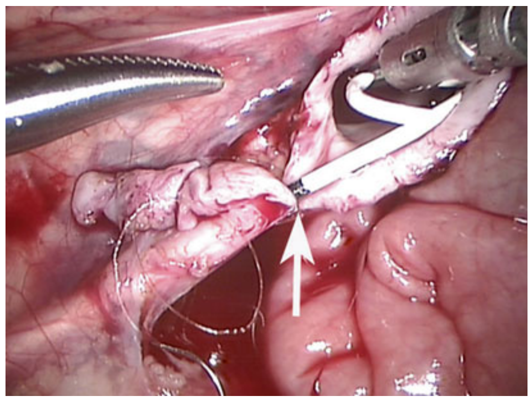

Fig. 7.5 Beginning the ureteropelvic anastomosis on a right-sided pyeloplasty. The inferior most apex suture has been placed (*arrow*). The pre-placed double J stent can be used to facilitate suture placement

7.4.2 Ureteral Reimplantation for Vesicoureteral Reflux

Robotically assisted *ureteral reimplantion* has been shown to have reliable success and be efficient [14–17]. The degree of advantage for younger children is uncertain, but for older children, this is an attractive option to limit the need for catheterization and inpatient stay. Bilateral reimplantations can be performed, and there is good evidence that the risk of *urinary retention*, as recognized in open extravesical reimplantation, is very low, but not absent [16, 17]. The principal means to avoid this is to avoid excessive

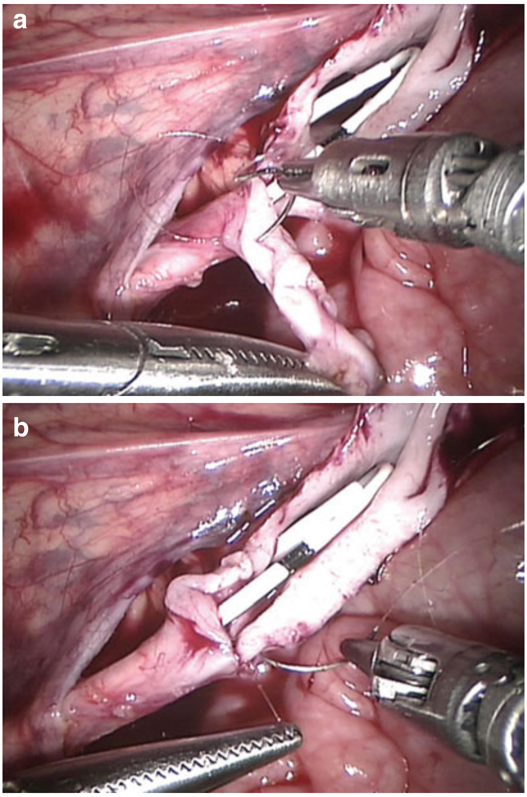

Fig. 7.6 (**a**) Anterior wall running anastomosis of a right-sided pyeloplasty using 5-0 absorbable monofilament suture. The part of the renal pelvis still attached to the ureter is used as a handle for manipulation to avoid injury to the anastomotic tissues. It will later be removed. (**b**) The posterior wall in this case is closed after the anterior due to positioning. Retracting on the tail of the suture stabilizes the tissues for suture placement

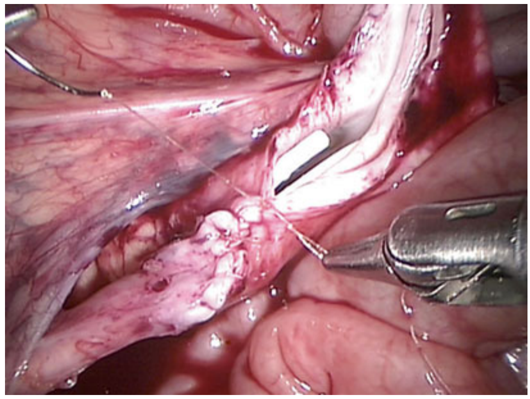

Fig. 7.7 The anastomosis is nearly complete with closure of the pelvis remaining

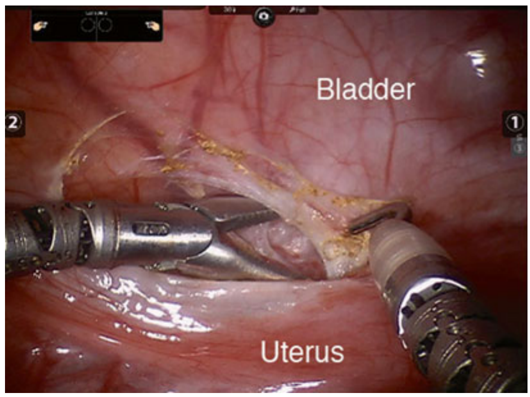

Fig. 7.8 Exposure of the left ureter in an extravesical reimplantation in a girl. The peritoneum between the bladder and uterus is incised transversely, and blunt dissection exposes the ureter

dissection away from the ureter and limit damage to the *perivesical nerves* [18].

Port positions include an umbilical port for the camera and in the midclavicular lines bilaterally at the umbilical level. In infants, the working ports should be just above the umbilicus to provide adequate room for the instruments.

Exposure of the ureter is initiated by incising the peritoneum transversely as it reflects onto the bladder anterior to the uterus in girls and just distal to the vas in boys (Fig. 7.8). Blunt dissection is used to develop the periureteral space, approaching the ureter just as it inserts into the bladder. There is always a small but distinct vessel that crosses over the ureter as either an inferior uterine or vesical artery. This is usually taken but occasionally can be preserved and mobilized superiorly as the ureter is mobilized. The hook cautery is most effective for ureteral mobilization with an initial elevation followed by progressive freeing of periureteral attachments, but not violating the ureteral adventitia (Fig. 7.9). The extent of *mobilization* is a judgment and usually amounts to about 5–6 cm and is just below the takeoff of the superior vesical branch of the *internal hypogastric artery*. The posterior attachments of the ureter cannot be directly seen behind the ureter but can be released by sliding the hook along the medial side of the ureter then directing it laterally under the ureter to catch these attachments, which are then cut with cautery.

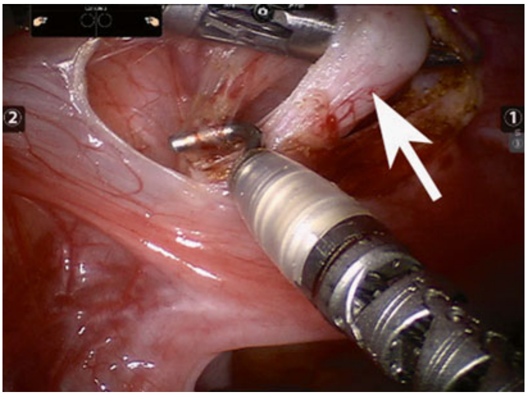

Fig. 7.9 Mobilization of the left ureter (*arrow*) using traction and hook cautery to release periadventitial tissues. Care is taken to stay close to the ureter without injury to the adventitial blood supply

Once the ureter is mobilized, the bladder is partially filled, and the line of the detrusor incision is marked based on where the bladder rolls over the ureter. The length is about 4 cm, but measurement is difficult as it varies with bladder filling or wall stretch. A *bladder hitch stitch* is then placed to lift and flatten the posterior wall of the bladder. The stitch (3-0 Vicryl) is passed on an SH needle through the abdominal wall just above the pubis and under internal vision. It should pass through near the obliterated umbilical artery. It is then passed through the bladder just superior and lateral to the top of the anticipated detrusor incision. The suture is looped around itself, and then a second bite of the bladder is made on the contralateral side and again looped. The location of the second bite is the same for unilateral and bilateral procedures. The needle is then passed outside and both ends lifted simultaneously (Fig. 7.10). The bladder is then filled to make the wall slightly tense, and the camera angle is shifted from 30° down to 30° up to facilitate the *detrusorotomy*.

The detrusor is incised from the top of the tunnel down to the hiatus. It is useful to first identify the depth needed to reach mucosa and then extend this by carefully holding the muscle and pushing the mucosa away inferiorly and laterally (Fig. 7.11). The freed muscle is then cut until the hiatus is reached, and a "V" incision made around the ureter. The hiatus is not incised circumferentially.

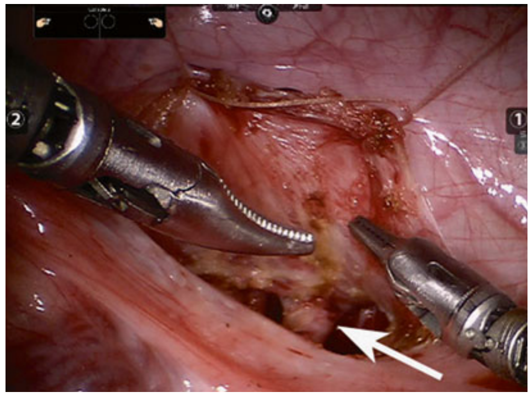

Fig. 7.10 Exposure of the back wall of the bladder and the mobilized ureter is facilitated by placement of a hitch stitch that is placed into two points of the bladder wall. This also stretches the bladder wall to facilitate creation of the detrusor tunnel. The mobilized ureter is indicated by the *arrow*

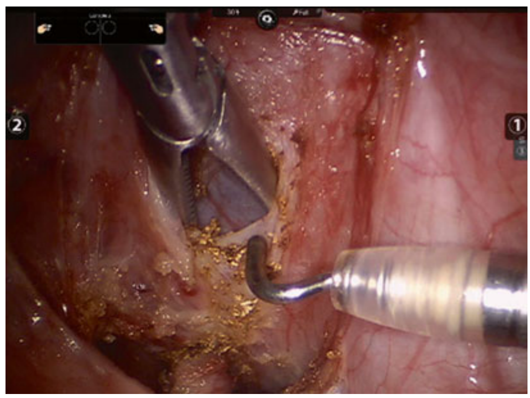

Fig. 7.11 Creation of the detrusor tunnel involves incision of the detrusor muscle without injuring the mucosa. The Maryland dissector can be used to gently spread the muscle fibers and lift them from the mucosa to permit incision with the hook cautery

Either the hook or 8 mm "hot shears" are used for this mobilization.

The detrusor edges are mobilized away from the mucosa slightly as flaps to cover the ureter. If the ureter is large, these should be made more generous. The *detrusor tunnel* is then closed with interrupted Vicryl suture (4-0 for young children, 3-0 for ages 8 and up) (Fig. 7.12). A total of five to seven stitches are usually sufficient. Once the tunnel is closed, the opposite side can be performed for bilateral, or the hitch stitch is cut, and the bladder filled partially to test for leaks. The

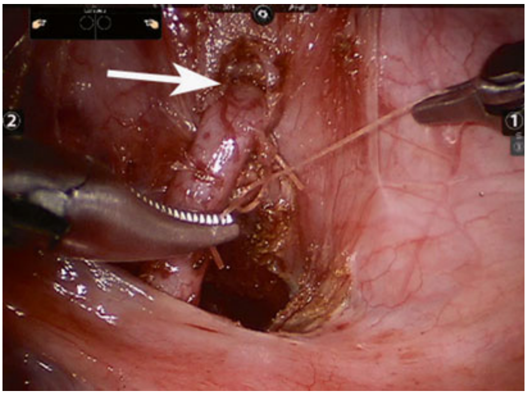

Fig. 7.12 Closure of the detrusor tunnel with interrupted absorbable sutures. The upper aspect of the tunnel and the ureter is indicated by the *arrow*

peritoneal incision is closed with a running 4-0 Vicryl.

A bladder catheter is not left in place for unilateral repairs if the mucosa has not been violated significantly, but for bilateral procedures, a catheter is left in place overnight. Parents are cautioned that some children will need to be re-catheterized if they fail a voiding trial, but this is seen in less than 10 %. A child with known and incompletely managed BBD may need the catheter in place longer.

7.4.3 Partial Nephrectomy

Robotic *partial nephrectomy* for *duplication anomalies* permits a precise control of the vasculature of the affected and remnant pole and definitive closure of the defect. Positioning and port placement are as with a pyeloplasty, although a right-sided upper pole partial nephrectomy will usually require a fourth port to lift the liver away. The colon is mobilized for both right and left procedures, and the affected ureter is identified near the lower pole. For most upper pole partial nephrectomies, it is dilated and is dissected free, ligated, and divided. It then serves as a handle to facilitate mobilization of the rest of the upper pole. Blunt dissection around the *ureter* in a cephalad direction under the hilum permits passing the ureteral stump superiorly and behind the vessels. It is then lifted to reveal the upper pole vessels, which are ligated. Either clips or suture may be used. If clips are used, care must be taken not to dislodge them. The plane between the upper pole pelvis and the lower pole parenchyma is developed bluntly, and then the thin renal parenchyma of the upper pole is incised with cautery or *harmonic scalpel*. If the upper pole collecting system is entered, one should ensure that any of the collecting system is not left in situ.

The defect from the upper pole is preferably closed using three *mattress sutures* over a tongue of retroperitoneal fat. While it is difficult to prove that this reduces the potential for a post-op *urinoma*, it seems reasonable and adds very little time. While this is more difficult with conventional laparoscopy and has not been done in many series, the incidence of urinoma seems higher in the laparoscopic reports compared to what has been reported with open [19]. While post-op urinomas have not been reported to cause clinical problems, they can become a concern to families.

No drain is routinely left in place, but if there is concern about violation of the lower pole, then a simple wound drain would be reasonable. No bladder catheter is left in place unless there is a similar concern.

7.4.4 Retrovesical Procedures

Robotic access to the retrovesical space is one of the areas of very clear value for this system. The articulated instruments are well suited to the tight working area and the need for care when dissecting in the deep pelvis. There are several early reports of robotic resection of *utricular cysts*, *seminal vesical cysts*, and persistent *Müllerian structures* using the robotic system [20].

The approach is with ports in position as with a ureteral reimplantation, and the peritoneum is incised between the bladder and rectum. The bladder remains attached anteriorly to keep it out of the field. For midline structures, it is important to stay directly on the structure to avoid injury to the lateral vasa or seminal vesicles. In some instances, the vasa will enter these abnormal structures and will need to be cut.

Table 7.1 Robotic pyeloplasty outcomes

Author	Study type	Patients	Age range	Success	Comment
Olsen [21]	Case series[a]	13	3.5–16.2	100 %	Retroperitoneal
Atug [22]	Case series	7	6–15	100 %	
Lee [11]	Case-control[b]	33 rob 33 open	0.2–19.6	97 %	Shorter hospital stay and narcotic use for robotic
Kutikov [23]	Case series	9	0.25–0.75	100 %	
Yee [24]	Case-control	8 rob 8 open	6.4–16.5	100 %	No significant differences but longer operative times
Franco [25]	Case-control	15 rob 12 lap	4–18	100 %	No significant differences between robotic and lap
Olsen [26]	Case series[a]	65	1.7–17.1	94 %	Retroperitoneal
Freilich [27]	Case series	5	3.4–14	100 %	Bilateral
Chan [28]	Case series	5	0.9–12	100 %	
Minnillo [29]	Case series[b]	155	10.5 mean	96 %	3 % required re-op
Rodriguez [30]	Case series	12	3.5–16	100 %	Stentless repair
Singh [31]	Case series	34	5–15	97 %	
Subotic [32]	Case series	19 rob 20 lap	>4 years robotic	100 %	Comparable outcomes between robotic and lap
Bansal [33]	Case-control[c]	9 rob 61 open	<12 months	100 % rob 98 % open	Infants only
Riachy [34]	Case-control[c]	46 rob 18 lap	rob 0.5–22; lap 0.25–18	100 % rob 87.5 % open	Operative time shorter for robotic, similar length of stay and narcotic use
Pelizzo [12]	Case series	3	<12 months	100 %	All infants under 10 kg

[a,b,c]Some of the same patients included in later report

They would not likely have been functional in any event. The structure is maintained intact for as long as possible but may need to be opened to permit determination of its distal extent. We usually try to remove the entire structure to where it enters the posterior *prostate* and suture ligate this neck with a figure-of-eight absorbable suture.

We have performed robotically assisted removals of large *ectopic ureters* that enter into the prostate or join the vas deferens, as well as seminal vesical cysts, typically associated with *dysplastic kidneys*. Some of these have been extremely large and very fibrotic, requiring careful tedious dissection, but the anatomic definition permitted by the endoscope and the controlled dissection makes this more efficient and certainly less morbid than an open procedure.

In the teenage male, they will have persisting postoperative pain and some bladder spasm for several days to weeks and may have a transient residual fluid collection.

7.5 Outcomes

Clinical outcomes for robotic procedures have been reported in various formats, predominantly as case series with a few comparative studies (Tables 7.1 and 7.2 for pyeloplasty and ureteral reimplantation). A formal prospective randomized trial has not been reported in the pediatric literature, and it may be nearly impossible to do so. In general, outcomes have been comparable to open or conventional laparoscopic approaches with some reduction in postoperative morbidity as measured by narcotic use and length of hospital stay. It must be recognized that these are very crude measures and do not capture the true impact of a surgical procedure. It is very clear from review of these studies that more sensitive and robust measures of the health impact of surgery on a child and their family are needed. It must also be recognized that the cost of robotic technology is an important factor in assessing its value, but this is a rapidly moving target that has many local

Table 7.2 Ureteral reimplantation – extravesical

Author	Study type	Patients	Age range	Success	Comment
Casale [15]	Case series[a]	41	1.3–7	97.6 %	Bilateral; no retention
Marchini [35]	Case-control	20 EV/19 IV 17 open EV 20 open IV	EV mean: 8.6 rob 6.1 open; IV mean: 9.9 rob 8.8 open	P2.2 % rob 93.2 % open IV; 100 % rob 94.2 % open	Multiple subgroups, including intravesical reimplants
Smith [17]	Case-control	25 EV 25 open EV	0.25–12	97 % rob 100 % open	3 transient retention in robotic group
Chalmers [36]	Case series	17 (6 bilat)	6.25 mean	90.9 %	No retention
Kasturi [16]	Case series[a]	150	2.25–9.3	99.3 %	Bilateral; no voiding dysfunction
Akhavan [14]	Case series	50 (28 bilat)	1.9–18	92.3 %	1 transient retention

[a]Some of the same patients included in later report

Table 7.3 Developmental robotic surgery in pediatric urology

Procedure	Descriptions	Comment
Intravesical ureteral reimplantation	[5, 35, 37, 38]	Remains challenging for access and maintenance of exposure
Continent catheterizable stoma	[39–43]	Effective and straightforward with appendix or ureter
Bladder neck reconstruction/sling	[44, 45]	Exposure of bladder neck is excellent and facilitates posterior dissection
Augmentation cystoplasty	[40, 46, 47]	Remains long operation. Advantages uncertain at present
Pyelolithotomy	[48, 49]	Limited application but useful for complex stone burden or when concomitant obstruction requires repair

variations in significance. Comparisons to conventional laparoscopy have limited value as this technology is used to such a limited degree in reconstructive pediatric urology and it may not evolve further if robotic systems remain available. It is unclear what impact and when competitive systems to the da Vinci System will have.

At present it is clear that robotic technology can provide for effective and safe minimally invasive reconstructive surgery for pediatric urology. Its applications have been growing with greater experience, and progressively more complex procedures are being reported with success, even if without efficiency.

7.6 Conclusions and Challenges

A number of other surgical procedures have been described using the robotic system in children but remain early in their development (Table 7.3). Continued exploration should be encouraged with careful and honest reporting of outcomes. There seems little doubt that the da Vinci robotic system offers enhanced ability to perform complex reconstructive and ablative urologic procedures in children, with reduced morbidity and equal efficacy. The value of the system, given its high cost, is not yet proven for all children. The adolescent shows a definite advantage in most renal and pelvis procedures, but the infant has a lesser degree of benefit. The dividing line is not at all clear.

It will also be very important to develop more robust measures of the impact of a surgical intervention on children and their families, as well as more accurate and relevant assessments of cost, to permit a better valuation of this technology as well as those that will surely follow.

The current da Vinci System is not at all designed for children but can be made to work effectively in the small child. There is a clear need for more pediatric-specific tools that reflect the types of procedures and tissues that are being manipulated. The smaller instruments (5 mm) are much less precise than the larger 8 mm ones. Integration with digital imaging technologies is an important emerging trend that will facilitate all pediatric urologic procedures.

The da Vinci platform is a clear *proof of principle* that *computer-assisted robotic devices* can enhance our surgical capabilities and offer reduced morbidity with equal and potentially even greater efficacy. The users of these evolving technologies need to be closely involved in the patterns of evolution and be rigorously honest with their appraisals, both to guide their development in appropriate and valuable direction and to maintain the credibility of their community.

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