Robotic Assisted Laparoscopic Surgery

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1. Introduction

Minimally invasive surgical techniques, including endoscopy, cystoscopy, arthroscopy, and abdominal laparoscopy, are now fundamental to surgical practice. Robotic assisted (RA) minimally invasive surgery has advanced the depth and breadth of surgical procedures performed with minimally invasive technology. RA technology is beneficial for reconstructive operations that require fine dexterity and precision. As urology residents, first exposure to RA minimally invasive operations typically occurs in adult patients for procedures such as radical prostatectomies or partial nephrectomies. Like many surgical and medical advances, robotic surgical techniques were initially introduced into the adult arena. Pediatric urologists have successfully adapted these techniques for pediatric patients. While many surgical principles remain the same, it is imperative to recognize essential differences necessary to safely and successfully perform pediatric robotic assisted laparoscopic (RAL) operations. This chapter will provide the fundamentals of robotic technology, the advent of pediatric RA techniques, indications for the use of robotic technology in children, the physiologic effects of these procedures, guidance for operative procedures, and the risks and benefits of a robotic approach. This chapter aims to provide a framework for understanding RAL surgery in children.

2. Robotic Technology

Robotic surgical technology provides many benefits over conventional laparoscopy. The most commonly used platform is the Da Vinci® Surgical system (Intuitive Surgical, CA). This technology does not allow for independent robotic motion or preprogrammed maneuvers. Robotic platforms allow for improved visualization with optical magnification, stereoscopic vision, and operator-controlled camera motion. Surgical movements are enhanced by eliminating the fulcrum effect, motion scaling, tremor filtration, and increased instrument tip dexterity.[1,2,3] Motion reversal is eliminated as the surgeon directly controls the instrument tip rather than the instrument handle, which requires reverse motion as in laparoscopy.[4] Currently, robotic systems lack haptic feedback. The Da Vinci® Surgical system has three components: the console, the robot with four working arms, and the instrument tower. The foot pedals of the console control the camera, electrocautery, and disengagement of the robotic instruments. The camera itself is held by one of the robotic arms. Unlike the triangulation of conventional laparoscopy, robotic trocar placement favors a straight line.

3. Evolution of Robotics in Children

The initial use of laparoscopic-assisted techniques in pediatric urology occurred in 1976 with a laparoscopic exploration to evaluate for nonpalpable testis in an 18 year old.[5] Pediatric laparoscopic renal surgery was first performed in 1992 when a multicystic dysplastic kidney was removed from an infant.[6] Laparoscopic pyeloplasty in children was first described in 1995.[7] Similar to conventional laparoscopy, RAL surgery was first introduced in adult patients. The earliest reported uses of RA technology in children occurred in the mid to late 1990s.[8,9] Some of the earliest reports of a fully integrated robotic system for pediatric surgery were reported for Nissen fundoplications.[10,11,12,13] From these initial forays into pediatric robotic surgery, robotic surgery in children has continued to expand.[14,15,16]

Using the Pediatric Health Information System database, pediatric urologic robotic surgeries increased by an average of 17.4% per year from October 2008 to December 2013. The most commonly performed procedures included pyeloplasty, ureteroneocystostomy, nephrectomy, and partial nephrectomy. [17] From 2003 to 2010, pediatric RAL pyeloplasties increased, conventional laparoscopic pyeloplasties plateaued, and open pyeloplasties declined. Minimally invasive approaches were still 40 times more likely to be performed in patients 11-18 years of age versus in infants.[18] With the addition of the years 2010 to 2015 to the data set, 75% of pyeloplasties were performed open, 10% laparoscopic, and 15% RA. During this period, robotic pyeloplasty grew 29% annually. In 2015, robotic pyeloplasty represented 40% of pyeloplasty operations. The largest area of growth was in children. 85% of infant pyeloplasties were still performed via an open approach. [19]

Recently, there have been increasing proponents of utilizing robotic surgery in the infant population, which has seen the slowest growth in adaptation. Feasibility has been demonstrated, and more centers are reporting on their experience.[15,16,20]

Pediatric robotic surgery represents a standard component for residency and fellowship training. Pediatric urology fellows can achieve near-expert levels within two years of additional training. The fellow operative time decreases with the robotic case volume; fellow operative times are projected to equal attending times after 42 cases have been performed.[21]

4. Advantages of Robotic Surgery in Children

Minimally invasive techniques in children, including RAL operations, allow smaller incisions to perform the equivalent open operation. Incisional length is usually notably reduced. These smaller incisions allow for a quicker and less painful recovery. Patients and their families can return to normal activities, sports, and occupations sooner. Compared to laparoscopy and open surgical approaches, 90-99% success rates are equivalent amongst operative approaches.[22] Numerous studies have documented that the complication rates for open versus minimally invasive operations do not differ significantly. [23,24,25] A multicenter study including 407 pediatric patients who underwent RAL pyeloplasty demonstrated a complication rate of 13.8%. Only 4.9% of the complications were Clavien grade III. There were no Clavien grade IV or V complications. [26] A subsequent multicenter study of 880 pediatric RAL operations showed 6.8% Clavien grade I, 8.1% Clavien grade II, and 4.7% Clavien grade III. There was one Clavien grade IC complication representing 0.1% risk. Complex reconstructive operations such as augmentation cystoplasty and catheterizable channel creation were associated with higher complications, similar to those in open procedures. [26]

Postoperative pain for children undergoing RAL urologic operations can also be minimized by utilizing regional anesthesia. Caudal or transversus abdominus plane (TAP) blocks decrease the need for intraoperative opioids and postoperative antiemetics. However, regional blocks do not significantly reduce the length of stay or postoperative opioid requirements for children who require them. [27] Many children can be comfortable with ketorolac and acetaminophen, with narcotics only if necessary.

In comparing open versus RAL ureteral reimplantation, children undergoing RAL operations had lower narcotic requirements on the first postoperative day. Thirty-five percent of the RAL children reported no pain versus eighteen percent of children who underwent open ureteral reimplantation. In children who reported postoperative pain, nine percent of RAL children reported severe pain versus forty-five percent of children undergoing open operations. Pain was assessed using PLACC, Wong-Baker FACES, and a visual analog scale. [28] A retrospective review of vesicoscopic versus open ureteral reimplantation reported less oral and intravenous narcotic use in the children who underwent RA vesicoscopic ureteral reimplantation. [29] A retrospective review of children undergoing robotic unilateral or bilateral extravesical ureteral reimplantation versus children undergoing open cross trigonal unilateral or bilateral ureteral reimplantation demonstrated less pain medication usage and shorter mean length of stay in children undergoing RA bilateral approach. There was no open extravesical group for this study. [30]

As demonstrated in the above-mentioned study, length of stay appears to be decreased in children undergoing RA procedures versus their open equivalent. Some studies have shown reduced pain requirements and length of stay, whereas other studies have not been able to demonstrate more than equivalence. [23,25,31] A population-based analysis of open, laparoscopic, and RAL pyeloplasty revealed a shorter mean length of stay for children undergoing RAL versus open pyeloplasty with a mean difference of 17 hours. There was no difference in median length of stay. [18] A review of the PHIS database from October 2008 to December 2013 demonstrated a shorter length of stay for RAL pyeloplasty, ureteral reimplantation, nephrectomy and partial nephrectomy compared to equivalent nonrobotic open surgery. [17] A meta-analysis comparing minimally invasive and open pyeloplasty techniques demonstrated a shorter length of stay in adult patients and a suggestion toward decreased narcotic requirement. [32] This reduced length of stay benefits patients and parents. Parents of children undergoing RAL pyeloplasty return to work sooner with fewer lost wages.[33] After discharge home, patients and families begin to focus on wound healing and cosmesis. Parental satisfaction has been higher after minimally invasive access versus open incisions regarding incisional scar, burden or postoperative follow-up, and ultimately "overall life."[34] Utilization of the hidden incision approach (HIDeS), as outlined below, can further improve postoperative cosmetic outcomes.

5. Patient Selection for Pediatric Robotic Surgery

RAL technology has significantly improved intracorporeal reconstruction and recovery for children undergoing urologic operations. However, as with all technological advances, recognizing the proper patient for RAL procedures is essential. RAL technology is not advantageous to everyone, and appropriate patient selection is imperative to a successful operation. When we consider laparoscopic surgery, access and pneumoperitoneum are parameters that require consideration. Children who have already undergone multiple intraperitoneal operations, or have ventriculoperitoneal shunts, are at greater risk for peritoneal adhesions, making access more challenging. Additionally, access to the surgical field may require lysis of adhesions to obtain proper visualization.

Children with significant cardiac, pulmonary or neurologic disease may also be poor candidates for the physiologic changes accompanying pneumoperitoneum and positioning, such as lateral decubitus or Trendelenburg. Patient size should also be considered as the robotic arms, especially the 5mm instruments, require a larger working area than the equivalent laparoscopic procedure. While an adult pneumoperitoneum contains a 5-6 liter working space, a 1 year old child will have a 1-liter intraabdominal working space.[35]

With the advent of robotic surgery in children, initial operations were performed in post-pubertal and older children. Currently, robotic procedures, such as pyeloplasty, can be performed on infants less than one year with no significant difference in length of stay, complications, or success rates compared to older children.[36] A distance of fewer than thirteen centimeters between the respective anterior superior iliac spines and puboxyphoid length of fewer than fifteen centimeters has been associated with increased instrument collisions due to limited working space. It may serve as a size criterion for robotic surgery in infants.[37]

6. Fundamentals of Anesthesia for Pediatric Robotic Surgery

Robotic-assisted laparoscopy requires pneumoperitoneum to create the intraabdominal space necessary to operate. Pneumoperitoneum results in increased intraabdominal pressure and elevation of the diaphragm. These physiologic changes result in decreased functional residual capacity, reduced lung compliance, increased airway resistance, increased V/Q mismatch, and increased physiologic dead space. [38] In small children, the elevation of the diaphragm from pneumoperitoneum can shift the endotracheal tube into an endobronchial location.

Transperitoneal carbon dioxide absorption begins at pressures of less than 10mmg Hg. With constant ventilation, maximal end-tidal carbon dioxide absorption can be reached at 40 minutes.[39] The carbon dioxide insufflation can also result in a carbon dioxide embolism, especially after a significant venous injury.[40,41] Increased intraabdominal pressure can also stimulate catecholamine release and activation of the renin-angiotensin system, thereby increasing mean arterial pressure and systemic vascular resistance.[42]

Pneumoperitoneum and the accompanied elevated intraabdominal pressure, hypercapnia, Trendelenburg position, and increased systemic vascular resistance all result in intracerebral effects. These effects include increased intracranial pressure and decreased cerebral perfusion. In the pediatric population, strong consideration for avoiding these factors should be given to preterm infants at heightened risk of intraventricular hemorrhage and children with reduced intracranial compliance.[41,43]

The kidneys are also affected by increased abdominal pressure. These effects are due to compression of the renal parenchyma and renal vasculature. This compression results in increased renovascular resistance, increased production of antidiuretic hormone, and activation of the renin-angiotensin system. [44] Oliguria can be seen intra- and post-procedure. Fluids should be administered rather than diuretics.

Cardiovascular alterations during pneumoperitoneum are closely related to intraabdominal pressures, hypercapnia, and patient position, such as Trendelenburg. These alterations can be decreased by maintaining an intraabdominal pressure of less than 12mm Hg. Intraabdominal pressures less than 15mm Hg result in decreased splanchnic blood flow, increasing venous return. The increased venous return results in increased cardiac output. Conversely, intraabdominal pressures greater than 15mm Hg result in decreased venous return and hypotension due to compression of the inferior vena cava and collateral veins. These physiologic changes result in decreased cardiac output and hypotension. In addition, initial port placement and insufflation can cause vagal stimulation with resultant bradyarrhythmias, nodal rhythm, and asystole. These events are more common in teenagers and young adults. Cardiovascular collapse is rare during minimally invasive surgery, but the surgeon must be aware of the potential causative factors. As mentioned, peritoneal stimulation can result in a strong vasovagal reflex, reduced venous return in reverse Trendelenburg, inferior vena cava compression due to high insufflation pressures, hypovolemia, hypercapnia, and venous carbon dioxide embolism.[39,41] Hypercapnia can increase systemic vascular resistance leading to acidosis. Acidosis can, in turn, cause decreased cardiac contractility with the resultant risks of arrhythmia and systemic vasodilatation.[45] The surgeon should aim to use the lowest possible intraabdominal pressure and the least amount of head down position to minimize the physiologic alterations in children.

Unlike conventional laparoscopy, the robotic trocars and arms are rigidly fixed to the robot. In a child, the robotic arms are often over the patient’s chest, abdomen, and head or lower extremities. Continued access to endotracheal tubes and intravenous lines must be considered when positioning the patient and robot. The robot can also interfere with resuscitation in the event of an intraoperative emergency. A consistent robotic team is helpful in recognizing concerns and adeptly addressing any issues. Muscle relaxation must be maintained throughout the robotic portion of the operation to avoid obscuring the operative field or causing inadvertent injury from the fixed robotic arms and intraabdominal instruments. Upon initiating general anesthesia, nitrous gas should be minimized to prevent bowel distention that can obscure the operative field and increase the risk of inadvertent bowel injury. Gastric distention should also be rapidly addressed to avoid bowel distention, as children have more rapid gastric emptying times than adults. [46] Gastric decompression should be performed after intubation and before abdominal access.

7. Patient Positioning, Access and Trocar Placement

Proper patient positioning is of paramount importance to maximize ergonomics and prevent instrument and arm clashing. Perhaps most importantly, however, adequate patient positioning should not only be tailored for the specific procedure being performed but should also minimize any possibility of inadvertent patient injury. Ideally, all potential pressure points should be meticulously and carefully padded. There should be no areas of undue or excessive pressure. Upper and lower extremity positioning should be checked for pressure points and hyperextension. All tubing, electrical cords, and other surgical adjuncts should be adequately wrapped and padded as necessary to prevent inadvertent pressure on the patient. Lastly, the patient needs to be secured to the table, especially when table rotation and patient positioning changes intraoperatively will be performed. A head butler, a tray mounted to the bed, can be placed to protect the head during pelvic cases. Instruments and cords can be safely placed atop the device without risk to the patient. Lastly, prior to draping, the adequacy of measures taken to secure the patient to the bed should be tested.

The two primary methods of abdominal access in pediatrics tend to be the Hasson (open) technique and the Veress needle technique. Other variations, such as optical or cutting trocars, are less commonly used. Open-access (Hasson) technique involves incisions of the skin, fascia, and muscle under direct vision until the peritoneum is exposed. The peritoneum is then entered sharply, and the initial trocar is placed under direct vision. Although the open technique has decreased the risk of major vascular injury in large multicenter analyses, the risk of inadvertent bowel injury persists. [47]

An alternate approach for the initial trocar placement is to use the Veress needle. The needle utilizes a spring-loaded “safety” insert designed to prevent iatrogenic visceral injury. The Veress needle is placed blindly into the abdominal cavity, and insufflation occurs through the needle. Proper placement is supported by placing a saline-filled syringe on the needle. Aspiration should show gas in the syringe, and saline injected into the needle as the syringe is removed should quickly enter the abdomen (the so-called hanging saline drop test). When gas is insufflated via the Veress needle, one should see high flow rates at low pressure. If these findings are not observed, the needle should be withdrawn and placement reattempted before the trocar is inserted. Unfortunately, there is no method for gaining intraperitoneal access which is free from complications. Furthermore, no definitive study has shown superiority of one method over another.

The anatomical positioning and placement of the camera and working trocars should be tailored according to the procedure. The laparoscopic principle of “triangulation” maintains its relevance in robotic surgery to optimize access to the organ of interest and minimize clashing of the robotic arms. Ideally, a working distance of 8-10 cm should be employed between adjacent trocars, especially if the

Si system is being utilized. The updated Xi system allows for smaller working distances between trocars, and 5 cm is feasible with this system, and triangulation is more flexible. The Si robot has both 8-mm and 5-mm diameter instruments and an 8 or 12-mm camera. The Xi robot only has 8 mm instruments and camera. Insufflation pressures and flow rates are procedure and surgeon-dependent, although most utilize pressures of 10-12 mm H_2O and flow rates of 1-4.[48] Recently, there have been trends towards using lower insufflation pressures (less than 10mm H_2O safely).[49]

8. Technical Points for Specific Procedures

8.1 Preoperative Preparation

Many of the below steps and procedures are surgeon-dependent. These are the preparative steps followed at the University of Minnesota Masonic Children's Hospital and The Mayo Clinic Children's Center. There are no preoperative diet restrictions or special bowel preparation instructions. Consideration can be given to preoperative laxatives in children with severe chronic constipation. Upon arrival to the operating room, they receive a dose of antibiotics, usually cefazolin (unless they have a documented allergy). Depending on surgeon preference, cystoscopy, retrograde pyelogram, and Double-J stent placement may be performed at the start of the procedure. We strongly advocate a supine patient positioning for most procedures. Some find a "flank up" position helpful for renal cases, although we find that bed rotation is adequate to move the intra-abdominal contents and expose the retroperitoneum. A "lithotomy" position is not necessary for the vast majority of cases and should be avoided. A foley catheter and an orogastric tube are placed prior to trocar placement.

8.2 Nephrectomy and Partial Nephrectomy

Trocar positioning can be performed as shown in either **Figure 1a** or **1b**. **Figure 1b** shows the "**H**idden **I**ncision **E**ndoscopic **S**urgery" or HIdES port placement which essentially shifts the camera port and the ipsilateral working port to below the waistline and uses the umbilicus for the other working port resulting in incisions not visible when the patient is wearing a bathing suit. The XI robot favors ports placed in a straight line.[50]

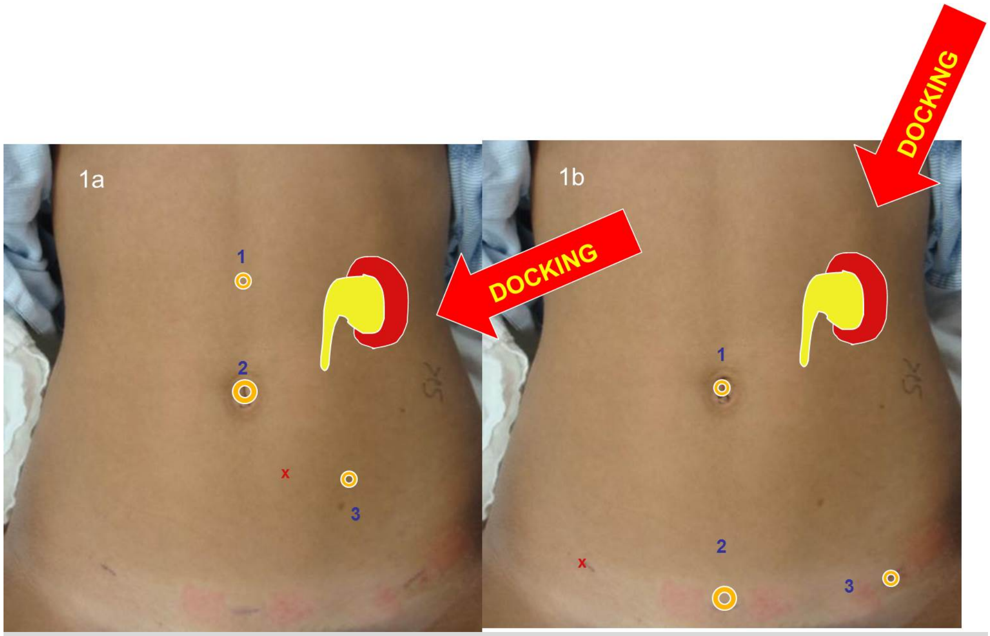

Figure 1: Port configuration for left renal surgery (pyeloplasty, heminephrectomy, nephrectomy) showing the "traditional" (a) And HIdES (b) configurations, respectively. Note, if the procedure is going to be done with robotic assistance, the robot needs to be docked from the ipsilateral side with traditional port placement and more from the ipsilateral shoulder if using the HIdES technique. 1: 8mm working port 2: 10 mm camera port 3: 8mm working port X: 5mm assist

Procedural steps are similar to laparoscopic approaches. For a robotic nephrectomy, the retroperitoneum is exposed by incision along the line of Toldt and reflecting the colon medially. The ureter is identified and traced up to the renal hilum, at which point vascular control is established and the pedicle stapled or ligated according to surgeon preference. Upper attachments are then taken down, and the adrenal gland is spared in most cases. The ureter can be transected at any point. Once the kidney is completely mobilized and free, it can be placed in a laparoscopic specimen bag and delivered through an extended incision at one of the trocar sites.

Heminephroureterectomy and partial nephrectomy may be indicated in children with duplication anomalies such as nonfunctioning upper pole kidney with ectopic ureter or ureterocele, cystic malformation of upper pole kidney, and nonfunctioning refluxing lower pole moiety.[51] Prior to final patient positioning, some surgeons prefer to cystoscopically place a stent in the unaffected ureter to aid in its identification. This technique can be performed through a transperitoneal or retroperitoneal approach in a similar manner to a nephrectomy, with identical port placement and initial exposure of the ureters and hilum. The upper and lower poles of the kidney are often divided by an anatomic plane that is often visualized with the aid of the 10x robotic magnification and high-definition 3D imaging. Resection of the affected moiety can be undertaken with multiple instruments available with both bipolar and monopolar cautery (monopolar hook or scissors, ultrasonic shears, or bipolar device). Once the heminephrectomy is complete, the robot typically needs to be re-docked from the foot of the bed to access the bladder to address the distal ureter. In the case of the Xi, the robot needs to be undocked to allow the boom to rotate.

9. Pyeloplasty

Pyeloplasty is performed for ureteropelvic junction obstruction (UPJO), which can be caused by intrinsic or extrinsic etiologies. Robotic-assisted laparoscopic pyeloplasty is performed similarly to traditional laparoscopic pyeloplasty with the added advantage of the robotic articulating and wristed instruments, allowing for simpler and perhaps more precise intra-corporal suturing. As with other retroperitoneal surgeries, RAL pyeloplasty can be performed through a transperitoneal or retroperitoneal approach with similar patient positioning, trocar placement, and docking as described.

The choice for preoperative cystoscopy and retrograde pyelogram with or without retrograde double J stent placement is surgeon-dependent. There are advantages and disadvantages to performing the stent placement antegrade vs. retrograde. The main advantage of performing the stent placement prior to the pyeloplasty is that positioning is confirmed by direct visualization and fluoroscopy. A string (or “dangler”) can also be left attached for subsequent stent removal without the need for cystoscopy. The main disadvantages stated by some are that it might be cumbersome to perform the repair with the stent in the way and that preoperative stenting obscures the actual location of the obstruction. Pre-stenting also leads to decompression of the collecting system, which can be helpful in the identification of the renal pelvis as well as dissection/mobilization of the renal pelvis.

Once the robot is docked, a transmesenteric or retro-colic approach can be implemented. On the right side, a retro-colic approach is almost always necessary, given that the transverse colon and hepatic flexure of the colon tend to be directly anterior to the renal pelvis. A transmesenteric approach is often feasible on the left side, especially in younger children. Care must be taken during a transmesenteric approach to not miss a lower pole crossing vessel, which can cause extrinsic ureteral compression and be the source of the ureteropelvic junction obstruction. The steps are as follows: The renal pelvis is exposed. We prefer to place a hitch stitch of 3-0 PDS to provide traction ventrally on the renal pelvis. The ureteropelvic junction is then transected, the proximal ureter spatulated, the pyelotomy is usually extended, and the ureter is reanastomosed in its new location using 2 running simple sutures of 5-0 or 6-0 absorbable suture material. We do not routinely perform reduction of the renal pelvis. Before completion of the anastomosis, an antegrade double-J ureteral stent is passed. The hitch stitches are removed, the robot is undocked, and the port sites are closed.

10. Uretero-ureterostomy

10.1 Approach and Identification of the ureteral obstruction

Access to the ureter can be through a transmesenteric or retroperitoneal approach. In the latter, the colon is reflected medially by incising along the white line of Toldt, exposing the retroperitoneum. The transmesenteric approach is particularly feasible in younger children where mesenteric adiposity does not obscure the vascular tributaries to the colon. If a ureteroureterostomy (U-U) is to be performed below the femoral vessels, the retroperitoneum is opened, and the ureters can easily be identified coursing along their normal path (**Figure 2**)

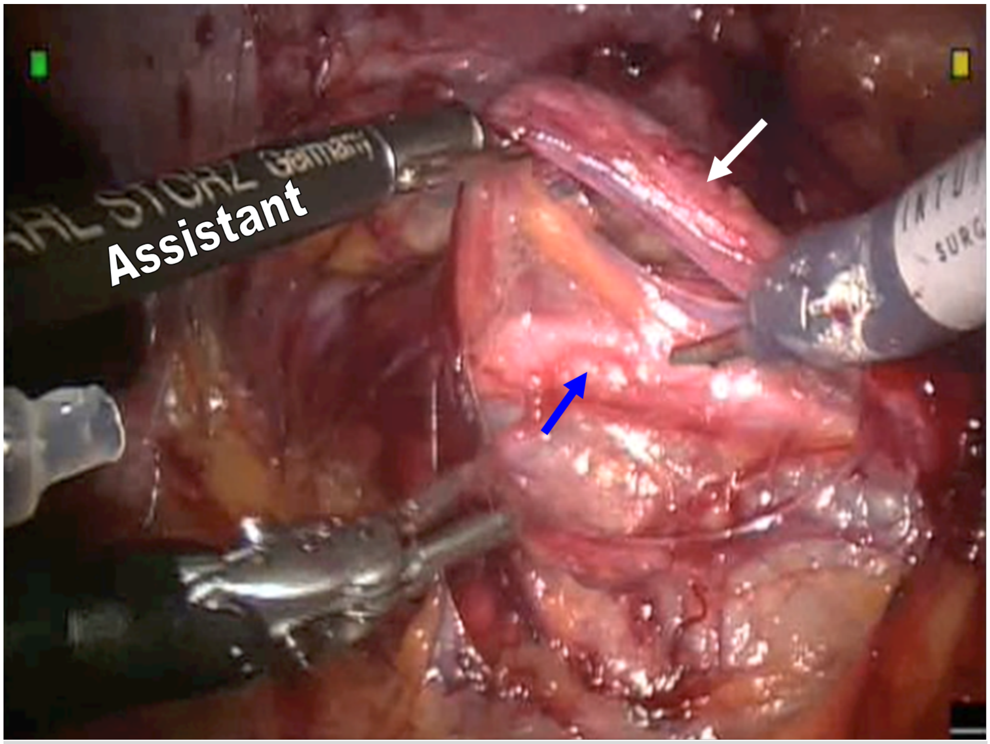

Figure 2: Pelvic visualization of duplicated ureters at the level of the pelvic inlet. Upper pole (ectopic) ureter is highlighted by the blue arrow. Recipient, lower pole ureter is highlighted by the white arrow.

In cases of ureteral obstruction, because the ureter is dilated proximal to the area of the obstruction, it can be identified more easily by first dissecting near the lower pole of the kidney. Caution should be exercised not to injure the gonadal vessels, which lie close to the ureter in this area. The dissection is then carried out distally toward the area of the obstruction. Isolation of the obstructed ureteral segment may be challenging because of previous inflammation, infection, and scarring. The use of indocyanine green has been described in helping identify ureteral stenosis intraoperatively. [52] The extent of ureteral dissection should be limited to prevent excessive devascularization. Placement of a holding suture often helps keep the surgical site suspended above the pooling of urine and blood. The easiest method of placing a “hitch stitch” is to pass a suture on a straightened needle from the outside through the abdominal wall, then through the structure to be held, and back out of the abdomen (**Figure 3**). This method allows the tension on the hitch stitch to be adjusted as needed. The ureter is then incised above and below the area of obstruction. If the case involves ureterolithiasis, the stone can be removed at this time.[46 The proximal segment of the ureter is spatulated medially and the distal segment laterally. Depending on surgeon preference, the anastomosis can be performed in an interrupted or a running fashion with 6-0 absorbable suture with the posterior wall approximated first. A fourth port may be helpful to allow the tissues to be moved and retracted to facilitate suturing. As stated above, a double-J stent can be placed either before the start of or during the procedure, although the former method tends to be easier. The stent is placed retrograde up to the stenotic site, and after the obstructed segment is removed, the stent is pulled out of the distal ureter and inserted into the proximal ureter.

In cases of ureteral duplication and ectopia, the ureters can be approached proximally or below the pelvic brim, and the trocar positions are shifted (**Figure 3**). The obstructed upper pole ureter can usually be identified because it is more dilated than the lower pole ureter. Again, placement of a stent into the intravesical, lower pole ureter simplifies ureteral identification during the robotic portion of the procedure. If a lower pole to upper pole U-U is to be performed for vesicoureteral reflux (VUR), a stent is placed into the recipient upper pole ureter. In these unique situations, the upper pole ureter (ectopia, ureterocele) or the lower pole ureter (reflux) is transected and anastomosed in an end-to-side fashion to the recipient ureter after spatulation of the donor ureter (**Figure 4** and **Figure 5**). The ureterotomy in the recipient ureter should be approximately the same size as the spatulated segment of the donor ureter.

After the completion of the anastomosis, the retroperitoneal wall can be reconstituted using a running 4-0 absorbable suture. The robot is disengaged, and the ports are removed under vision. We close all fascia with a single interrupted 2-0 absorbable suture on a UR-6 needle. A drain is not routinely used since we prefer to leave a ureteral stent. The skin can be closed with a 5-0 absorbable subcuticular stitch. Patients are admitted overnight. The Foley catheter is removed on postoperative day one, and the patient is sent home if stable. Ureteral stents are removed 3-4 weeks post-operatively.

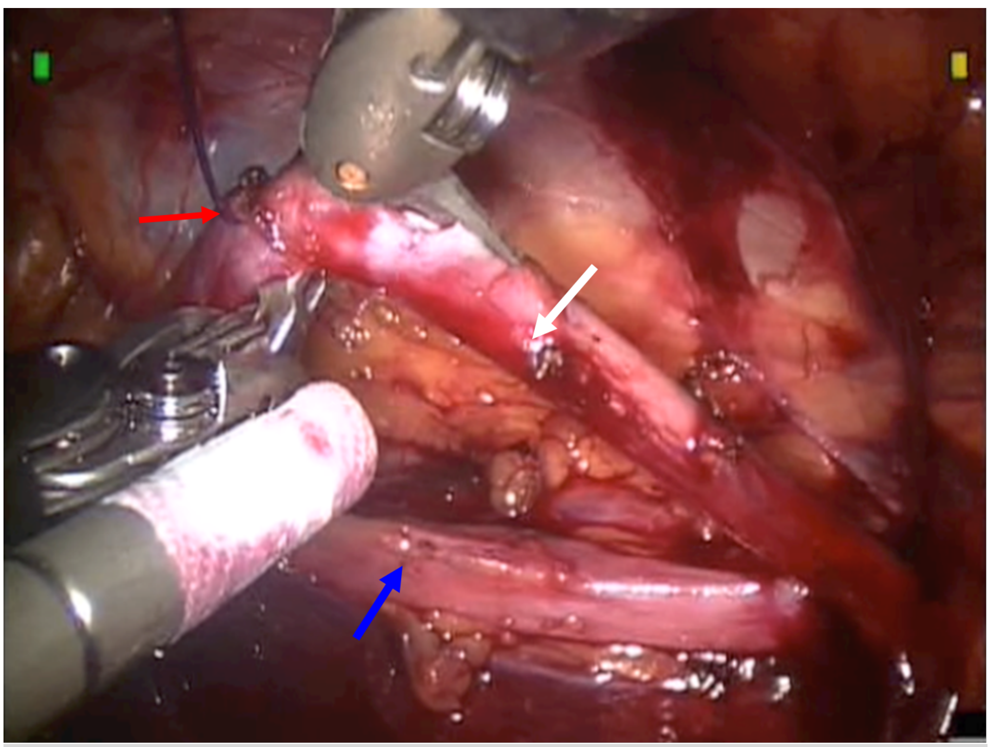

Figure 3: Pelvic visualization of duplicated ureters at the level of the pelvic inlet. Upper pole (ectopic) ureter highlighted by the blue

arrow. Recipient, lower pole ureter highlighted by the white arrow. Hitch stitch highlighted in red is seen here to stabilize the recipient lower pole ureter.

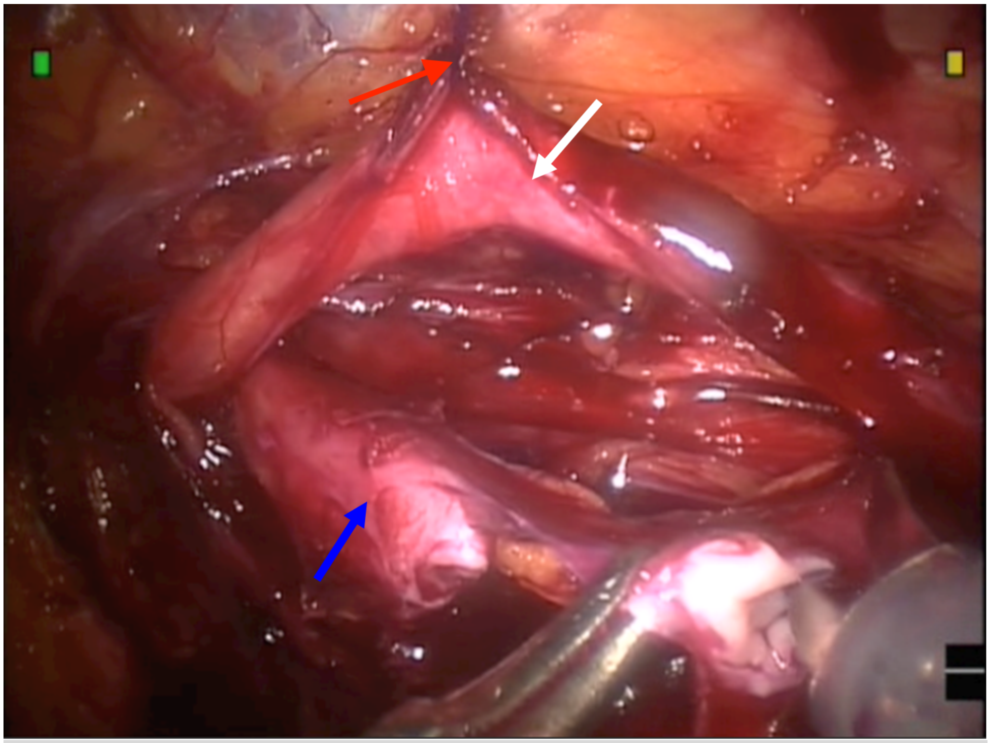

Figure 4: Pelvic visualization of duplicated ureters at the level of the pelvic inlet. Upper pole (ectopic) ureter highlighted by the blue arrow and is shown transected and in the process of spatulation. Recipient, lower pole ureter highlighted by the white arrow. Hitch stitch highlighted in red is seen here to stabilize the recipient lower pole ureter.

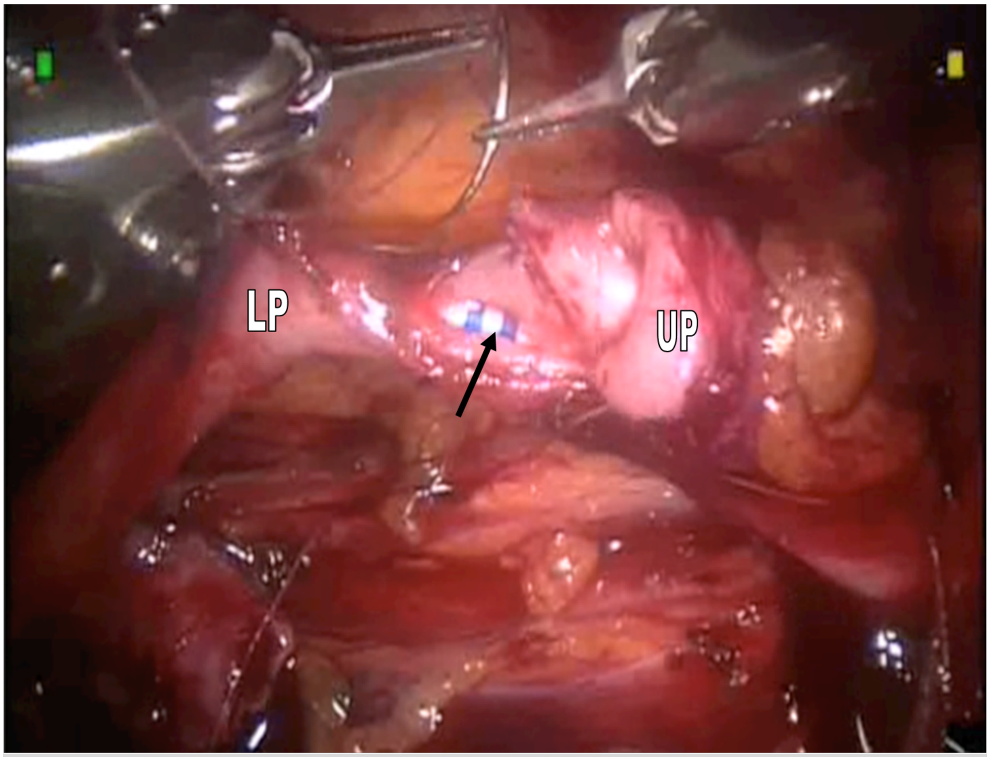

Figure 5: Pelvic visualization of duplicated ureters at the level of the pelvic inlet. Upper pole (UP) ureter and recipient, lower pole ureter (LP) shown being anastomosed end to side.

11. Ureteral Reimplant

Open ureteral reimplantation is the gold standard for the surgical management of primary vesicoureteral reflux (VUR). Successful laparoscopic and robotic-assisted laparoscopic ureteral reimplantation has been described via both extravesical and intravesical approaches.[53] Indications for reimplantation in children with VUR are controversial but may include breakthrough urinary tract infection, worsening reflux, and unresolved high-grade reflux with evidence of upper tract scarring/damage. Port placement can be seen in **Figure 6**.

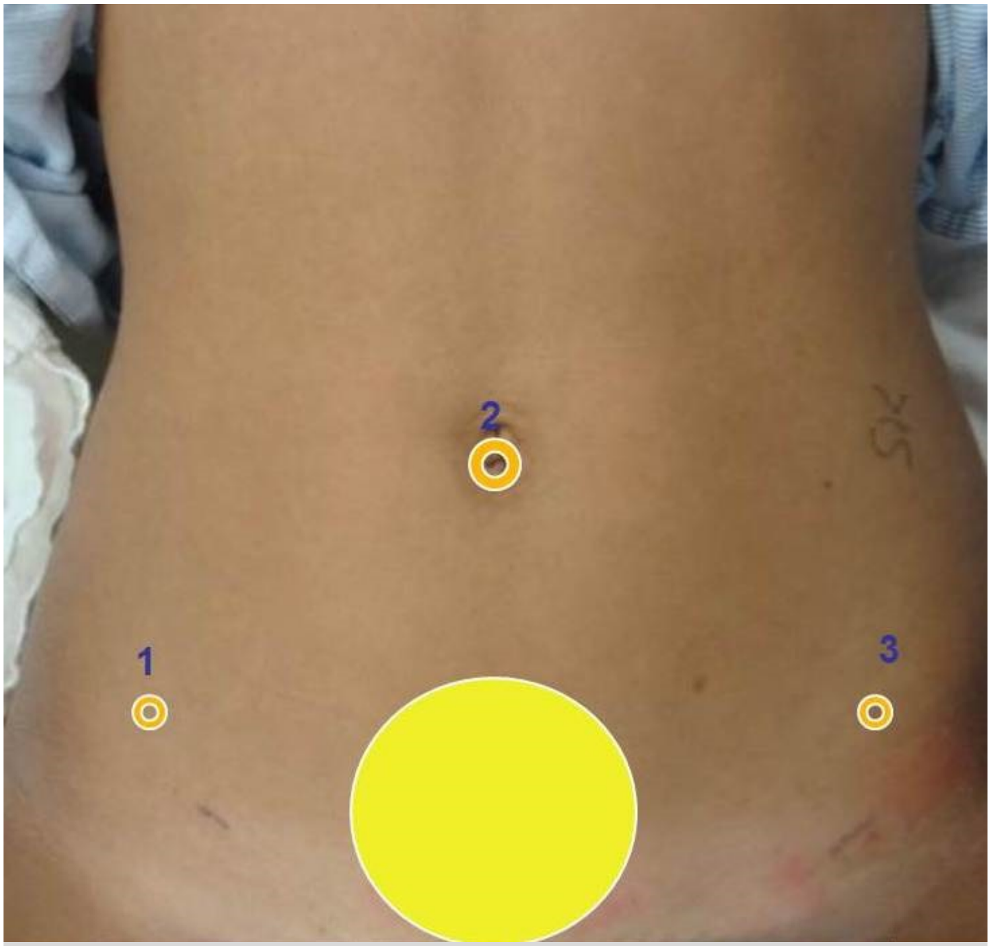

Figure 6: Port configuration for pelvic surgery (reimplant, bladder neck reconstruction, continent catheterizable conduits using the HIdES techniques. 1: 8mm working port 2: 10 mm camera port 3: 8mm working port.

11.1 Intravesical Ureteral Reimplant

This is one of the few procedures where patient positioning in lithotomy may be helpful, as trocar placement is aided by cystoscopy. The bladder is filled with saline through a cystoscope, and a camera port is placed directly into the dome of the bladder under direct visualization. We advocate the placement of “box stitches” on either side of all trocars to assist in postoperative bladder closure and minimize urine leaks. The working ports (8-mm or 5-mm) are inserted similarly. All ports are secured to the abdominal wall. (**Figure 7**) To establish pneumovesicum, the bladder is emptied, and CO2 is insufflated through the ports. The robot can then be docked in between the patient’s legs. The reimplantation is performed in a manner similar to the open technique, with insertion of a 6-cm segment of a 5Fr feeding tube or 4Fr open-ended ureteral catheter into the ureter. The ureteral stent is secured with 4-0 absorbable suture prior to ureteral dissection. Next, hook or scissors cautery is used to dissect and mobilize the ureters. The submucosal tunnels are formed using the scissors starting from the original hiatus in a cross-trigonal manner to the contralateral side of the trigone. After incision of the mucosa at the site of the new hiatus, the ureter is brought through the submucosal tunnel, and ureteral anastomosis is performed using 4-0 absorbable anchoring sutures to secure the ureter to the bladder musculature. 5-0 absorbable sutures are used to attach the ureter to the mucosal cuff, and the original hiatal mucosa is closed using a running 5-0 absorbable suture. [54] The trocars are removed, and the cystotomies are closed. A urethral catheter is placed and removed at the surgeon's discretion. Of note, this procedure is highly challenging and has been associated with significant complications. [55]

Figure 7: Port configuration for trans-vesical surgery.

11.2 Extravesical Ureteral Reimplant

The extravesical approach is performed in the manner of the open Lich-Gregoir technique. The extravesical approach to ureteral reimplantation can be performed robotically, either unilaterally or bilaterally. The patient is positioned supine, and ports are configured, as shown in **Figure 6**. The ureter is identified and dissected proximally and distally to the level of the ureterovesical junction. A detrusorrhaphy is performed in line with the lie of the ureter. It is essential to clear the external layer of the bladder mucosa of any detrusor muscle. If the mucosa is inadvertently entered, it can be oversewn in a figure of eight manner with a small absorbable suture. The ureter is placed within the detrusorrhaphy, and the muscle is closed over the ureter in a running or interrupted fashion with a 3-0 absorbable suture. In males, care must be taken to avoid damage to the vas deferens. In females, it is possible to injure the ipsilateral branch of the uterine artery.

Significant complications have been associated with robotic-assisted ureteral reimplantation, and no published series demonstrates equivalence or superiority of RAL reimplant over traditional reimplantation.[56] Complications reported include recurrent vesicoureteral reflux, urine leak, ureteral obstruction, urinary retention, and ureteral necrosis.

Videos

Robotic Ureterocalicostomy --Pediatric

Robotic Pyeloplasty Step By Step: Benjamin R Lee CORE

Presentations

Robotic Assisted Laparoscopic Surgery Presentation 1

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