Minimally invasive surgical management of pelvic-ureteric junction obstruction: update on the current status of robotic-assisted pyeloplasty

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BACKGROUND

Pelvi-ureteric junction (PUJ) obstruction is characterized by a functionally significant impairment of urinary transport caused by intrinsic or extrinsic obstruction in the area where the ureter joins the renal pelvis. The majority of cases are congenital in origin; however, acquired conditions at the level of the ureteropelvic junction may also present with symptoms and signs of obstruction. Historically, open pyeloplasty and endoscopic techniques have been the main surgical options with the intent of complete excision or incision of the obstruction. The advent of laparoscopy and robotic-assisted applications has allowed for minimally invasive reconstructive surgery that mirrors open surgical techniques.

AIMS

We review the current status of robotic-assisted laparoscopic pyeloplasty and report on the result, continuing evolution, and potential role for this surgical procedure.

MATERIALS AND METHODS

A review of the recent literature encompassing laparoscopic and robotic-assisted pyeloplasty was conducted with particular attention to operative techniques, surgical outcomes, and complication rates.

RESULTS

Laparoscopic and robotic-assisted approaches are able to duplicate the open technique, and not surprisingly, are now being shown to be as efficacious as the gold standard open approach. The laparoscopic remains technically challenging due to the high proficiency level required for intracorporeal suturing, although added experience has resulted in shorter operative times. The advent of robotics has further expanded the breadth of this reconstructive procedure while preserving the benefits of decreased pain, shorter hospitalization, rapid convalescence, and an improved cosmetic result.

DISCUSSION

The introduction of robotics to the field of minimally invasive surgery facilitates this procedure and may allow for more widespread implementation by surgeons of varying skill levels. These benefits must be balanced against the increased costs of the robotic platform.

CONCLUSION

Clinical reports have demonstrated that robotic-assisted pyeloplasty is a safe, feasible, and effective technique for treating ureteropelvic junction obstruction in short term studies. Additional studies with prolonged follow-up will ultimately provide valuable information as to the long-term efficacy of robotic-assisted laparoscopic pyeloplasty.

KEYWORDS

kidney, pelvi-ureteric junction, obstruction, pyeloplasty, laparoscopy, Anderson-Hynes, robotics

INTRODUCTION

Historically, open pyeloplasty has been the standard treatment for congenital or acquired PUJ obstruction (PUJO) in adults and children, with overall success rates of 90–100% [1]. Technological advances have enabled the introduction of endoscopic, laparoscopic and robotic-assisted (RA) approaches over the last several years. First described in 1993 by Schuessler *et al.* [2], laparoscopic pyeloplasty (LP) maintained the decreased morbidity associated with endoscopic approaches while showing comparable success rates to the conventional open approach [3]. However, the technically challenging nature of LP had limited this procedure to selected medical centres with advanced laparoscopic surgeons.

The introduction of RA surgery has broadened the surgical dimensions for minimally invasive surgery. Specifically, the availability of the da Vinci™ Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) has facilitated complex reconstructive laparoscopic procedures. The benefits imparted to the surgeon include enhanced three-dimensional visualization, improved dexterity, greater precision, increased range of motion, and reproducibility. With increasing experience, RA pyeloplasty (RAP) is more commonly being considered as the initial treatment for PUJO in adults and children. In this article we review the recent advances in the area of RAP, and evaluate this technique as a viable option in appropriately selected patients.

FIG. 1. The patient placed in the semilateral decubitus position in preparation for left RAP.

PATHOGENESIS AND MANAGEMENT OPTIONS FOR PUJO

PUJO can result from several aetiological factors, and can be classified as congenital or acquired in origin. Congenital PUJO is typically characterized by an intrinsic luminal narrowing caused by an aperistaltic ureteric segment. Crossing arteries or veins supplying the lower renal pole are another congenital cause, although many patients with crossing vessels do not have symptomatic or radiological evidence of obstruction. High insertion of the ureter can cause PUJO and might coincide with other renal anomalies, such as ectopia or abnormal fusion. Acquired PUJO can be the result of long-standing VUR that leads to dilatation of the renal pelvis and upper ureter, with subsequent development of elongation, tortuosity and kinking. Other causes of obstruction include fibroepithelial polyps, urothelial tumours, urolithiasis, and inflammation or scarring caused by previous surgery.

Patients with anomalies of the PUJ can present with signs and symptoms of obstruction, such as flank pain, upper UTI or renal calculi formation secondary to inadequate urinary drainage. Over time, impairment or deterioration in renal function can occur in the affected renal unit. Occasionally individuals are asymptomatic and are diagnosed on the basis of radiological imaging. These patients can reasonably be observed and followed with routine monitoring of renal function and symptoms.

The reference standard for achieving unobstructed urinary flow has been open operative repair and reconstruction of the PUJ in the form of pyeloplasty. Antegrade and retrograde endoscopic approaches became popular as initial procedures of choice, due to their minimally invasive nature and patient preference. However, success rates with these alternative techniques have not proved comparable with those of pyeloplasty, especially in cases of long strictures, crossing vessels, or a large redundant renal pelvis [4,5].

LAPAROSCOPIC PYELOPLASTY

LP remains an option in the hands of skilled laparoscopists and in areas where access to robotic technology is limited. The laparoscopic technique has been refined with extensive experience and the results have been shown to be comparable to open pyeloplasty, with the benefit of decreased postoperative morbidity [3]. Complication rates during and after LP are reportedly up to 11.5–12.7%, with urine leak and bleeding being the most common complications [6,7]. Nevertheless, this procedure remains technically challenging and continues to be limited to selected medical centres.

ROBOTIC-ASSISTED SURGERY

The incorporation of robotic technology with the laparoscopic approach has allowed for more widespread implementation of complex reconstructive urological procedures. The da Vinci Surgical System enables the surgeon to manoeuvre the laparoscopic camera and robotic arms from a remote unit. A scrubbed assistant exchanges robotic instruments and can aid the surgeon via an accessory port by retracting, suctioning and introducing sutures. The robotic system provides magnified three-dimensional vision, tremor filtering, motion scaling, and articulating movements with six degrees of freedom that permits movements beyond the scope of traditional laparoscopic instruments, thus facilitating dissection and suturing.

ROBOTIC-ASSISTED PYELOPLASTY

After the induction of general anaesthesia, a retrograde pyelogram can be taken to define the anatomy. If desired, an internal ureteric stent can be placed at that time, along with an indwelling Foley catheter. Alternatively, a ureteric stent can be placed in an antegrade fashion after transecting the PUJ.

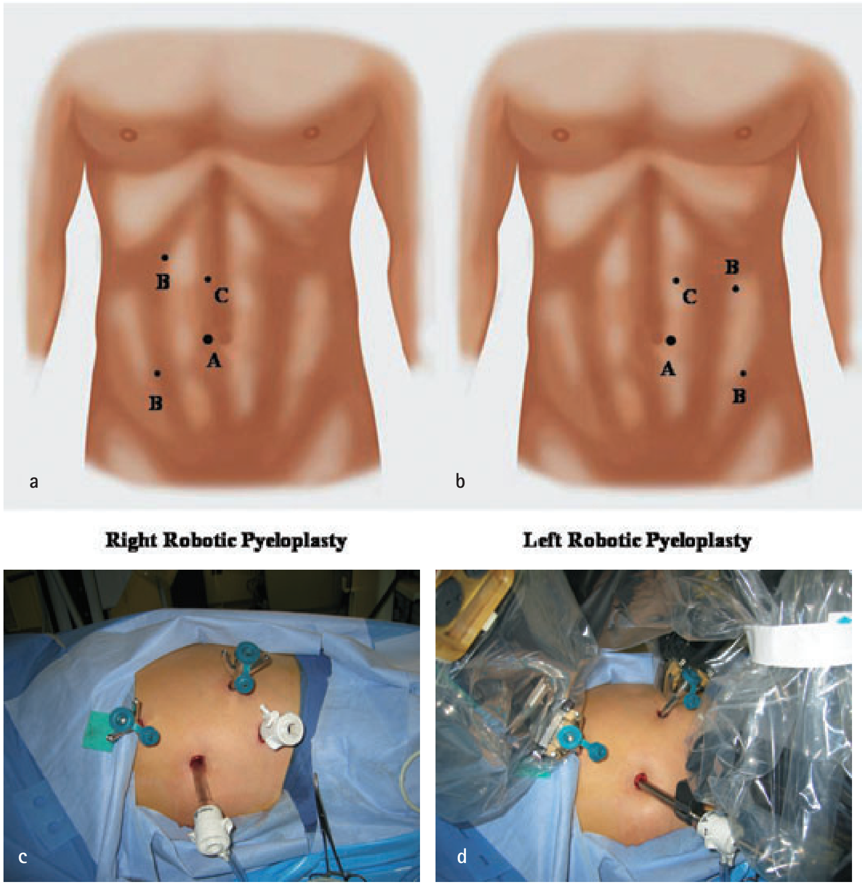
The transperitoneal approach is the most common route described, and is preferred as it offers a greater operative space and familiarity with anatomical landmarks. A three arm da Vinci Surgical System with a bedside assistant is used for the procedure. If available, a fourth robotic arm can be used for retraction, but is not required for robotic pyeloplasty. The patient is placed in a semilateral decubitus position and pneumoperitoneum is created (Fig. 1). Three trocars (two 8-mm robotic trocars, Intuitive Surgical, and one 12-mm trocar) are placed in a triangulated configuration (Fig. 2a–d). An additional 10-mm assistant port is placed to allow an assistant to introduce and retrieve sutures, aid in retraction, and provide suction. This trocar can be placed either infra-umbilically or subxiphoid, based on surgeon preference.

The Anderson-Hynes dismembered pyeloplasty technique is similar to other previously described methods [2,8,9]. Initially, the colon is mobilized and the renal pelvis and PUJ identified. Some investigators have noted that routine steps in conventional laparoscopy, such as colon reflection, can be more cumbersome with the standard da Vinci robot, and require increased attention to visual rather than tactile cues [10]. The improved design of the robotic arms on the second-generation da Vinci S system allows for easier completion of these manoeuvres.

Robotic instruments used for the procedure can include needle drivers, bipolar forceps and monopolar scissors. On the left side, the descending colon is displaced medially to gain access to the PUJ. On the right side, the peritoneum is incised from the liver attachments to the iliac vessels and parallel to the ascending colon, allowing identification of the PUJ. The ureter and renal pelvis are completely mobilized only at the level of the PUJ. Extensive dissection of the proximal ureter is avoided to maintain the vascular supply to the ureter and PUJ. At this point, the diseased PUJ is identified. A crossing lower-pole vessel, if identified, should be preserved, a manoeuvre that is greatly facilitated with robotic technology (Figs 3,4).

For Anderson-Hynes dismembered pyeloplasty, the renal pelvis is circumferentially transected above the PUJ and the proximal ureter is spatulated laterally. In patients who require concomitant stone removal, a robotic instrument is removed and the arm is undocked. This robotic port is used to pass a flexible nephroscope or ureteroscope into the renal pelvis. Stones in the pelvis or calyces are grasped using either a flexible grasper or a stone basket. A specimen bag might be required for very large stones [11]. A systematic and thorough endoscopic examination, along with review of preoperative imaging studies, should be conducted to ensure stone clearance.

FIG. 2. (a) Trocar template for right RAP; (b) Trocar template for left RAP. A, robotic camera trocar; B, robotic arms; C, assistant trocar. (c) Trocar placement for left RAP with the assistant trocar in the infra-umbilical location. (d) Trocar placement with da Vinci robot docked.



A segment of the diseased PUJ is excised at this time using robotic Potts or curved scissors (Fig. 5). In the case of crossing vessels, the ureter and renal pelvis are transposed anterior to the vessel before starting the anastomosis. If the renal pelvis is redundant, excess tissue can be excised and reconstructed after the anastomosis. An absorbable 4–0 suture on a RB-1 needle is placed through the apex of the spatulated ureter and at the most dependent portion of the renal pelvis. The type of suture used, monofilament or polyfilament, is selected based on surgeon preference. Alternatively, an SH needle can be used. The posterior aspect of the anastomosis is then completed in a running fashion.

If an indwelling stent was not placed cystoscopically, it is placed into the ureter over a guidewire via an antegrade approach. The guidewire can be passed through the abdominal wall using a 14 G angiocatheter, or the assistant can pass it through the accessory trocar. The stent is advanced over the guidewire until the end is visualized, at which point the guidewire is removed. The distal coil of the stent is positioned within the bladder and the proximal coil is positioned within the renal pelvis. This technique has been described in detail [12]. If there is a concern about adequate positioning of the stent, cystoscopy or fluoroscopy can be used before completing the procedure. Once the ureteric stent is placed and confirmed to be in the correct position, the anterior anastomosis is completed.

Alternatively, a continuous running suture method can be used, with two sutures that are initially pre-tied together, or with two separate sutures that are each tied together after placing the first stitch on opposite ends of the renal pelvis, which are then tied to one another after half of the anastomosis is completed [13]. After completing a watertight anastomosis, a drain is placed and can exit the patient via one of the robotic trocar sites.

Non-dismembered pyeloplasty can be used for appropriately selected patients, using robotic assistance. Different methods of non-dismembered repairs have been described for laparoscopic and RAP, e.g. the Culp-DeWeerd spiral flap [14], Fenger plasty [15], Y-V plasty [16], Heineke-Mikulicz repair [17], and Davis intubated ureterotomy [18]. The PUJ incision and suturing in these repairs are done in a similar manner as in the open operation. Selection of the type of repair depends on PUJ anatomy and surgeon preference.

FIG. 3. Left RAP. CV, crossing vessel; U, ureter; RP, renal pelvis; K, kidney. (a) Crossing artery and vein anterior to the PUJ. (b) Transection of the PUJ and spatulation of the ureter. (c) Transposition of the PUJ over the crossing vessels. (d) completed anastomosis anterior to crossing vessels.

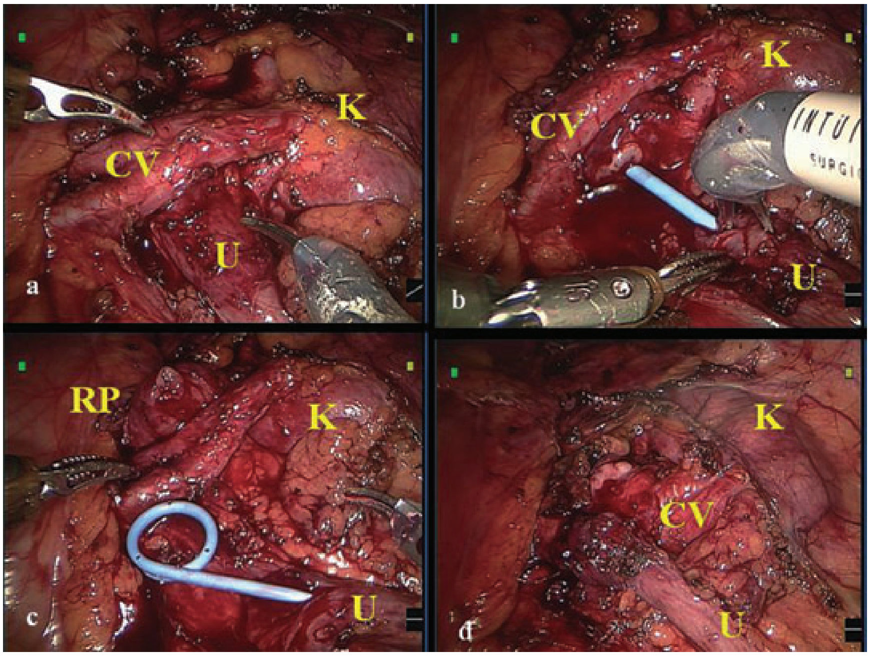
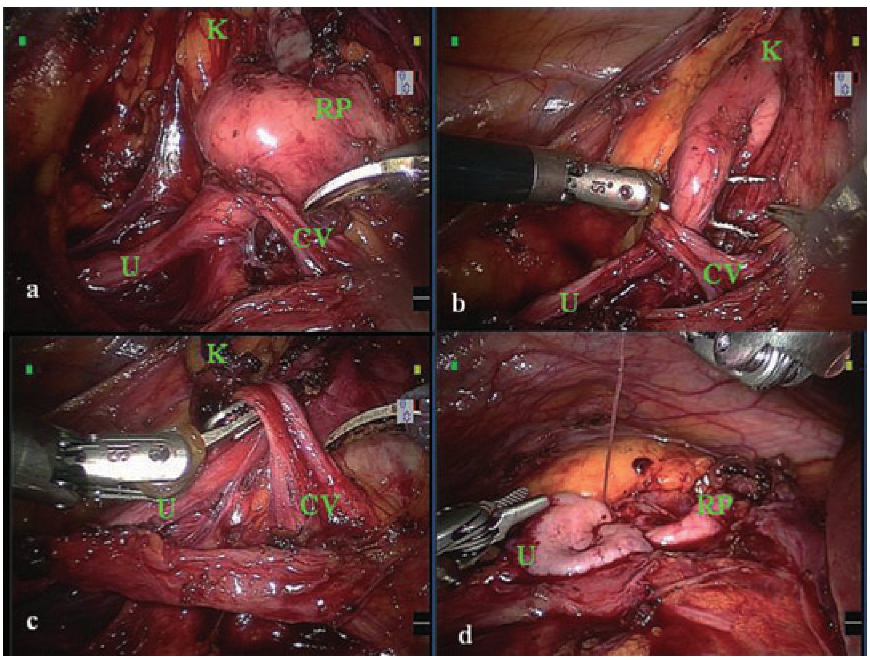


FIG. 4. Right RAP. CV, crossing vessels; U, ureter; RP, renal pelvis; K, kidney. (a) Dilated renal pelvis obstructed by crossing vessels. (b) Mobilization of the PUJ. (c) Mobilization of crossing vessels. (d) Posterior wall of anastomosis after transection and spatulation.

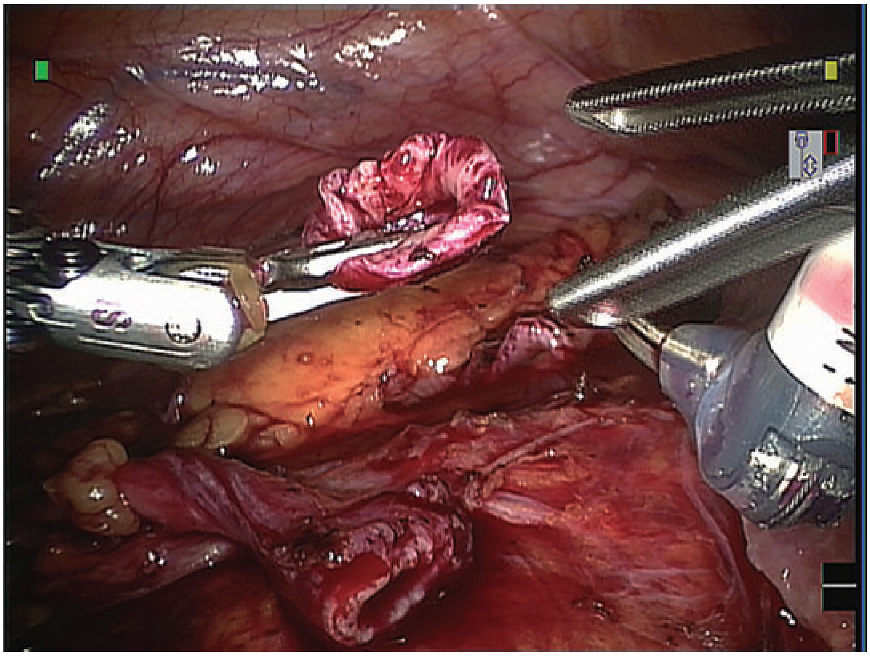


REVIEW OF CONTEMPORARY REPORTS

The increasingly widespread availability of robotic systems, and surgeon experience, has led to the recent publication of large series of RAP with a longer follow-up since the initial report in 2002. Selected outcomes of contemporary LP and RAP are provided in Table 1 [7,13,18–25]. These series represent recent work from high-volume surgeons and centres, or are large multi-institutional collaborations between surgeons with standardized laparoscopic or robotic technique. Reported success rates are generally determined both by subjective improvement of patient symptoms, including pain, and objective evidence in the form of resolution of obstruction on diuretic renal scan or IVU after surgery. Unfortunately, there is no consensus on a standardized definition for success, and this continues to be a problem in comparing series by different groups. Short-term data (<1 year of follow-up) were published in 2005 showing that RAP was safe and reproducible [13,26]. The largest single-institution series was published in 2007, in which Schwenter *et al.* [18] reported on 92 cases of transperitoneal RAP. The mean operative duration in this group was 108.3 min, with minimal blood loss. At a mean follow-up of 39.1 months, 80 patients (97%) had resolution of their obstruction, based on diuretic renal scan results, while three required additional procedures. With durable long-term success rates, this group uses the robotic approach as the preferred technique for managing PUJO. Mufarrij *et al.* [19] recently published a large multi-institutional retrospective review of RAP, reporting on 140 patients from three academic medical centres. Of these procedures, 23 (16.4%) were secondary repairs after initial attempts at PUJ repair, predominantly failed laser endopyelotomy. The mean (range) operative time and hospital stay was 217 (80–510) min and 2.1 (0.75–7) days, respectively. Overall, 95.7% of patients had resolution of obstruction on diuretic renal scan. Ten major complications were reported, of which seven included stent migration requiring ureteroscopic repositioning. Notably, there were no significant differences in operative time, length of stay, estimated blood loss, or time to resolution of symptoms between patients undergoing primary vs secondary repair. There were also no differences in any variables in patients who had concomitant stone extraction or antegrade vs retrograde stenting.

The initial report of paediatric dismembered LP was in 1995 [15], and the robotic technique is currently being applied to increasingly many children. Table 2 [27–31] lists selected outcomes from RAP in children. Robotic surgery remains challenging in these patients due to their size and the use of smaller calibre robotic trocars and instruments. Franco *et al.* [32] recently compared LP with RAP in children and found no statistically significant difference between the groups in terms of operative times or outcomes, in the hands of an experienced laparoscopic surgeon. As instrumentation continues to develop, it is likely that surgeons will continue to use minimally invasive techniques in smaller and younger patients, in an attempt to further lower morbidity while achieving similar or improved surgical outcomes.

FIG. 5. The diseased segment of the PUJ is excised with robotic scissors.



DISCUSSION

The continuing development of surgical therapies has had a profound effect on the management of PUJO. Endoscopic approaches initially showed promise, although the long-term success rates of these techniques were lower than those reported for open pyeloplasty, and were associated with increased bleeding when the aetiology of the obstruction was a crossing vessel. These incisional methods were also associated with a greater risk of developing fibrosis and subsequent re-stenosis. The success rate of open pyeloplasty can be attributed to the fact that this procedure addresses the specific situations in which endoscopic repairs are likely to fail.

LP and RAP can duplicate the open technique, and not surprisingly, are now being shown to be as effective as the standard open approach. The major disadvantage of the laparoscopic approach is that it is technically more challenging due to the high proficiency level required for intracorporeal suturing, although added experience has resulted in shorter operative times. The advent of robotics has further expanded the breadth of this reconstructive procedure, while preserving the benefits of decreased pain, shorter hospitalization, rapid convalescence, and an improved cosmetic result. Also, the da Vinci Surgical System allows the novice laparoscopist to perform this procedure reproducibly and learn it more quickly. Furthermore, the superior magnification, visualization and articulation afforded by the robotic system can also allow PUJ reconstruction in complex situations, such as failed previous endopyelotomy, PUJO in a horseshoe kidney, and solitary kidneys [19].

Nevertheless, there are concerns about the role of RAP; as with similar robotic procedures, the high cost of the robotic platform has led many to question whether the advantages of robotic instrumentation are justified. In the hands of those experienced in LP, the transition to the robotic platform increased the cost by 2.7 times, as shown by a single-surgeon unrandomized comparison [33]. For inexperienced urologists who do not have extensive experience with intracorporeal suturing, the potential exists for the robotic machinery to substantially increase the speed of learning and possibly justify its high cost. Future studies are needed to determine the overall cost-effectiveness of RAP in experienced and inexperienced surgeons, as well as at low- and high-volume robotic centres.

The technique of RAP continues to develop and some variations on this technique deserve mention. To duplicate the laparoscopic technique, some surgeons initially made an interrupted repair of the reconstructed PUJ when making the transition to RAP [13]. With increased comfort with robotic suturing, most reports currently describe a continuous running anastomosis using two sutures, one for the posterior wall of the pelvi-ureteric anastomosis and one for the anterior wall. No single study has compared the outcomes using interrupted vs continuous suturing, although neither technique has resulted in poorer patency rates for the reconstructed PUJ. Surgeon preference dictates whether the anastomosis is made with a monofilament or polyfilament suture, as well as the type of needle used. Currently most authors report using a RB needle, but an SH needle might be required in cases where the renal pelvis or ureter are excessively thick. Occasional cases have been reported in which surgeons elected to perform a non-dismembered repair; this can occur in cases where the renal pelvis is not dilated or intrarenal. In these cases, the PUJ anatomy and surgeon preference dictated which type of repair was used.

Another variation in technique involves the use of robotic assistance for the whole procedure, vs only for the anastomotic reconstruction. Initial concerns about the use of the standard da Vinci robot for renal surgery centred on robotic arm collisions outside the patient, thus limiting the usefulness of the robotic system for such procedures. As a result, many initially mobilized the colon and identified the PUJ using pure laparoscopy [26]. This issue has been mitigated by the second-generation da Vinci S, which has thinner arms that are better suited for robotic renal surgery. Many surgeons currently have access to the four-arm version of the da Vinci robot, which while requiring an additional incision, can be advantageous in situations where the

TABLE 1 Selected large series of LP and RAP in adults

Ref	Year	No. of cases	Approach (%)	Operative time, min	Technique	Ports	Stenting	Hospital stay, days	Follow up months	Success rate, %	Complication rate, %
LP											
[37]	2000	67	Trans Retro	119 (90–210)	Fenger (63) Y-V (4)	3 or 4	RG	4.1	25 (4–60)	98	3
[7]	2001	55	Retro	185 (100–260)	DM (48) Fenger (7)	3 or 4	RG	4.5	14	88	12.7
[20]	2005	93	Trans	179.4 (80–350)	DM (59) Y-V (20) Fenger (7)	3 or 4	RG 50% AG 50%	4 (2–7)	12 (3–27)	93	18.4
[21]	2005	147	Trans	246 (100–480)	DM (106) Y-V plasty (28) Fenger (11) Others (2)	3	RG	3.1 (1–8)	24 (3–84)	95	8.8
[22]	2006	170	Retro (98) Trans (2)	140 (58–290)	DM (170)	4	RG	3 (2–14)	12 (3–72)	96.2	7.1
[23]	2009	118	Trans (99) Retro (1)	205 (85–390)	DM (94) Y-V (18)	N/A	RG	4.7 (3–11)	12.4 (3–60)	94.5	11.9
RAP											
[24]	2005	32	Trans	300	DM (31), Fenger (1)	4 T/3 R	RG 100%	1.1	8.6 (1.5–16)	94	3
[25]	2005	26	Trans	245 (165–390)	DM (23) Y-V (3)	4 (46%) T 3 (54%) T 3 R	RG 100%	2	6 (2–12)	95	0 major/ 11.5 minor
[13]	2005	50	Trans	122 (60–330)	DM	4 T/3 R	RG 100%	1.1	11.7 (1–28)	96	0
[18]	2007	92	Trans	108.3 (72–215)	DM	4 T/3 R	AG 94% RG 6%	4.6	39.1 (3–73)	96.7	3
[19]	2008	140	Trans except 1 Retro	217 (80–510)	DM	4 or 5 T/3 R	AG 71% RG 29%	2.1	29 (3–63)	95.7	7.1 major/ 2.9 minor

Trans, transperitoneal; Retro, retroperitoneal; RG, retrograde; AG, antegrade; DM, dismembered; T, total; R, robotic.

TABLE 2 Selected series of RAP in children

Ref	Year	No. of cases	Age, years	Operative time, min	Technique	Approach	Follow up months	Open conversion rate, %	Success rate, n/N or %
[28]	2005	7	12	184 (165–204)	DM	Trans	10.9	0	7/7
[29]	2006	33	7.9	219 (133–401)	DM	Trans	10	0	94
[30]	2006	8	11.5	363 (255–522)	DM	Trans	14.7	0	8/8
[31]	2006	9	5.6	122	DM	Trans	n/a	0	9/9
[27]	2007	67	7.9	146 (92–300)	DM (59) Non-DM (8)	Retro	12.1	1.4	94

Trans, transperitoneal; Retro, retroperitoneal; DM, dismembered.

surgeon's assistant is not comfortable with laparoscopic surgery. It remains to be seen if greater use and availability of newer robotic systems will translate into the use of robotic surgery for a higher proportion of the procedure. Even if this is the case, it will be difficult to determine whether this would offer any benefit to the patient's ultimate outcome. Reproducibility of the technique across surgeons is one potential result of using robotic-assistance for the whole procedure.

Some surgeons have a preference for retrograde or antegrade stenting of the ureter before completing the anastomosis. While retrograde stenting adds additional operative time needed for cystoscopy and cannulation of the ureter, it also probably prevents one of the more prevalent complications of stent malpositioning that is seen in larger series. As reported by Mufarrij *et al.* [19], six of 99 patients who were stented antegradely required ureteroscopy to reposition the stents, leading to increased anaesthesia time and risk of manipulation or disruption of the reconstructed PUJ.

Other areas of future investigation will probably aim at even further reduction of the morbidity of RAP. Kaouk *et al.* [34] recently reported completing 10 adult cases of retroperitoneal dismembered RAP, and suggested that this approach might possibly allow pyeloplasty as an outpatient procedure. This approach allows the most direct access to the PUJ and limits urinoma formation to the retroperitoneum. The authors noted that they encountered problems with collisions of the robotic arms in the limited retroperitoneal space in initial cases, and some concerns as to the reliability of identifying anterior crossing vessels using this approach. Before this report, retroperitoneal RAP had only been reported in significant numbers in one series of children [27]. A further future direction is the application of single-access or natural-orifice procedures to pyeloplasty. Recently Huber *et al.* [35] reported the use of the da Vinci system and natural-orifice surgery in a porcine model for pyeloplasty, and the initial report of robotic single-incision pyeloplasty has also been published [36]. The feasibility of this type of surgery for urological applications in humans is unknown, but this remains an exciting frontier to further minimize surgical morbidity.

CONCLUSION

Minimally invasive surgical techniques provide a beneficial alternative to open surgical procedures, with the advantages of decreased postoperative pain, shorter convalescence, and improved cosmesis. Since the introduction of surgical robotics, advances in technology and instrumentation have allowed for complex reconstructive procedures. Clinical reports show that RAP is a safe, feasible and effective technique for treating PUJO in short-term studies. The morbidity from the robotic procedure closely resembles that seen with laparoscopic techniques, and is substantially less than with open surgery. Moreover, the overall success rates of RAP are better than with endoscopic methods, and comparable with the more conventional open technique. Unlike LP, which requires advanced laparoscopic skills, RAP has made the procedure more reproducible and available to more surgeons. Additional studies with a prolonged follow-up will ultimately provide valuable information as to the long-term efficacy of RAP.

CONFLICT OF INTEREST

None declared.

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Abbreviations: **(RA)P**, (robotic-assisted) pyeloplasty; **LP**, laparoscopic pyeloplasty; **PUJO**, PUJ obstruction.