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ORIGINAL ARTICLE

Robot-assisted laparoscopic pyeloplasty (RALP) in children with horseshoe kidneys: results of a multicentric study

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Abstract

Purpose This multicentric study aimed to report our experience with robot-assisted laparoscopic pyeloplasty (RALP) in children with horseshoe kidney (HSK).

Methods The records of 14 patients (11 boys and 3 girls with an average age of 9 years), who underwent RALP for repair of pelvi–ureteric junction obstruction (PUJO) in HSK in five international pediatric urology units over a 5-year period, were retrospectively reviewed. A dismembered pyeloplasty with no division of isthmus was performed in all the cases.

Results The average operative time including docking was 143.5 min (range 100–205). No conversions to laparoscopy or open surgery or intra-operative complications occurred. Patients were discharged on postoperative day 2 following catheter and drain removal. The JJ stent was removed at mean 33 days postoperatively. Overall success rate was 92.8%. As for postoperative complications, we recorded a urinary tract infection (UTI) and stent-related irritative symptoms, managed with medical therapy, in two patients (II Clavien) and an anastomotic stricture in one patient needing surgical revision with no further recurrence (IIIb Clavien). At follow-up, all the patients (one after redo-surgery) reported complete resolution of symptoms, improvement of hydronephrosis on ultrasound and no residual obstruction on diuretic renogram.

Conclusions Our experience suggested that RALP in HSK is safe, feasible and with good medium-term outcomes in expert hands. An accurate pre-operative planning associated with a standardized technique is key points to achieve good surgical and functional outcomes in these challenging cases. The da Vinci robot technology offers the advantages of MIS procedures and overcomes the technical challenges of laparoscopic approach.

Keywords Horseshoe kidney · Robot · Pyeloplasty · Children · Technique · Complications

Introduction

Horseshoe kidney (HSK) is the most common renal fusion abnormality, occurring in approximately 1:400–600 individuals [1]. It is more common in men than in women by a factor of 2:1 [2]. Most patients with horseshoe kidneys are often asymptomatic, but a concomitant pelvi–ureteric junction obstruction (PUJO) is the most common complication, occurring in approximately 15–30% of HSK [3]. The increased incidence of PUJO in HSK may be related to high insertion of the ureter into the renal pelvis, to anatomic relation of the ureter with HSK isthmus, or to multiple aberrant crossing vessels [4, 5]. Other common complications in these kidneys include urolithiasis and an increased risk of trauma [6]. The management and surgical indications for these patients are the same as in those with normal kidneys and include symptomatic patients with recurrent flank pain, urinary infections, worsening hydronephrosis, and renal function or the presence of urolithiasis [6]. Traditionally, management of these patients has involved open dismembered pyeloplasty with documented 90% success rate [7]. Recently, laparoscopic pyeloplasty has been proposed as a minimally invasive alternative to open surgery, with similar

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short- and medium-term results [8, 9]. However, the laparoscopic approach can be very challenging and time consuming in HSK, due to unfamiliar and variable anatomy, also in experienced hands [10, 11]. The advent of robotic technology has reduced some of the technical difficulty associated with the laparoscopic repair, by providing surgeons with high-resolution three-dimensional visualization and enhanced dexterity with EndoWrist instrumentation [12].

Currently, there is no consensus regarding the optimal surgical approach for treatment of PUJO in HSK. In addition, only a few cases of minimally invasive pyeloplasty in HSK have been reported in the literature, with less than 20 robotic procedures described in children and adult patients [4, 5, 11, 13–16].

This multicentric study aimed to report our experience with robot-assisted laparoscopic pyeloplasty (RALP) in children with horseshoe kidneys, focusing on the technical aspects of the procedure.

Materials and methods

The records of 14 patients (11 boys and 3 girls), who underwent RALP for repair of PUJO in horseshoe kidneys in five international centers of pediatric urology over a 5-year period (January 2013–January 2018), were retrospectively reviewed. The average patients' age at presentation was 9 years (range 4–12) and their average weight was 26.2 kg (range 12–35). The indications for RALP in our series were restricted to patients older than 1 year of age and of a weight higher than 10 kg.

The major presentation symptoms were recurrent colicky flank pain in seven patients and urinary tract infections (UTIs) in four patients, whereas three children were asymptomatic and the pathology was incidentally discovered during an abdominal ultrasound performed for other indications. There was no history of renal calculi or hematuria in any of the patients. Further evaluation showed a horseshoe kidney with concomitant PUJO. The side of PUJO was right in five patients and left in nine patients.

Pre-operative workup included abdominal ultrasound (US) followed by Mag3 renogram in all the patients. Pre-operative renal function was normal in all the cases. All the patients underwent pre-operatively magnetic resonance urography (MRU) and/or computed tomography (CT) scan with three-dimensional reconstruction for an accurate pre-operative anatomical evaluation, due to the higher risk of aberrant vessels (Fig. 1).

Postoperative follow-up was performed with renal US at 1, 3, 6 months after surgery and thereafter every 6 months for 2 years. A Mag3 renogram was performed 6 months after surgery in all the patients. All the patients received antibiotic prophylaxis till the removal of JJ stent.

Outcome parameters measured included operative time, anastomotic time, analgesic requirement, length of hospital stay, success rate, intra-operative and postoperative complications, and re-operations. The average operative time was defined as the total time spent into the operating room including anesthesia, robot docking time and operative time. The success of surgery was defined by postoperative resolution of symptoms, reduction of anterior–posterior pelvic diameter (APD) on ultrasound and relief of obstruction on Mag3 renogram, defined by the presence of ureteric excretion at 10–15 min.

Postoperative complications were classified according to the Clavien–Dindo grading system [17].

The study received the appropriate Institute Review Board (IRB) approval at each participating center.

Surgical technique

The transperitoneal route was adopted in all the cases. After the induction of general anesthesia, the patient was rolled into a semilateral decubitus position rotating the operative side up by 45° axially using silicone pads underneath the patient (Fig. 2). A sterile Foley catheter was inserted into the bladder. Four trocars were positioned in all the procedures: the first 8-mm robotic camera port was placed infra-umbilically using open Hasson technique; after induction of pneumoperitoneum, the two operative 8-mm robotic ports were placed under vision on the emiclavear line, one 2 cm under the subcostal arch and the other 3 cm above the inguinal ligament. Finally, the fourth 5-mm assistant port was positioned on the pararectal line, mean 6 cm caudal to the

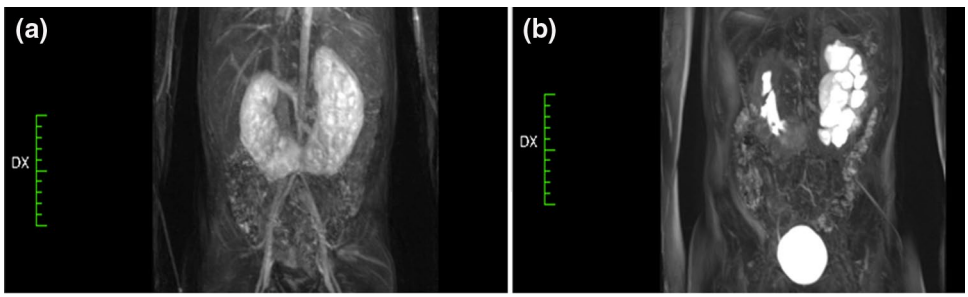

Fig. 1 A magnetic resonance urography (MRU) showing a horseshoe kidney (**a**) with a marked left hydronephrosis and absent drainage of the radiographic contrast also in late acquisitions (**b**)

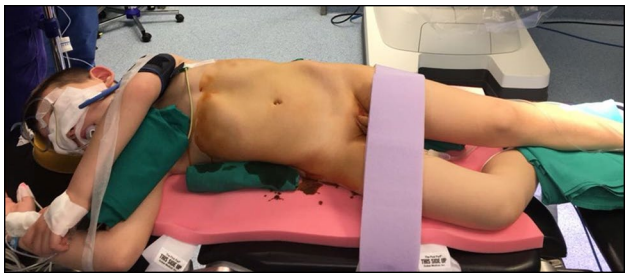

Fig. 2 Patient's position

Fig. 3 Ports' position

robotic camera port and the da Vinci xi robot was docked using a three-arm configuration. Unlike the standard port position for RALP, the ports for HSK were placed about 5 cm more caudally than usual, due to the low-lying position of the horseshoe kidneys (Fig. 3). After incision of the Toldt line and the lowering of the colon, the dilated renal pelvis was detected and isolated, together with the pelvi–ureteric junction (PUJ) and the cranial portion of the ureter, preserving the gonadal veins. The PUJ was fully exposed, ensuring that any further anterior crossing vessels were preserved. The PUJ was then transected and excised. A dismembered Anderson–Hynes pyeloplasty was then performed, with transposition of any identified crossing vessels to avoid any compression of the reconstructed PUJ. A JJ stent was placed into the ureter in an anterograde fashion through the assistant port. The pyeloplasty was carried out with 5–0 monofilament sutures: two or three interrupted stitches were placed at each end and two running sutures completed the anastomosis between the spatulated ureter and the renal pelvis (Fig. 4). The isthmus was preserved in all the cases. The Toldt fascia was reconstructed with separate stitches and a 15 F abdominal drain was placed through the 5-mm assistant port. Trocars' orifices were closed using resorbable sutures.

Results

All the procedures were successfully completed using the da Vinci surgical system with no need for conversion to laparoscopy or open surgery. Neither intra-operative complications nor major bleedings were reported in our series. The average total operative time including docking was 143.5 min (range 100–205) whereas the average anastomotic time was

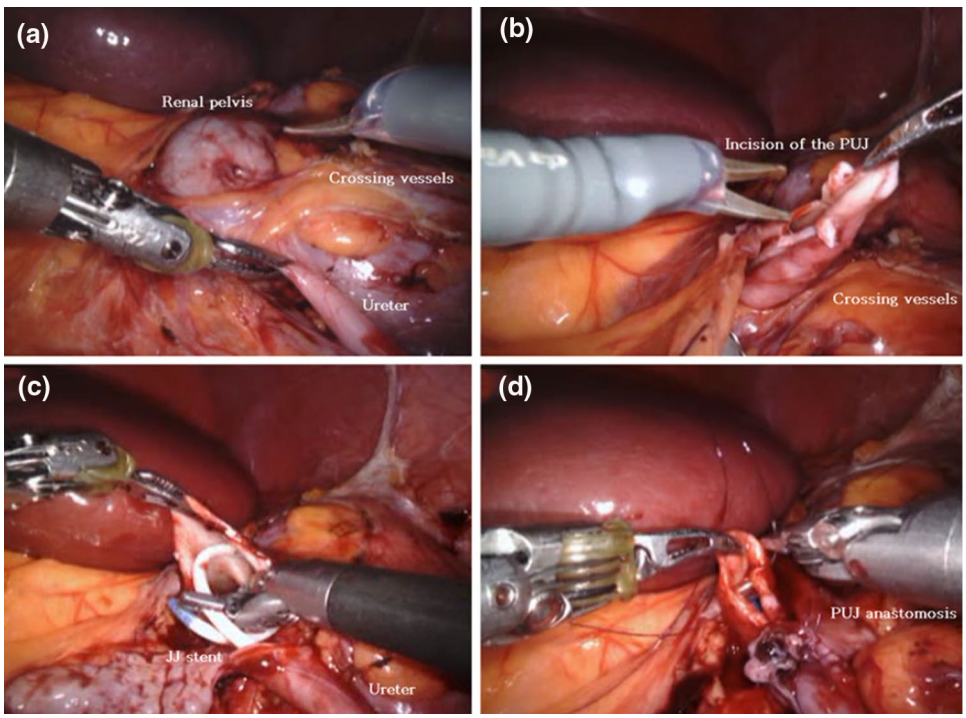

Fig. 4 Operative steps. **a** Isolation of PUJ and identification of eventual crossing vessels. **b** Incision of the PUJ. **c** Insertion of JJ stent in an anterograde fashion. **d** Completion of ureteropelvic anastomosis according to the Anderson–Hynes technique

43.7 min (range 25–80). Surgical findings included crossing vessels in five cases. The bladder catheter was removed on day 1 postoperatively and the abdominal drain on day 2. Physical activity and full oral intake were resumed on the same day of surgery. The average analgesic requirement (paracetamol 15 mg/kg/8 h and tramadol 1–2 mg/kg/6 h) was 30 h (range 24–48). The average length of hospital stay was 2.8 days (range 2–4). The JJ stent was removed under a short-duration general anesthesia, at mean 33 days postoperatively. Overall surgical success rate was 92.8%.

With regard to postoperative complications, one patient had an episode of urinary tract infection (UTI). Renal ultrasound showed no evidence of perirenal collections or hematomas and the patient was treated with antibiotic therapy (II Clavien). One patient presented stent-related irritative symptoms, managed with oxybutynin (II Clavien). One patient reported an anastomotic stricture needing surgical revision. He underwent a robotic-assisted redo-pyeloplasty with no further recurrence (IIIb Clavien). In this last case, the surgical technique involved the resection of the old scars in the connecting area of upper ureter and pelvis with the dissection extending deep beyond the parenchyma extending almost to the neck of the lower calyx. Anastomosis of the ureter to this point afterwards provided a funnel-shaped upper ureter, ensuring adequate urine drainage from renal pelvis/lower calyx postoperatively.

The average length of follow-up was 15.5 months (range 6–24). At follow-up, all the patients (one after redo-surgery) reported complete resolution of symptoms, improvement of hydronephrosis on ultrasound and no residual obstruction on diuretic renogram (postoperative renal drainage 10 min).

All the patients' demographics and outcome parameters are reported in Tables 1 and 2.

Table 1 Patients' demographics in our series

Case number	14
Sex	
Male	11 (78.6%)
Female	3 (21.4%)
Average age (years)	9 (range 4–12)
Average weight (kg)	26.2 (range 12–35)
Side of PUJO	
Right (*n*)	5 (35.7%)
Left (*n*)	9 (64.3%)
Symptoms	
Colicky flank pain (*n*)	7 (50%)
Hematuria (*n*)	0
Urinary tract infections (UTIs) (*n*)	4 (28.6%)
Renal calculi (*n*)	0
Asymptomatic (*n*)	3 (21.4%)
Pre-operative workup	
Ultrasound (US) (*n*)	14 (100%)
Mag3 renogram (*n*)	14 (100%)
Magnetic resonance urography (MRU) (*n*)	11 (78.6%)
Computed tomography (CT) (*n*)	3 (21.4%)

Discussion

For several years, open dismembered pyeloplasty has been the gold standard treatment for PUJO, with reported overall success rates of 90–100% for patients with normal kidneys [18] and 55–80% for patients with HSK [19, 20]. Recently, laparoscopic pyeloplasty has been proposed as a minimally invasive alternative to open surgery, with success rates comparable to those of open repair [8, 9], but the long and flat learning curve has prevented its widespread application in pediatric urology [6]. Long operative times and proficiency in intra-corporeal suturing and knot-tying have represented the main hurdles to the diffusion of laparoscopic pyeloplasty. In particular, the laparoscopic approach can be very challenging and time consuming in HSK, due to unfamiliar and variable anatomy, also in experienced hands [10, 11]. The advent of robotic technology has reduced some of the technical difficulty associated with the laparoscopic pyeloplasty, by providing surgeons with an excellent three-dimensional view of the operative field, increased manual dexterity for the dissection and improved intra-corporeal suturing and knotting [12]. The use of RALP for PUJO in horseshoe kidneys is relatively recent [14]. Currently, there is no consensus regarding the optimal surgical approach for the treatment of PUJO in children with HSK. In addition, only a few cases of minimally invasive pyeloplasty in HSK have been reported in the literature [4, 5, 11, 13–16], with only five robotic procedures described in children [4, 12]. Considering the rarity of the pathology and the limited diffusion of RALP in pediatric surgical centers, we decided to carry out this multi-institutional study, with the aim to collect data from a higher number of patients and improve evidence regarding the treatment of children with HSK. Analyzing the current pediatric literature, our series is the largest among those published until now [4, 12].

On the basis of our experience, the use of the robotic platform may offer undeniable technical advantages, provided that an adequate pre-operative workup and a well-codified surgical technique are followed. The primary technical challenges of pyeloplasty in this population relate to aberrant lower pole vessels, unfamiliar caudal position and malrotation of the kidney, and the renal isthmus [14, 21]. To optimize success of surgery, anatomic complexities can be anticipated with appropriate pre-operative imaging [21]. A CT angiogram can accurately delineate the vasculature and collecting system [4]. MRU can also be utilized for simultaneous evaluation of renal function and anatomy [22].

Table 2 Outcome parameters in our series

Average operative time (min)	143.5 (range 100–205)
Average anastomotic time (min)	43.7 (range 25–80)
Average analgesic requirement (h)	30 (range 24–48)
Average hospital stay (days)	2.8 (range 2–4)
Average resumption of oral intake (h)	9 (range 6–12)
JJ stent removal (days)	33 (range 21–60)
Intra-operative complications (*n*)	0
Conversion to open surgery or laparoscopy (*n*)	0
Postoperative complications	
Urinary tract infection (UTI) (*n*)	1 (7.1%)—II grade Clavien
Stent-related irritative symptoms (*n*)	1 (7.1%)—II grade Clavien
Stricture of anastomosis (*n*)	1 (7.1%)—IIIb grade Clavien
Urinoma (*n*)	0
Other (*n*)	0
Re-operations (*n*)	0
Follow-up (months)	15.5 (range 12–24)
Symptoms (flank pain)	
Before surgery (*n*)	7
After surgery (*n*)	0
Degree of hydronephrosis at US	
Average pre-operative APD (mm)	25.5
Average postoperative APD (mm)	7.4
Renal drainage on Mag3 renogram	
Before surgery (min)	45
After surgery (min)	10

APD anterior–posterior pelvic diameter, *US* ultrasound

The first key step of the procedure is the adequate port placement; the ports for HSK should be placed about 5 cm more caudally than usual, due to the low-lying position of the horseshoe kidneys to improve the access to the PUJ. Surgical treatment in the form of excision of stenotic PUJ, trimming of a redundant pelvis, transposition of any aberrant vessels and ureteropelvic anastomosis are the principles of management [23]. Although a robot-assisted transmesenteric approach has been reported as a safe and feasible option for the management of PUJO in selected patients with HSK [24], we believe that the transperitoneal approach should be preferred to obtain a better surgical control of vascular abnormalities frequent in HSK, including crossing polar vessels. It is important to identify during the dissection phase any crossing vessels and to transpose them behind to the reconstructed PUJ to avoid any extrinsic compression following pyeloplasty. Another important issue in HSK patients is represented by the division of isthmus, which was performed in the past by many authors during open surgical repair, followed by nephropexy of the ipsilateral kidney and dismembered pyeloplasty, in the belief that the isthmus might play an etiological role in PUJO in some cases [23]. Culp et al. reported that isthmectomy may allow the kidneys to lie in a more dependent position that maintains the patency of newly reconstructed PUJ [25]. After division of the isthmus, the medial portion of the separated kidney rotates to lessen the obstruction. Other authors proposed a different approach entailing a simple dismembered pyeloplasty using open or laparoscopic technique without additional division of the isthmus and lateral nephropexy of the kidney, suggesting that this division is unnecessary and, in some cases, risky [10, 26]. It was general policy to avoid such a surgical step also in RALP of PUJO in HSK. The results of our series confirmed that a simple dismembered Anderson–Hynes pyeloplasty without additional division of the isthmus and lateropexy of the kidney was a highly effective and safe procedure for treating PUJO in patients with HSK.

Additionally, the robotic-assisted approach also revealed very useful as redo procedure. One patient of our series with recurrent PUJO was re-operated using robotic transperitoneal approach. In this case, the surgical technique involved the resection of the old scars in the connecting area of upper ureter and pelvis with the dissection extending deep beyond the parenchyma extending almost to the neck of the lower calyx. Anastomosis of the ureter to this point afterwards provided a funnel-shaped upper ureter, ensuring adequate urine drainage from renal pelvis/lower calyx postoperatively.

An important issue for widespread application of RALP remains its high cost, intended as the initial capital cost of the equipment, together with the costs of the associate disposables [14]. Robotic pyeloplasty might cost more than standard laparoscopy but the enormous advantages provided in terms of surgeon's ergonomics, length of surgery, precision, and facility of intracorporeal suturing may outweigh these limitations [12, 14]. Prospective studies addressing cost–benefit in high-risk populations are needed to draw such conclusions.

Limitations of this study are its retrospective nature and the small number of patients included; however, this limitation is due to the high rarity of this pathology in the pediatric population. For this reason, we collected the data from several pediatric centers with the efforts to achieve a more objective evidence regarding the treatment of this rare pathology.

In conclusion, our experience suggested that the indications for robotic-assisted laparoscopic pyeloplasty in children can be extended to anatomically challenging cases such as patients with horseshoe kidneys. Considering the rarity of the pathology, we believe that these patients should be addressed only in centers with a strong experience in MIS and in particular in robotic surgery, and a strict collaboration between different pediatric surgical centers should be advocated to manage the most challenging cases. Our results confirmed that RALP for horseshoe kidney is safe, feasible and with good medium-term outcomes in expert hands. These are challenging cases and an accurate pre-operative planning associated with a standardized technique is key points to achieve good surgical and functional outcomes. The da Vinci robot technology offers the advantages of MIS procedures and overcomes the technical challenges of laparoscopic approach.

Author contribution CE: project development, data collection, manuscript writing, and manuscript editing; LM: data collection, data analysis, and manuscript editing; TB: data collection, data analysis, and manuscript editing; GM: data collection, data analysis, and manuscript editing; SS: data collection, data analysis, and manuscript editing; ME: project development, data analysis, manuscript writing, and manuscript editing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest or financial ties to disclose.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Research involving human participants and/or animals This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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