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REVIEW

The evolving role of laparoscopic surgery in paediatric urology

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Orchidopexy;
Undescended testes;
Reimplantation

ABBREVIATIONS

LO, laparoscopic orchidopexy; FSO,

Abstract ***Objectives:*** We review the various applications of laparoscopic and robotic-assisted laparoscopy in paediatric urology, as the laparoscopic and robotic approach in this population is gradually being recognised.

Methods: We searched PubMed for human studies in English that were published between 1990 and the present, focusing on laparoscopic nephrectomies and partial nephrectomies, laparoscopic and robotic pyeloplasties and ureteric reimplantation, laparoscopic orchidopexy and varicocelectomy. We also reviewed robotic-assisted laparoscopic urological major reconstructions. Key articles were reviewed, extracting the indications, techniques, and the advantages and disadvantages.

Results and conclusions: Laparoscopy has a defined place in modern paediatric urological surgery. Laparoscopic nephrectomies, pyeloplasties and abdominal exploration for the evaluation and management of impalpable undescended testicles have

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Fowler-Stephens orchidopexy; LP, laparoscopic pyeloplasty; L(P)N, laparoscopic (partial) nephrectomy; LUR, laparoscopic ureteric reimplantation; UDT, undescended testis; LV, laparoscopic varicocelectomy

become the standard of care. Robotic-assisted laparoscopic surgery is developing as a safe and effective option even for infant patients.

Introduction

Laparoscopic surgery has a defined place in modern paediatric urological surgery. Nephrectomies, pyeloplasties and abdominal exploration for the evaluation and management of impalpable undescended testes have become the standard of care in most specialised centres. Because the patients are small and the surgery complex, the adoption of the laparoscopic approach is relatively slower in children than in adults.

Several studies have shown that laparoscopic pyeloplasty (LP) in older children, nephrectomies and laparoscopy for intra-abdominal testes have an advantage over open surgery [1–4]. Potential benefits include a faster recovery (measured by shorter hospitalisation and time to ambulation), reduced postoperative pain and improved cosmesis. Other laparoscopic procedures showed no convincing evidence for the superiority of the laparoscopic approach, and are still being performed openly by many paediatric urologists. One example is the use of open pyeloplasty in infants via a dorsal lumbotomy incision or a small muscle-splitting flank incision.

Laparoscopic urological procedures in children have an acceptable rate of complications. In different series the complication rate was 1–2.7% (when excluding preperitoneal insufflation and subcutaneous emphysema as a complication) [5,6]. Passerotti et al. [7] reported lower complication rates when an open technique was used than for the Veress technique (0.8% and 2.3%, respectively, $P = 0.006$). In that series the incidence of Clavien's system grades III and IV complications was 0.8%.

Here we review the various applications of laparoscopic surgery and robotic-assisted laparoscopy in paediatric urology. We focus on the indications, technique, and the advantages and disadvantages of each.

Nephrectomy

Laparoscopic nephrectomy (LN) was first performed in adults by Clayman et al. in 1991 [8]. Koyle et al. [9] reported the first paediatric LN in 1993 and since then numerous series have shown the feasibility and safety of this procedure, thus making this approach the standard of care for paediatric nephrectomy [10–15].

In contrast to the adult population, a paediatric nephrectomy is commonly used to remove benign lesions or non-functioning kidneys. The LN offers many advantages, which include excellent visualisation and magnification, better cosmesis, reduced postoperative pain, and shorter recovery and hospital stay. Another distinctive advantage of the LN is the ability to extend the ureteric dissection distally into the pelvis, thus omitting the need for a second incision in cases where nephroureterectomy is desired [15].

Access to the kidney can be through a transperitoneal or retroperitoneal approach. The advantages and disadvantages of each method are commonly debated. The transperitoneal approach allows a larger working space, which is helpful in patients with large multicystic dysplastic kidneys, significance adhesions after pyelonephritis, and massively hydronephrotic kidneys. The transperitoneal approach also permits easier access to the upper pole with less manipulation and risk to the normal lower moiety in cases of a partial nephrectomy in a duplicated collecting system. The advantages of the retroperitoneal access include quicker access to the renal hilum and avoidance of having to dissect the colon. Kim et al. [1] reported a systematic review comparing 401 and 288 patients who underwent retroperitoneal and transperitoneal laparoscopic surgeries, respectively. The authors found no statistically significant difference in success and complication rates, or variables assessing recovery.

In a transperitoneal nephrectomy, the colon is first taken down by incising the lateral line of Toldt. Dissection and ligation of the hilar vessels should be completed before the kidney is mobilised, to maintain visualisation. In most cases the ureter can be identified along the psoas muscle, and lead to the renal hilum. The renal vessels are then dissected free and independently ligated with metal or Hem-o-Lok clips. Smaller vessels are commonly controlled with a harmonic scalpel, bipolar cautery or LigaSure.

Partial nephrectomy (PN)

PNs in children are usually indicated for a non-functioning renal segment of a duplex system. In those cases the demarcations between the segments are usually very clear and the affected unit is often hydronephrotic or cystic; therefore the anatomical plane is easily defined and separation between the poles is straightforward. The critical feature in the paediatric PN is protection of the renal vasculature of the remnant segment.

Several published reports compared experiences with open and laparoscopic PNs (LPNs) [16–18]; most of these reports concluded that LPN is safe and superior to the open approach in terms of postoperative pain, shorter hospital stay and cosmesis. However, the LPN took longer (6–65 min longer in the different retrospective reviews) and has a prolonged learning curve [16–18].

Lee et al. [18] reported their initial experience with nine cases of robotic-assisted LPNs and emphasised that in addition to the general laparoscopic procedure, the robotic system offers better visualisation and dexterity that might improve efficiency and safety compared with the standard laparoscopy.

Pyeloplasty

The transperitoneal LP was first described by Peters et al. in 1995 [19]. Yeung et al. [20] reported the retroperitoneal approach in 2001. Since then, many groups have reported their series, including overall complication and success rates, which are not significantly different from the open approaches [2,19–22]. Most studies show a statistically significant longer operative duration and a trend towards decreased in-hospital stay and analgesic consumption with the laparoscopic approach [2,21].

Tanaka et al. [2] used a multi-institutional database to retrospectively review patients undergoing LP (324) or open (4937) pyeloplasty. They found that patients aged >10 years gained the most benefit from laparoscopy in terms of shorter hospital stay and decreased postoperative pain than did younger patients.

The most significant challenge in LP is the difficulty of precise intracorporeal suturing. Bonnard et al. [21] emphasised the significant learning curve required for LP, and Farhat et al. [22] showed that teaching LP was not feasible when the surgeon had no advanced experience in laparoscopy. Those factors might be why this approach has failed to gain widespread acceptance for treating paediatric PUJ obstruction.

Robotic-assisted LP

The major advantages of the robotic system include wristed instrumentation, allowing greater ability to perform precise suturing for reconstruction, and the stereoscopic system offering three-dimensional vision. Disadvantages include increased cost, lack of tactile feedback and lack of adequate paediatric-sized ports and instruments [23].

The most significant challenge in LP is the difficulty in precise intracorporeal suturing. The use of the robotic system helps to overcome this problem, by making suturing easier, thus shortening the learning curve for those surgeons with no expertise in advanced laparoscopic surgery [24].

Franco et al. [25] compared a conventional LP group with a robotic-assisted LP group, and found a similar outcome and overall operative time; this can possibly be explained by the decreased time needed to make the anastomoses, but a longer robotic set-up time. Limitations to that study are that the LP group was operated by a highly experienced laparoscopic surgeon, supporting the view that the results might not be generally applicable.

Braga et al. [26] reported a systematic review and meta-analysis to evaluate the effect of robotic-assisted vs. conventional LP. Eight studies were included and showed that the overall use of the robotic system was associated with a 10-min reduction in operative duration ($P = 0.15$) and significantly shorter hospital stay than with the conventional LP group ($P < 0.01$). There were no differences between the approaches in complication ($P = 0.40$) and success rates ($P = 0.62$).

In our current practice, children of <20 kg undergo an open pyeloplasty via a dorsal lumbotomy incision. We found this approach to be well tolerated, with mild postoperative pain and short recovery time. Larger patients are managed with robotic-assisted LP.

Laparoscopic ureteric reimplantation (LUR)

Open UR has been the standard of surgical care for treating VUR, with 95–98% success rates and a low rate of complications [27]. In the last decade several groups [28–31] have pioneered the LUR; these groups tried to achieve the same surgical outcome with less morbidity.

LUR is technically challenging and a highly demanding surgery that requires an experience in laparoscopic technique, and has a steep learning curve. Limited data are available to truly assess the efficacy and safety of this procedure in children.

Different procedures have been described to achieve an antireflux effect. The extravesical (Lich-Gregoir) technique is most commonly used. Lakshmanan and Fung [28] reported, in one of the earliest series of 71 refluxing ureters, no postoperative reflux or obstruction, suggesting an efficacy similar to that of open surgery. The transvesical pneumovesicoscopic approach was introduced to mimic the Gil-Vernet and Cohen technique. Canon et al. [31] compared 52 patients who had laparoscopic vesicoscopic cross-trigonal UR to 40 control patients who had an open procedure. The resolution rates of VUR for the vesicoscopic and open groups were 91% and 97%, respectively. The mean operative times for the vesicoscopic and open procedures were 199 and

92 min, respectively, and less oral and intravenous analgesia was needed after surgery in the vesicoscopic group.

Robotic-assisted LUR

Robotic-assisted LUR appears to be a feasible option to correct reflux; the robot facilitates the dissection and intracorporeal suturing, therefore shortening the operative time and improving the success rate compared to conventional LUR [32]. In 2004 Peters [33] reported an early series of 24 children who had a successful robotic-assisted LUR. Casale et al. [32] reported on 41 patients who underwent robotic extravesical reimplantation for bilateral VUR; the operative success rate was 97.6%. There were no complications and there were no episodes of urinary retention. Smith et al. [34] compared 25 children who underwent robotic-assisted extravesical LUR with a control group of 25 undergoing open cross-trigonal UR. The mean operative time was 12% longer in the robotic group ($P < 0.05$). The mean length of stay (33 h vs. 53 h) and pain medication use were significantly less in the robotic group ($P < 0.001$). The overall success rate was 97% for robotic-assisted LUR vs. 100% for open LUR.

LUR and robotic-assisted LUR are developing but controversial. The open approach offers faster surgery with excellent results and a straightforward recovery. More data are needed to justify the added value of this more costly approach.

Impalpable testis

The management of an impalpable undescended testis (UDT) with laparoscopy has gained wide acceptance in the paediatric urological community. Since the earliest reports of Cortesi et al. [35] in 1976 of using laparoscopic techniques to identify impalpable testes, there are now several thousand reported cases documenting that laparoscopy is not only an accurate diagnostic tool for locating the testis, but an appropriate tool to facilitate the management of the impalpable UDT [36,37].

The principles of laparoscopic surgery for the UDT are similar to those of the open approach. These principles include mobilisation of the spermatic vessels and the vas, hernia repair and redirecting the testis to the scrotum via a straight route. The advantages of a laparoscopic approach include an accurate anatomical assessment of testicular position and viability, optimal exposure and magnification, as well as minimal invasiveness of the procedure [37].

Diagnostic laparoscopy

The prevalence of UDT is 3% at birth in term infants and 1% at 3 months old; ≈20% of UDT is impalpable. Ideally the patient should be 6–12 months old during the procedure [37]. Imaging has a low added value for the diagnosis of the impalpable UDT [38,39], and therefore the definitive diagnostic step is an examination under anaesthesia. If the testis cannot be palpated in the inguinal area then diagnostic laparoscopy should be used.

The primary aims of diagnostic laparoscopy for impalpable testes are to identify the presence or absence, the location, and the anatomy of the impalpable testis. Diagnostic laparoscopy aids in determining the feasibility of a single or two-stage orchidopexy or, if the testis is found to be abnormal, whether orchidectomy is indicated [37]. After inserting the laparoscope, the midline structure first viewed is the urinary bladder, and just lateral and along the anterior abdominal wall runs the inferior epigastric vessels, which are at the medial border of the internal ring. Examining the normal side is useful for appreciating normal anatomy. At this point there are three possible scenarios: (1) an intra-abdominal testis (Figs. 1 and 2). (2) Blind-ending vessels and vas above the internal ring, a condition referred to as 'vanishing testes', and most commonly caused by a prenatal vascular event. In this case the spermatic vessels are commonly hypoplastic. (3) Normal internal spermatic vessels and vas deferens exiting the internal ring. In this case, if an inguinal hernia is seen, an extra-abdominal testis which was difficult to palpate upon physical examination would be anticipated. If a closed internal ring is

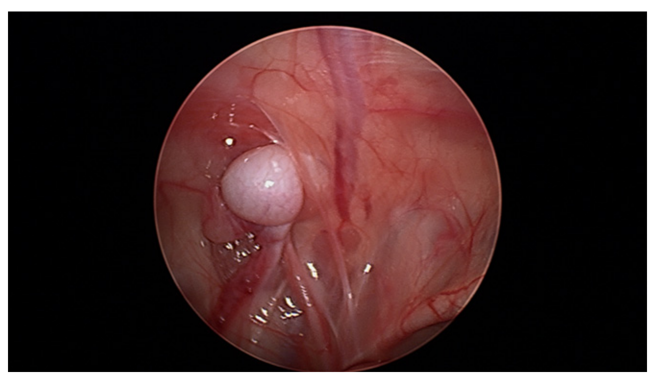

Figure 1 A low intra-abdominal testis allows a single-stage LO.

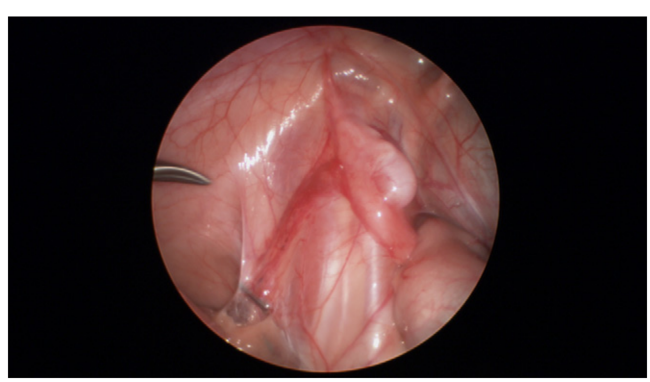

Figure 2 A high intra-abdominal testis after spermatic vessel clipping for first stage laparoscopic FSO.

seen an atrophic testicular remnant in the inguinal or scrotal region is expected [40]. Most testicular remnants or 'nubbins' will have histological evidence of ischaemia, necrosis and haemosiderin deposition. Viable residual testicular elements are rarely present [41].

We tend to remove the atrophic testicular nubbin to histologically confirm that no testicular tissue is left in the abdomen. In this case we also perform a scrotal orchidopexy with permanent sutures to the normal contralateral testis, to prevent possible testicular torsion in the future.

Laparoscopic orchidopexy (LO)

The advantage of LO for an intra-abdominal testis is the ability to mobilise the proximal spermatic vessels, which is usually a major challenge in a very high orchidopexy approached inguinally. In addition, by performing the Prentiss manoeuvre, we redirect the testis to the external ring in a more direct approach to the scrotum. Magnification is facilitated by the LO and allows a delicate dissection and maximal preservation of the spermatic and collateral circulation. The success rate in terms of the position and viability of the testis after the LO is at least comparable to the open approach in many published series [3,4,42]. Baker et al. [4] found a higher success rate (defined as lack of atrophy and intrascrotal position) for the LO than for the historical open approach. In that multi-institutional retrospective report, the success rates depended on the procedure performed (97.2% for 'primary' LO, 74.1% for one-stage Fowler-Stephens orchidopexy (FSO), and 87.9% for two-stage FSO). Atrophy rates were highest in the single-stage FSO, at 22%, whereas atrophy occurred in only 2% of testes after a straightforward LO. The two-stage FSO had intermediate results of a 10% atrophy rate.

Laparoscopic Flower-Stephens Orchidopexy

A two-stage FSO is used in older children with a high intra-abdominal testis, where the testis is usually found within 1–2 cm of the internal ring. Tight spermatic vessels or testes > 2 cm from the internal ring usually indicate a staged procedure. The first stage consists of clipping and dividing the spermatic vessels and allowing the collateral circulation to develop. The second stage of the orchidopexy is usually completed 6 months later, in the same manner as described in single-stage orchidopexy.

Laparoscopic varicocelectomy (LV)

A varicocele is present in 10–15% of the adolescent male population [43]. The major indications for varicocele treatment include failure of testicular growth, testicular pain, diminished fertility and cosmesis. Loss of testicular volume is defined as > 20% of testicular size between the testicles, as measured by ultrasonography. After successful varicocele surgery compensatory testicular growth occurs in 50–80% of patients [44]. Several studies confirmed the efficacy of the laparoscopic approach to ligation of the spermatic vein (Fig. 3). Podkamerer et al. [45] evaluated 654 patients randomly assigned to LV or open varicocele repair. In all cases, the modified Palomo technique with lymphatic preservation was used. Success rates were measured by the rate of recurrence and occurrence of hydrocele; these were similar in the two groups. The LV group had a shorter operative time and recovery; postoperative analgesic use was almost half after LV. Barroso et al. [46] reported a systematic review comparing 1344 LV and 496 open spermatic vein ligations. The rate of hydrocele formation was not statistically different between the groups, both in the Palomo (mass ligation of the spermatic vessels) and modified Palomo (spermatic artery preservation) procedures.

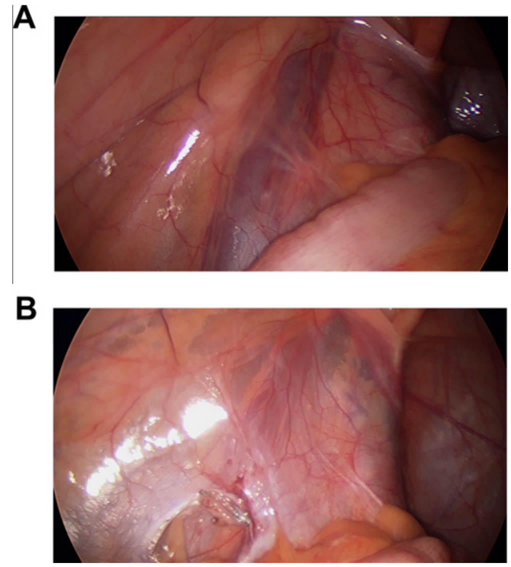

Figure 3 (a) A distended left spermatic vein before clipping and (b) a collapsed spermatic vein after clipping.

Major reconstructive procedures

Appendicovesicostomy

There are few reports describing the use of laparoscopy and robotic-assisted techniques for the appendicovesicostomy Mitrofanoff continent catheterisable channel. In 2004 Casale et al. [47] described a pure laparoscopic Mitrofanoff appendicovesicostomy with the use of an endoscopic stapling device to harvest the appendix. In 2006 Nguyen et al. [48] described their preliminary experience with the robotic-assisted Mitrofanoff procedure. In these 10 patients, urinary leakage developed after surgery in one, requiring an open revision, and minor incontinence developed in two, of which one was corrected with dextranomer/hyaluronic acid injection and one resolved with no intervention. Recently Bargrodia and Gargollo [49] extended the scope of complex robotic reconstruction in children. They described successful robot-assisted bladder neck reconstruction, bladder neck fascial sling and appendicovesicostomy in four patients with neurogenic bladder.

Bladder augmentation

Bladder augmentation is a major reconstruction procedure for which the open procedure is the reference standard. The procedure requires a tremendous amount of suturing. Very few authors have described their experience with laparoscopic bladder augmentation [50]. Robotic-assisted laparoscopy might overcome the challenge of intracorporeal suturing. In 2008 Gundeti et al. [51] reported the first successful complete robotic-assisted laparoscopic augmentation ileocystoplasty and Mitrofanoff appendicovesicostomy.

Conclusion

Laparoscopic surgery has an important role in modern paediatric urological surgery. Many laparoscopic procedures are already a standard of care in most specialised centres. Robotic-assisted laparoscopic surgery has developed in the last few years as a safe and effective option even for infant patients. The robotic system should be adjusted further to orientate this technology to use in children, and more data are needed to justify the superiority of this approach.

Conflict of interest statement

The authors have no conflict of interest to declare.

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