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Laparoscopic Approach for Intravesical Surgery Using Pneumovesicum in Urology: Literature Review

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Minimally invasive laparoscopic surgical procedures are increasingly being used in the management of various urological diseases. In particular, the laparoscopic approach for intravesical surgery using pneumovesicum (LPV) is a minimally invasive alternative with potential advantages including decreased morbidity, shorter hospital stays, and improved cosmesis. We review the applications of LPV in urology, summarize data for different surgical approaches, and provide an overview of patient management, as well as other considerations. This narrative review focused primarily on articles indexed in PubMed, Google Scholar, Scopus, and Embase databases. No formal search strategy was used, and no meta-analysis of data was performed.

Keywords: Laparoscopy; Urology; Pneumovesicum; Transvesicoscopy

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INTRODUCTION

The development of the laparoscopy instrument has enabled various surgical methods. For instance, the laparoscopic approach for intravesical surgery using pneumovesicum (LPV) has transformed the concept of infusing the bladder with gas instead of water. This concept, also known as pneumovesicum, was initially described 50 years ago. [1] Since then however, pneumovesicum has not been widely used for cystoscopy or cystometry. However, this procedure has recently received attention because of its application to transvesical laparoscopy. The LPV was initially described by Yeung et al. [2] during laparoscopic ureteroneocystostomy. To our knowledge, the term is not clearly defined and is sometimes referred to as a combination of LPV, pneumovesicoscopic, or transvesicoscopic approaches.

LPV is very helpful in overcoming challenging surgical procedures. In addition, many studies have shown that LPV has potential benefits over traditional techniques, including improving cosmesis, reducing postoperative pain and postoperative ileus, fewer wound complications, and shorter hospital stays [2-7]. It can also overcome many complications that may occur in transperitoneal laparoscopy. First, because CO_2 insufflation is limited to the bladder, the intraabdominal pressure is not sufficiently excessive to cause oliguria. Second, CO_2 pneumovesicum does not appear to affect the renal arterial or venous flow, nor does it introduce a CO_2 embolism [8].

However, LPV has not been used to treat several diseases because it requires a small working space. In addition, some procedures are technically demanding, even for an experienced laparoscopic surgeon [9,10]. Nevertheless, studies on LPV have

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demonstrated excellent results, and it has been employed in various aspects of urological diseases beyond vesicoureteral reflux (VUR) management. Herein, we review the application of LPV in urology, summarize data of different surgical approaches, and provide an overview of patient management, as well as other considerations.

MATERIALS AND METHODS

We performed a narrative review of relevant research. While no formal search strategy was employed, the following search terms were primarily used to identify relevant sources: transvesicoscopy, pneumovesicum, pneumovesicoscopic, transvesical laparoscopy, and pneumovesical laparoscopy. PubMed, Scopus, and Embase were searched to identify potentially relevant published literature. The search was performed in November 2017. References from relevant sources were examined to identify additional sources for this review. A synopsis of relevant references was created.

RESULTS

Overview of Included Studies
Total 52 studies about LPV published between 2005 and 2017 were reviewed. Ureteral reimplantation were described in 18 studies, management mesh complication in 6 studies, management of vesico-vaginal fistula (VVF) in one study, removal of bladder foreign body in 9 studies, management of benign prostate hyperplasia (BPH) in 5 studies, management of prostate cancer in 2 studies, management of distal ureter and bladder cuffing in nephroureterectomy in 7 studies and bladder diverticulectomy in 4 studies.

Port Placement, Pneumovesicum Establishment, and Complications
The bladder should be distended with saline under cystoscopy to establish pneumovesicum [2]. The laparoscopic port is then inserted under a cystoscopy guide, and the bladder is inflated with CO_2 while draining the saline. Although the number of ports depends on the procedure, most require three for suturing. Two 3- or 5-mm trocars are used for the working ports, and a 5-mm trocar for the midline camera port that houses a 0° 5-mm telescope [11]. However, transvesical laparoendoscopic single-site surgery (T-LESS) can be performed in patients who do not need delicate suturing or adults who have a relatively large working space [12-14]. When suturing is needed, a 1.5-cm longitudinal skin incision is made 2 cm above the pubic symphysis, and the inner ring of a TriPort access system is inserted directly into the bladder via a skin incision under cystoscopic control.

The main reason for open conversion in LPV surgery is port displacement. A related study on ureteral implantation using LPV showed an open conversion rate of approximately 5%–10%, predominantly due to port displacement [15]. To overcome this limitation, some researchers have suggested that 5-mm locking trocars (Pediport, Covidien, Dublin, Ireland) or self-retaining trocars with an umbrella (Pediport Ref 240 ST diameter 5.5 mm, Covidien) could reduce port displacement rate without significantly depending on cystopexy [5,6]. However, open conversion can occur even if port access is difficult or pneumovesicum (PV) is not maintained. Valla et al. [6] reported that 6% of patients in their case series were converted to an open approach, because of the difficulty of port access to the bladder. In particular, increased elasticity and mobility of the bladder in patients younger than 2 years lead to more difficult PV maintenance.

Common complications related to port insertion include intraperitoneal urine leakage and emphysema. Most emphysema-related PVs are resolved with conservative management. However, intraperitoneal urine leakage requires prolonged urethral catheterization. Urinary leakage should be considered after catheter removal when abdominal distention is noted, especially in cases of oliguria and adequate hydration [11]. Kutikov et al. [11] observed that all the leaks at port sites were intraperitoneal, and that all patients needed urethral catheterization. Ports may traverse the peritoneum and induce gas leakage into the peritoneal cavity if the port was placed too cephalad. Pneumoperitoneum can lead to collapsed bladders, poor visibility, and emphysema. Jayanthi and Patel [16] reported that transumbilical Veress needle placement vent CO_2 and allow the bladder to distend appropriately.

Kilincaslan et al. [17] reported that long-term PV or excessive CO_2 pressure in the bladder can cause upper tract injury. In their experimental VUR model, they found that the intraipsilateral upper urinary tract and the contralateral renal medulla had significant histopathological changes upon intrauterine CO_2 insufflation. However, Xiang et al. [8] demonstrated that CO_2 pneumovesicum at a pressure of 10 mmHg for 2 hours did not result in any demonstrable deleterious effect in their pig model. In addition, CO_2 was mildly acidic (carbonic acid) and CO_2 pneumovesicum may have irritated the mucosal wall of the bladder.

Therefore, it could feasibly affect bladder overactivity. However, few studies have evaluated the impact of CO_2 pneumovesicum on the urinary tract and bladder function in humans.

Ureteral Reimplantation With LPV
Cohen technique

Minimally invasive surgical procedures using laparoscopic techniques have been shown to be effective in managing patients with VUR. Since Lakshmanan et al. first reported laparoscopic extravesical reimplantation, various types of laparoscopic ureteral reimplantation techniques have been developed in this patient population [18]. The concept of transvesical laparoscopy surgery was first introduced in 2001 by Gill et al. [19] in a laparoscopic cross-trigonal ureteral reimplantation. Yeung et al. [2] were the first to report the cross-trigonal ureteral reimplantation technique under LPV with the bladder filled with CO_2. This method demonstrated better success rates than the open cross-trigonal reimplantation. Current techniques have been shown to be safe, with a low complication rate and excellent success rates (92%–98%) (Table 1) [2,5-7,9,10,19-21].

Most operative techniques are similar to those described by Yeung et al. [2] and Valla et al. [6]. The procedure is mostly per-formed in the supine or lithotomy position, using three laparoscopic ports [2]. Intravesical mobilization of the ureter, dissection of the submucosal tunnel, and a Cohen type of ureteral reimplantation were performed under endoscopic guidance, similar to the open procedure. Generally, ureter mobilization is advanced for 2.5 to 3 cm into the extravesical space. The muscular defect in the ureteral hiatus was repaired with two or three 5-0 absorbable interrupted sutures to reduce air leakage in the perivesical space [2,6,21]. Maryland graspers, L-hooks, or endoscopic scissors facilitate the creation of a transverse submucosal tunnel. Resection or spatulation of the terminal part of the ureter or leaving the mucosal collar depends on the surgeon's preference [6]. In addition, ureteral stents or feeding tubes are not routinely used, but they may be considered in some patients undergoing bilateral ureteral reimplantation or those with megaureters requiring tapering ureteroplasty [2,15].

Compared with open surgery, the benefits of LPV ureteric reimplantation include reduced bladder trauma and improved cosmesis. Valla et al. [6] demonstrated that the absence of wide cystotomy, the presence of gauze in contact with bladder mucosa, intravesical retraction, and minimal manipulation of the tissue around the trigone lead to decreased bladder trauma. In

Table 1. Published articles on pneumovesical laparoscopic ureteral reimplantation for management of vesicoureteral reflux

Study[a]	Reported year	Case No.	Age[b] (yr)	Operative time[b] (min)	Urethral catheter indwelling[b] (day)	Hospital stay[b] (day)	Follow-up[b] (mo)	Perioperative complication (%)	Open conversion (%)	Success rate (%)
Politano-Leadbetter technique										
Choi [4]	2015	10	6.9	Uni, 93; Bi, 133	5.1	6.2	9.0	0	0	100
Soh [7]	2015	12	9.0	Uni, 88; Bi, 324	2.3	3.7	47.3	8.3	0	94.4
Cohen technique										
Yeung [2]	2005	16	4.1	Uni, 112; Bi, 178	1.0	1.9	27.6	0	6.2	96.0
Steyaert [9]	2005	50	4.2	N/A	3.0	N/A	N/A	18.0	12.0	97.5
Kutikov [11]	2006	27	5.0	Bi, 138	N/A	1.9	N/A	11.1	0	92.6
Canon [24]	2007	52	5.7	199	N/A	2.1	11.0	6.0	2.5	91.0
Chung [3]	2008	9	7.2	214.8	2.0	9.3	N/A	0	22.2	95.0
Valla [6]	2008	72	4.2	Uni, 82; Bi, 113	2.0	2.8	24.0	0	5.6	92.0
Jayanthi [16]	2008	103	N/A	N/A	1.5	N/A	N/A	2.0	2.9	94.0
Kawauchi [77]	2009	30	14.5	Uni, 145; Bi, 230	2–3[c]	3.0	N/A	N/A	0	96.0
Marte [5]	2010	14	13.6	Uni, 112; Bi, 178	3.0	3.0	12.0	14.2	0	94.7
Abraham [78]	2011	19	2.2	210	3.0	3.0	20.9	0	10.5	93.3
Hong [10]	2011	28	6.0	Uni, 166; Bi, 189	1.4	1.4	8.6	3.6	7.1	94.6
Emir [21]	2012	11	6.9	Uni, 217; Bi, 306	3.0	3.8	54.0	9.0	0	91.0
Chung [79]	2012	48	3.7	155.6	1.6	1.6	16.3	0	6.2	96.4
Soh [7]	2015	12	15.0	Uni, 235; Bi, 268	2.4	3.4	39.2	0	0	94.7
Ansari [15]	2017	17	4.6	Bi, 135	1.2	4.0	24.0	2.0	5.9	94.1

Bi, bilateral; Uni, unilateral; N/A, not applicable.
[a]First author [reference number]. [b]Mean. [c]Range.

addition, the current approach reduces hospital stay, provides less postoperative discomfort, and reduces the cost of hospital stay, compared with the open approach [3,10].

However, there is a learning curve because of the small working space within the bladder, and intravesical laparoscopic free-hand suturing is needed. Steyaert and Valla [9] reported that all six conversions in their cohort occurred in the first series of 20 cases. Hong et al. [10] also reported that the mean operative time significantly decreased for the last 13 patients, compared with the first 13 (140 minutes vs. 220 minutes). The mean postoperative hospital stay was also significantly shorter for the last 13 patients than that for the first 13 (1.08 days vs. 1.69 days) [10]. In addition, the smaller the bladder, the smaller the working space. Hence, Kutikov et al. [11] and Valla et al. [6] suggested that the current method does not seem applicable to children younger than 6 months of age and a calculated cystographic bladder capacity of 130 mL could be considered the limit.

Politano-Leadbetter technique

Although the LPV ureteric reimplantation using the Cohen procedure has many advantages, the Cohen procedure has the distinct disadvantage of making future transurethral endourological cannulation and stone operation practically impossible [22]. To overcome this limitation, physicians in our center first described the Politano-Leadbetter technique with LPV [23]. However, few studies have been published on clinical results of the Politano-Leadbetter technique with LPV (Table 1) [4,7].

Port placement and creating the pneumovesical space are similar to those in the LPV Cohen technique. However, the location of the neo hiatus is different, because it is located along a straight line, superior to the original orifice [23]. The method of creating the submucosal tunnel and neo hiatus differs based on the surgeon's preference. Our center used a Diamond-Flex (Snowden-Pencer, CareFusion, Waukegan, IL, USA) to create the submucosal tunnel in our first experience report [23]. However, Soh et al. [7] inserted the cystoscope through the neo hiatus and dissected the ureter under cystoscopic visualization. Recently, our center presented a modified method of creating a submucosal tunnel and neo hiatus. After ureteral retraction under the submucosal tunnel from the neo hiatus, lifting the ureter exposes the posterior side of the bladder. In addition, muscle fibers are incised using hook electrocautery until the ureter can freely move from the base of the new hiatus [4].

Soh et al. [7] compared the results between LPV ureteral re-

implantation Politano-Leadbetter and Cohen techniques. They reported that the operative time was slightly longer in the Politano-Leadbetter technique than that in the Cohen technique. However, no difference was found in the duration of hospital stay or success rate. However, our center reported an average of 92.5 minutes for unilateral and 150 minutes for bilateral reimplantation, which is comparable to that obtained in a previous study on the Cohen technique (Table 1) [4].

The LPV Politano-Leadbetter technique has important advantages over the Cohen technique. Soh et al. [7] reported that the tunnel length can be increased by advancing the ureter orifice to make a new one in various physiological positions by incising rather than tunneling into more distal epithelium and closing it over the ureter. In addition, a long tunnel can be created using the LPV Politano-Leadbetter technique, which is more effective in higher grades of reflux and orthotopic ureteral location after surgery [4]. Above all, the LPV Politano-Leadbetter has the potential advantage of allowing future transurethral endourological procedure, while a stone surgery practically impossible with the Cohen procedure [6,24].

Megaureter or ureteral stricture

Kutikov et al. [11] first reported short-term outcomes of Glenn-Anderson reimplantation using LPV for megaureter management or ureteral stricture in 2006. However, the operative success rate was 80% for primary obstructed megaureter, and 2 of 5 patients experienced urine leakage. In a case series of 63 patients, Liu et al. [25] reported that the modified LPV Glenn-Anderson procedure was feasible and effective with minimal morbidity. They emphasized 2 major modifications to the traditional procedure. First, the bladder wall was incised superior laterally to move the hiatus proximally along the course of the ureter, and the detrusor muscle was sutured to the seromuscular layer of the ureter. Second, the mucosal groove rather than the tunnel was used to advance from the ureteral hiatus to the neck of the bladder. In their case series, 90% of the ureters were considered cured, and 10% improved.

Kim et al. [26] reported successful results for laparoscopic intravesical detrusorrhaphy with ureteral plication of the megaureter. The most prominent aspect of their surgery was the plication of the ureter. After ureteral mobilization and resection of the distal portion, they inserted a 6F Foley catheter into the megaureter to maintain tension during plication. They reported a mean operative time of 214 minutes including preoperative evaluation and successful surgical outcomes, improvement of

obstruction, reduction of ureteral caliber, and absence of VUR while maintaining an orthotopic ureteral position [26]. However, tailoring of the ureter usually demands more time than simple reimplantation. Furthermore, caution should be exercised when considering Glenn-Anderson procedure in children younger than 6 months of age with small bladder capacity [11]. In addition, studies on the current approach are limited, and long-term follow-up data are lacking.

Management of Intravesical Mesh Erosion With LPV

Perforation of the bladder and urethra or erosion of the midurethral tape mesh after anti-incontinence surgery or cystocele repair surgery is not uncommon, and has potentially serious complications. These complications are associated with synthetic material mesh, and their incidence ranges from 0.07% to 1.5% [27,28]. Surgical management is a priority because most of the bladder exposed meshes induce bladder stone formation or voiding symptoms. Traditionally, the transurethral or transvaginal approach has been used when mesh erosion is small. However, if it is not properly managed, vesicovaginal or urethrovaginal fistulas may develop [29,30]. The open approach has been used when mesh erosion is large or the bladder is perforated. However, obtaining the visual field is difficult if the mesh erosion is close to the ureteral orifice or near the bladder neck, even if the open approach is used.

However, LPV can be applied to manage patients with mesh erosion and it has excellent visualization and surgical outcomes. Al-Badr and Fouda [31] were the first to report successful outcomes for tension-free vaginal tape erosion management using LPV, but they only performed excision of the tape. Ingber et al. [32] then reported successful clinical results for single-port LPV mesh removal and reconstruction surgery. This approach has been reported to be very useful with advantages such as excellent visualization of the material when the mesh is in the anterior bladder neck [33]. In addition, Roslan and Markuszewski [34] reported that the operative time (mean, 59 minutes) and the length of hospital stay (mean, 2.4 days) were feasible with the current approach in a study of 9 patients with bladder mesh erosion (Table 2).

Compared with the transurethral approach, the current approach enables reconstruction using suturing not only by removing the erosion tape. This reconstruction technique leads to a faster recovery of the patient's symptoms than did the transurethral approach. Kim et al. [33] reported that reconstruction with suturing improved symptoms within 7 days in most patients, whereas patients with the transurethral technique had a symptom recovery period of 1 month in a previous case series. In addition, they demonstrated that closure of the mucosal and

Table 2. Published articles on LPV for the management of mesh complications: summary of selected outcomes literature

Study[a]	Reported year	Case No.	Initial surgery (n)	Port placement	Operative time[b] (min)	Involved site	Urethral catheter indwelling[b] (day)	Follow-up[b] (mo)	Recurrence	Symptom recovery (day)
Al-Badr [31]	2005	3	TVT	Single with cystoscope	N/A	Lateral wall	3.0	1.5	No	3
Ingber [32]	2009	2	N/A	Single (Triport)	113	Bladder neck, dome	7.0	7.0	No	N/A
Bekker [80]	2010	1	Prolift	3 With cystoscope	31	Lateral wall	14.0	1.5	No	N/A
Yoshizawa [81]	2011	2	TOT	3	146	Lateral wall	7.0	18.0	No	N/A
Kim [33]	2012	3	TOT	3	N/A	Bladder neck, anterior wall	3.6	6.7	No	3−7[c]
Roslan [34]	2013	9	TVT (2) Gynemesh (2) TOT (1) Prolift (1) Etc (3)	Single (Triport)	59	Bladder neck, anterior wall	5.9	18.8	No	N/A

LPV, laparoscopic approach for intravesical surgery using pneumovesicum; TVT, tension-free vaginal tape; N/A, not applicable; TOT, transobturator tape.
[a]First author [reference number]. [b]Mean. [c]Range.

muscle layers can prevent re-exposure of the erosion mesh [12,33]. However, Jo et al. [35] reported that mesh remnants were observed in 1 of 5 patients per group at 2-month follow-up using the transurethral approach.

Management of VVF With LPV

Surgical management of VVFs is most commonly performed vaginally, abdominally, or laparoscopically. Minimally invasive laparoscopic surgery is increasingly being performed, including laparoscopic VVF repair and robotic-assisted approach [36-40]. In their systematic review, Miklos et al. [41] reported that laparoscopic extravesical VVF repair has cure rates similar to the traditional transvesical approach. However, the laparoscopic or laparoscopic with robotic approach has distinct disadvantages, including increased learning curve, time, costs, and surgeons' experience [42]. Specifically, the long operative time (over 5–6 hours) was attributed to the difficulty in the identification of the fistulous tract, difficult dissection of the vesicovaginal space, and the need for defect suturing [43].

To overcome these limitations, a direct approach to the fistula tract using LPV has been attempted. Recently, Nerli and Reddy [44] first described that VVF repair with LPV technique is feasible and safe, and results in lower morbidity and quicker recovery time. Port placement and the method of creating the pneumovesical space are similar to the transvesicoscopic ureteral reimplantation technique. They presented the advantages of the current technique, including injury prevention to other intraperitoneal organs, need for peritoneal drain, and prolonged ileus. Above all, the current approach led the surgeon directly over the fistula, resulting in easy dissection of the bladder from the vagina [41]. However, this technique is unable to interpose healthy tissues such as the omentum and the tissue between the bladder and the vagina. Unfortunately, the management of outcomes with this approach has not been reported. Although this procedure has the potential to be a good treatment option in patients with VVF, more studies are needed to assess its safety and efficacy.

Removal of Bladder Stone or Foreign Body With LPV

Open cystolithotomy is the most commonly used treatment modality for the removal of large bladder stones. In recent years, cystolithotripsy using Holmium laser has been widely used and its application range is gradually increasing. LPV can be used for patients with large bladder stones or multiple bladder stones. Hwang et al. [45] first reported bladder stones of 3 cm or more via laparoscopic entrapment sac using PV. Our center has also reported the utility of pneumovesical cystolithotripsy using a T-LESS for multiple small bladder stones [46]. They demonstrated that large bladder stone removal using PV is better than conventional cystolitholapaxy, and it reduces bladder damage except during port insertion, reduces the risk for urethral stricture, and has short operation time [45,47,48]. The open extraperitoneal approach or the transurethral approach using Holmium laser is known to be effective in managing large bladder stones [49]. Thus, LPV for bladder stones is restricted in special cases.

However, LPV can be a useful option in removing foreign bodies which are difficult to remove using the transurethral approach (e.g., long wire). Reddy et al. [50] reported that the LPV technique was also applied for removal of foreign bodies from the bladder. Through a single 10-mm port insufflated with 12 mmHg of CO_2, they crushed Blu Tack, a puttylike substance, and then removed it from the bladder of a 14-year-old boy [50]. The transurethral approach has limitations in the removal of linear foreign bodies due to sexual curiosity. In particular, the LPV approach has many advantages. As a result, scissors are

Table 3. Published case reports on LPV for the management of foreign bodies in the bladder

Study[a]	Reported year	Country	Material	Length (cm)	Anesthesia	No. of port	Operative time (min)	Hospital day (day)
Reddy [50]	2004	United Kingdom	Organic rubber	N/A	General	Single	N/A	2
Pandey [82]	2012	India	Foley catheter	N/A	Spinal	Single	N/A	N/A
Ko [51]	2010	Korea	Electric wire	149	General	Single	21	1
Przudzik [12]	2015	Poland	Metallic cable	N/A	General	Single	25	1
Jin [83]	2016	China	Intrauterine device	N/A	General	Two	N/A	7

LPV, laparoscopic approach for intravesical surgery using pneumovesicum; N/A, not applicable.
[a]First author [reference number].

used for materials that are difficult to cut with a laser (Table 3). Przudzik et al. [12] and Ko et al. [51] described the advantage of using laparoscopic scissors with PV in the removal of a long cable in the bladder. The foreign body removal method using PV can be very useful in special cases where there is a risk of damaging the urethra or other injuries when pulling out via the transurethral approach. In addition, it offers short hospital stay and is less invasive [51].

Management of BPH With LPV

Mariano et al. [52] first presented the laparoscopic approach for the treatment of patients with large prostatic adenomas in 2002. Since then, many clinical studies have assessed laparoscopic simple prostatectomy. In a meta-analysis, Lucca et al. [53] reported that minimally invasive simple prostatectomy (conventional laparoscopic or robot-assisted approach) provides similar improvements in the maximum flow rate (Qmax) and International Prostate Symptom Score (IPSS) as open simple prostatectomy, and has distinct advantages including blood loss (de-

crease 187 mL), duration of catheter use (decrease 1.3 day), and hospital stay (decrease 1.6 day).

Desai et al. [54] first reported using the single-port laparoscopic transvesical enucleation of the prostate (STEP) technique using PV in 2008. In addition, they also observed that an entire adenoma can be effectively enucleated in a case series using the STEP technique, and found that it is suitable for patients with a large median lobe or coexisting bladder calculi [55]. Simple prostatectomy via the transvesical approach has some potential advantages over the transperitoneal laparoscopic approach. There is no need for peritoneal violation when using the transvesical approach, but it provides effective tamponade of the venous channels and excellent exposure of the prostatic fossa for additional hemostatic maneuvers if required and for confirming the adequacy of adenoma enucleation [55-58]. In particular, Wang et al. [57] demonstrated that the STEP technique improved the associated parameters, such as Qmax (27.7 mL/sec), total IPSS (-18.2), and quality-of-life scores (-3.56) in a case series and literature review. However, they included STEP data

Table 4A. Single-port laparoscopic transvesical enucleation of the prostate using pneumovesicum: summary of selected outcomes literature

Study[a]	Reported year	No. of patients	Country	Prostate volume[b]	Excised prostate (%)	Age[c] (yr)	Operative time[c] (min)	Hospital day[c] (day)	Catheterization time[c] (day)	Blood loss[c] (mL)	Complication	Open conversion	Transfusion
Desai [54]	2008	3	USA	124	86.6	76.7	200.0	1.7	4.0	500.0	1/3	0/3	1/3
Desai [55]	2010	34	USA	102±51	66.3	69.0	116.0	3.0	6.0	460.0	8/34	4/34	2/34
Oh [56]	2011	32	Korea	73±20	76.7	70.2	109.4	3.0	5.3	177.0	0/32	0/32	2/32
Lee [58]	2012	7	Korea	101±16	53.7	N/A	189.3	3.1	5.3	600.0	0/7	1/8	2/7
Wang [57]	2012	8	China	83.8±19	64.6	71.9	160.9	7.0	8.6	418.8	3/8	1/9	1/8

N/A, not applicable.
[a] First author [reference number]. [b] Mean ± standard deviation. [c] Mean.

Table 4B. Single-port laparoscopic transvesical enucleation of the prostate using pneumovesicum: outcomes of IPSS and urodynamic parameter

Study[a]	Preop total IPSS	Preop QoL	Preop Qmax (mL/sec)	Pre-PVR (mL)	Postop IPSS	Postop QoL	Postop Qmax (mL/sec)	Post-PVR (mL)
Desai [54]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Desai [55]	19±5	N/A	7.8±3.8	N/A	3±1.7	N/A	44±18	N/A
Lee [58]	23.57±2.15	N/A	6.7±2.3	170.3±101.3	11.43±2.44	N/A	17.1±3.4	34.1±21.1
Oh [56]	27.1±7.3	4.7±0.7	5.8±1.6	N/A	4.0±1.1	1.1±0.4	36.2±6.6	66.3±25.0
Wang [57]	25.6	4.6	9.8	N/A	4.1±1.4	1.4±1.2	22.7±4.6	36.1± 40.0

Values are presented as mean ± standard deviation.
IPSS, International prostate symptom score; Preop, preoperative; Postop, postoperative; QoL, quality of life; Qmax, maximum urinary flow rate; PVR, postvoid residual urine volume; SD, standard deviation; N/A, Not applicable.
[a] First author [reference number].

without using PV. The surgical outcomes of STEP with PV are listed in Table 4A, B.

The current approach has several limitations. Surgeons without experience in laparo-endoscopic single-site surgeries or conventional laparoscopy may have a steep learning curve [58]. In addition, Desai et al. [55] reported that the dissection toward the apical adenoma is more difficult than in the conventional laparoscopic approach. The current approach is less suitable for small glands, morbidly obese patients, and patients with a long and predominantly infravesical prostates [55].

Holmium laser enucleation has recently emerged as an effective treatment because it guarantees similar and durable functional results as well as a significantly reduced transfusion rate, a shorter period of catheterization, and a shorter hospital stay [59,60]. In addition, bipolar transurethral resection of the prostate (TURP) has been proposed to treat large adenomas with similar efficacy and lower morbidity, compared with open prostatectomy [61]. Although STEP has better cosmesis than open surgery or conventional laparoscopic surgery, it may require a suprapubic catheter and result in an external wound than did TURP or Holmium laser enucleation. Therefore, STEP does not seem to be more advantageous than other procedures for most patients with BPH [58].

Oncology
Prostate cancer
Laparoscopic with or without robot-assisted radical prostatectomy (RP) has been increasingly used for the surgical treatment of patients with localized prostate cancer, with results comparable to open retropubic RP [62,63]. As part of an attempt to performed more minimally invasive surgery, Desai et al. [64] tried the transvesical approach robot-assisted laparoscopic RP using PV in 2 fresh cadavers. In their initial report, the total operative time was 3 and 4.2 hours, respectively, and the time to obtain transvesical access was approximately 30 minutes. Since then, Gao et al. [65] first presented their initial clinical experience with single-port transvesical laparoscopic RP using PV in 16 consecutive patients with localized prostate cancer. In their case series, the mean operative time was 105 minutes, and mean blood loss 130 mL. Overall, 81.2% of the patients showed continence when the catheter was removed, and 75% of the patients achieved potency 12 months postoperatively.

The current technique has some advantages, including not needing to mobilize the bladder or dissecting the perivesical space [65]. In addition, PV minimized the effects of mechanical

ventilation, potentially enabling the procedure to be performed under regional (spinal and epidural) anesthesia [64]. However, lymph node dissection and bladder reconstruction cannot be done using that approach [64,65]. Furthermore, it is likely to require considerable training and experience because of limited operating space, considerable clashing of instruments, limited precision of tissue handling and retraction.

Given these limitations, these methods are not selected by many clinicians. For these methods to be widely performed in patients with prostate cancer, the development of techniques, to avoid instrument clashing, and surgical methods, to overcome the long learning curve, is needed. In addition, longer survival and functional data, and randomized prospective studies in a larger cohort of patients are necessary to determine the appropriate role of the current approach [65].

Upper tract urothelial cell carcinoma
Radical nephroureterectomy (RNU) with excision of the bladder cuff is recognized as the standard treatment for patients with upper tract urothelial cell carcinoma [66]. However, controversy still exists about the best method for managing the distal ureter and bladder cuff. Many techniques for ureter and bladder cuff resection have been described, including open excision, endoscopic excision, and laparoscopic stapling [67]. Among these techniques, the endoscopic approach was associated with higher intravesical recurrence (5-year intravesical recurrence-free survival rate of 42%) in a large multicenter study [68]. In addition, Matin and Gill [69] reported that positive margins were more frequently associated with the laparoscopic stapling approach than with either the transvesical or open techniques in a retrospective study. While the absolute intravesical recurrence rate was different between the transvesical and extravesical approaches, they found no difference in any of the outcomes between these approaches [68].

Cheng et al. [70] first described using a transvesical PV method for managing the distal ureter during laparoscopic RNU. They observed that the approach minimized tumor seeding with early closure of the ureteric orifice during distal ureteric dissection and used a PV instead of fluid irrigation. Since then, bladder cuffing with PV has been performed in various institutions; the results are reported in Table 5.

After establishing the PV, three ports or laparoendoscopic single ports are placed into the bladder transversely above the pubic bone. The distal ureter, bladder cuff, and intramural ureter are then completely dissected using electrocautery [71]. As

Table 5. Published case report on the LPV for the management of distal ureter and bladder cuffing in nephroureterectomy

Study[a]	Reported year	No. of patients	RNU surgery type (n)	Operating time for distal ureter[b] (min)	Extravasation on cystography	Positive surgical margin	Tumor site (n)	T stage (n)	Follow-up (mo)[c]	Intravesical recurrence	Systemic recurrence
Cheng [70]	2008	1	LNU (1)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Giannakopoulos [84]	2012	10	ONU (2) LNU (8)	82.5	2/10	0/10	Ureter (2) Renal pelvis (8)	Ta-1 (7) T2 (2) T3 (1)	31 (12–55)	3/10	2/10
Zou [73]	2010	6	LNU (6)	26.5	0/6	0/6	Ureter (2) Renal pelvis (4)	Ta-1 (2) T2 (3) T3 (1)	18 (5–28)	0/6	0/6
Roslan [13]	2014	5	LNU (5)	59.0	0/5	0/5	Ureter (0) Renal pelvis (5)	Ta-1 (2) T2 (1) T3 (2)	6 (4–10)	N/A	N/A
Guzzo [85]	2008	1	LNU (1)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mak [71]	2011	10	LNU (10)	N/A	0/10	N/A	Ureter (3) Renal pelvis (7)	Ta-1 (3) T2 (2) T3 (5)	46 (22–67)	4/10	1/10
Nunez Bragayrac [86]	2014	5	LNU (5)	35.0	0/5	0/5	Ureter (0) Renal pelvis (5)	N/A	16.2 (1–38)	N/A	1/5

LPV, laparoscopic approach for intravesical surgery using pneumovesicum; RNU, radical nephroureterectomy; LNU, laparoscopic nephroureterectomy; ONU, open nephroureterectomy; N/A, not applicable.
[a]First author [reference number]. [b]Mean. [c]Median (range).

soon as the distal ureter is dissected, an ENDOLOOP knot is used to ligate the ureter to avoid tumor spillage and aid in the identification of the ureter during final laparoscopic extraction. The bladder defect at the site of the ureteral dissection is closed in 2 layers with a 2-0 (or 1-0) absorbable polyglactin suture.

This method has several theoretical advantages, including en bloc removal of the entire specimen, excellent visualization of the bladder and minimization of the potential for tumor seeding with early closure of the distal ureteral orifice, and the use of PV instead of fluid irrigation [72]. In addition, this method does not require large transvesical incision, so it improves recovery times, and minimizes bladder spasms and hematuria. However, only small case series with limited number of patients with upper tract urothelial cancers were conducted, and the follow-up duration was short. In addition, the theoretical risk for tumor seeding during port insertion is present. Fortunately, no studies have shown pelvic, peritoneal, or port site recurrence after the current surgery. Finally, this surgical procedure should be avoided if patients showed urothelial cancer in the intramural ureter or have history of overactive bladder or pelvic irradiation [73].

Bladder Diverticulectomy

Bladder diverticulum can be found immediately under transvesical approach. This procedure has been performed by some surgeons. Pansadoro et al. [74] first described transvesical laparoscopic bladder diverticulectomy using PV via a 3-port technique. Roslan et al. [14,75] was the first to publish a case series for T-LESS for bladder diverticulectomy. Recently, Magdy et al. [76] demonstrated a natural orifice transluminal endoscopic surgery for bladder diverticulectomy.

Although port placement may different for each surgeon, the surgical method does not. After the PV is established, circumferential incision of the mouth of the diverticulum was made using monopolar electrocautery scissors. The diverticular mucosa is then grasped and separated from the detrusor muscle attachments. Bladder defects were closed using barbed suture in one layer.

Roslan et al. [75] presented that the current approach provides the same benefits as the laparoscopic approach in terms of blood loss, postoperative analgesic requirements, and hospital stay, but the operative time (mean operative time, 122 minutes) is comparable to that achieved during open or endoscopic

surgery. However, the current method may be difficult to apply in domal and anterior wall diverticula, which are not common sites [76]. In addition, relatively small operative field and clashing of the instruments can be potent limitations of this approach [14].

DISCUSSION

LPV has been applied in various urology fields. It is expected to be used in other fields in the future because of its excellent visibility, less morbidity, and improved cosmesis. However, the difficulty of the procedure and relatively long learning curve needs to be overcome. In addition, the lack of long-term follow-up data makes surgeons hesitant to choose the current approach. However, with the expected development of instruments including those for robotic surgery, the limitations of the current approach are likely to be overcome. Additional studies are needed to better define the ideal surgical approach and present evidence of usable treatment options for various urological diseases.

AUTHOR CONTRIBUTION STATEMENT

· Full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis: *Bum Sik Tae, Jae Hyun Bae*
· Study concept and design: *Bum Sik Tae, Jae Hyun Bae*
· Acquisition of data: *Bum Sik Tae, Hoon Choi*
· Analysis and interpretation of data: *Bum Sik Tae, Jae Hyun Bae*
· Drafting of the manuscript: *Bum Sik Tae, Jae Hyun Bae*
· Critical revision of the manuscript for important intellectual content: *Hoon Choi, Jae Young Park, Jae Hyun Bae*
· Statistical analysis: *Bum Sik Tae*
· Administrative, technical, or material support: *Jae Hyun Bae*
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