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Robot-assisted Bladder Diverticulectomy Using a Transperitoneal Extravesical Approach

Gianluca Giannarini [a], *Marta Rossanese* [b], *Luciano Macchione* [b], *Giuseppe Mucciardi* [b], *Alessandro Crestani* [c], *Vincenzo Ficarra* [b,*]

[a] *Urology Unit, Santa Maria della Misericordia University Hospital, Udine, Italy;* [b] *Urology Section, Gaetano Barresi Department of Human and Paediatric Pathology, University of Messina, Messina, Italy;* [c] *Oncological Urology Unit, Veneto Institute of Oncology IOV-IRCCS, Padua, Italy*

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Abstract

Background: Acquired bladder diverticula (BD) are a possible complication of bladder outlet obstruction (BOO) due to benign prostate enlargement (BPE). Robot-assisted bladder diverticulectomy (RABD) has been proposed as an alternative to open removal; however, only a few small series have been published.
Objective: To describe our surgical technique for RABD and to assess perioperative results and functional outcomes at 6-mo follow-up.
Design, setting, and participants: A prospective single-centre, single-surgeon cohort of 16 consecutive men with posterior or posterolateral BD due to BOO/BPE undergoing RABD between May 2017 and December 2021 was analysed.
Surgical procedure: RABD was performed with a four-arm robotic system via a transperitoneal approach. BD were identified intraoperatively via bladder distension with saline solution through an indwelling catheter with or without concomitant illumination using flexible cystoscopy and fluorescence imaging. Extravesical BD dissection and removal were performed.
Outcome measurements and statistical analysis: Operating room time, estimated blood loss, intraoperative and postoperative complications, indwelling catheter time, and timing of associated procedures for BOO/BPE were assessed. The International Prostate Symptom Score (IPSS) and postvoid residual volume (PVR) were compared between baseline and 6 mo after surgery.
Results and limitations: Median age and maximum BD diameter were 68 yr (interquartile range [IQR] 54–74) and 69 mm (IQR 51–82), respectively. The median operative time was 126 min (IQR 92–167) and the median estimated blood loss was 20 ml (IQR 15–40). No intraoperative complications were recorded. The urethral catheter was removed on median postoperative day 5 (IQR 5–7). Two men experienced 90-d postoperative complications (persistent urinary infection requiring prolonged antimicrobial therapy). Bipolar transurethral resection of the prostate was performed 3 wk before RABD in seven men and concomitant to RABD in nine men. Median IPSS significantly decreased from 25 (IQR 21–30) to 5

* Corresponding author. Urology Section, Gaetano Barresi Department of Human and Paediatric Pathology, University of Messina, Policlinico Universitario G. Martino, Via Consolare Valeria 1, Messina, Italy.
E-mail address: vficarra@unime.it (V. Ficarra).

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(IQR 5–6), and median PVR from 195 ml (IQR 140–210 ml) to 30 (IQR 28–40) ml (both $p < 0.001$) at 6-mo follow-up in comparison to baseline. A limitation is the rather small cohort with no control group.

Conclusions: RABD is a safe and effective minimally invasive option for treatment of acquired BD in men with BOO/BPE. Validation of our results in larger series with longer follow-up is warranted.

Patient summary: We describe our surgical technique for robot-assisted removal of pouches in the bladder wall (called diverticula) in men with bladder outlet obstruction caused by benign prostate enlargement, and report functional results at 6 months after the operation. This minimally invasive technique was found to be safe and effective.

1. Introduction

Endoscopic or surgical treatment of bladder diverticula (BD) is recommended in men with lower urinary tract symptoms (LUTS) and bladder outlet obstruction (BOO) due to benign prostate enlargement (BPE) unresponsive to medical treatment and associated with elevated postvoid residual volume (PVR), recurrent urinary tract infections, bladder calculi, and/or poor BD emptying. Moreover, BD treatment is indicated in patients with ureteric obstruction due to ab extrinseco compression and to prevent malignant degeneration, which is observed in up to 10% of cases [1].

Open bladder diverticulectomy via a transvesical or extravesical approach has been the gold-standard surgical treatment for BD for many years. Alternatively, transurethral fulguration with or without neck incision has been proposed for small BD, and for large BD in patients who are unfit for major surgery [2,3].

Pure laparoscopic or robot-assisted bladder diverticulectomy (RABD) was introduced in the past couple of decades as a minimally invasive alternative to the open approach [4,5]. After the initial case described by Berger et al. in 2006 [5], fewer than 80 robotic cases were reported in the literature up to 2018, with the majority of series including five or fewer cases [6]. Very recently, Liu et al. [7] and Develtere et al. [8] reported on the largest robotic series in the literature, consisting of 20 (including two for an intradiverticular urothelial cancer) and 23 cases, respectively. Notably, in the study by Liu et al. [7], the robotic approach was associated with better perioperative outcomes in comparison to the open strategy. No study has compared robotic and laparoscopic approaches.

Because of the limited number of cases reported, the surgical technique for RABD is not yet standardised, with several different methods described for BD identification and different approaches used for BD excision. While some authors have proposed that BD can be identified via injection of saline solution through the indwelling catheter, others have suggested catheterisation of the diverticulum with a balloon or the use of flexible cystoscopy and/or Firefly technology [9,10]. Furthermore, some authors prefer an extravesical and others a transvesical or a transdiverticular approach [7].

The objectives of the present study were: (1) to describe our surgical technique for transperitoneal extravesical RABD; (2) to assess perioperative and functional outcomes at 6-mo follow-up; and (3) to compare our results with those reported in the most representative RABD series published in the literature.

2. Patients and methods

2.1. *Patients*

Clinical records for patients with acquired BD associated with BOO/BPE and undergoing RABD at our institution from May 2017 to December 2021 were prospectively collected in a dedicated database. All patients gave consent to participate and authorised data collection for scientific purposes.

Digital rectal examination, the International Prostate Symptom Score (IPSS) questionnaire, and abdominal ultrasound with postvoid residual volume (PVR) measurement were performed as the initial diagnostic work-up. Furthermore, abdominal computed tomography with contrast medium was performed to evaluate BD size, location, and relation to the pelvic ureter. Finally, preoperative flexible urethrocystoscopy was performed to evaluate the prostate and bladder neck, to exclude the presence of concomitant bladder cancer, and to check the distance between the BD neck and ureteric orifices.

All patients undergoing RABD also received interventions to relieve BOO/BPE. Our policy with regard to the indication and timing for the two procedures is as follows. Bipolar transurethral resection of the prostate (TURP) is performed if the prostate volume is $\leq$100 cm^3, while robot-assisted simple prostatectomy (RASP) via the same transperitoneal, extravesical approach as for RABD and with transcapsular access as for open simple prostatectomy according to Millin's technique is performed if the prostate volume is >100 cm^3. If the prostate volume is $\leq$60 cm^3, bipolar TURP is performed concomitant to RABD. If the prostate volume is >60 cm^3, the two procedures are staged, with RABD preceded by bipolar TURP by 3 wk. The reason for this is the potentially higher risk of complications (namely bleeding) in the case of TURP for larger prostates, which may negatively affect the outcomes of concomitant RABD. RASP and RABD are always performed concomitantly. In the case of concomitant procedures, we always perform bipolar TURP (or RASP) as the first step.

2.2. *Surgical technique*

A third-generation cephalosporin and elastocompressive stockings plus low–molecular-weight heparin were used for prophylaxis of infections and thromboembolic events, respectively. All procedures were performed under general anaesthesia by a single expert surgeon using a four-arm da Vinci Xi robotic platform.

The patient is placed in a supine 15–25° Trendelenburg position, allowing for side-docking of the robotic system. A transurethral 18-Ch Foley catheter is inserted to allow for emptying and filling of the bladder. A six-port transperitoneal approach is used. The camera port is placed 2 cm above the umbilicus. Two 8-mm instrument ports are placed four fingers laterally and caudally to the camera port, bilaterally. The fourth arm is placed four fingers laterally to the left 8-mm instrument port. The 12-mm AirSeal port is placed 2–4 cm cranially to the right anterior superior iliac spine and is connected to the insufflation system. A 5-mm assistant port for a suction device or Johann grasper is placed 4 cm laterally and cranially to the camera port. Usually, a 0° lens and three EndoWrist instruments are used: monopolar curved scissors or a large needle driver is placed in the right robotic arm, bipolar fenestrated forceps in the left one, and a ProGrasp instrument in the fourth one.

The BD is identified via injection of saline through the indwelling catheter with or without concomitant transillumination using flexible cystoscopy and/or Firefly technology (Fig. 1). Posterior or posterolateral BD are usually clearly visible through the peritoneum covering the bladder posterior wall. The peritoneum is then incised using monopolar scissors to identify the diverticulum fundus. The diverticulum sac is circumferentially mobilised and isolated from the surrounding tissues using blunt dissection and monopolar coagulation until the neck is identified and completely isolated (Fig. 2). The vas and umbilical arteries are isolated and spared in all cases. The ureters are always identified, and may be suspended with a vessel loop to facilitate mobilisation. The diverticulum neck is incised using monopolar scissors, starting from the anterior wall and achieving partial dissection from the posterior bladder wall (Fig. 3). Traction is applied to the sac with the ProGrasp instrument to complete the excision of the posterior wall of the diverticulum neck. The sac is stored in an Endobag inserted through the right 12-mm port. The cystotomy is closed in a double watertight layer using a Vicryl 4-0 running suture for the bladder mucosa and a Vicryl 3-0 running suture for the detrusor muscle, similar to bladder closure in open surgery. The bladder is filled with 250 ml of saline solution to confirm a watertight suture. The peritoneum is sutured using a 15-cm V-Loc 90 3-0 barbed suture with a V-20 tapered needle. A drain is inserted through the trocar of the fourth robotic arm, and removed on postoperative day 1. A cystogram is performed on postoperative day 4 to evaluate the presence of any leakage before catheter removal.

2.3. *Data collection and study outcomes*

The following parameters were prospectively collected in a dedicated database: age at surgery, body mass index, Charlson comorbidity score, American Society of Anesthesiologists score, IPSS, prostate volume, and PVR. Moreover, the BD number, maximum size, and location characteristics were recorded. Endoscopic and/or surgical procedures performed before or concomitant to RABD were also noted.

The following perioperative parameters were assessed: operating room (OR) time, estimated blood loss (EBL), intraoperative complications, indwelling catheter time, and length of stay (LOS). Postoperative complications observed within 90 d after surgery were recorded and graded according to the Clavien-Dindo classification [11]. While grades 1 and 2 were considered as minor complications, grades 3 and 4 were classified as major complications.

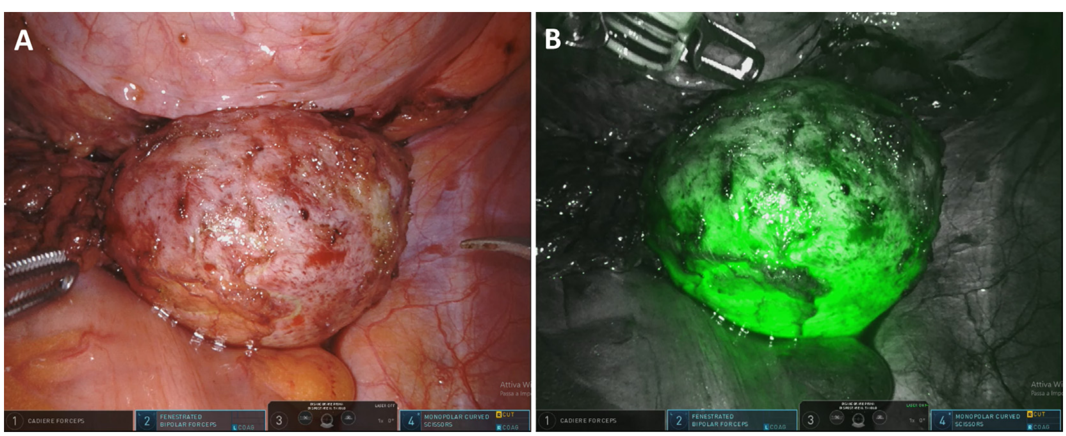

Fig. 1 – Bladder diverticula are identified by injecting saline through an indwelling catheter with or without concomitant transillumination using (A) flexible cystoscopy and (B) Firefly technology.

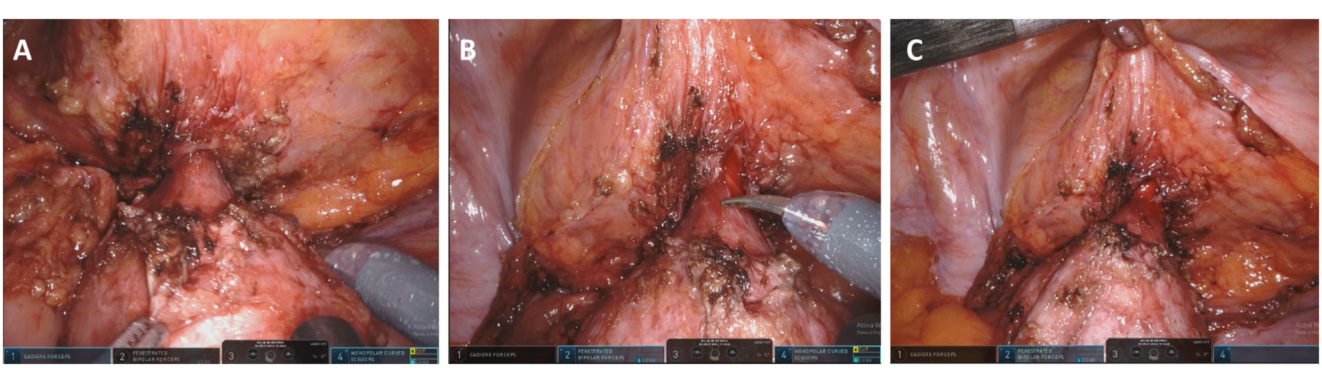

Fig. 2 – The bladder diverticular sac is circumferentially mobilised from the surrounding tissues (A) using blunt dissection and monopolar coagulation until (B, C) the neck is identified and completely isolated.

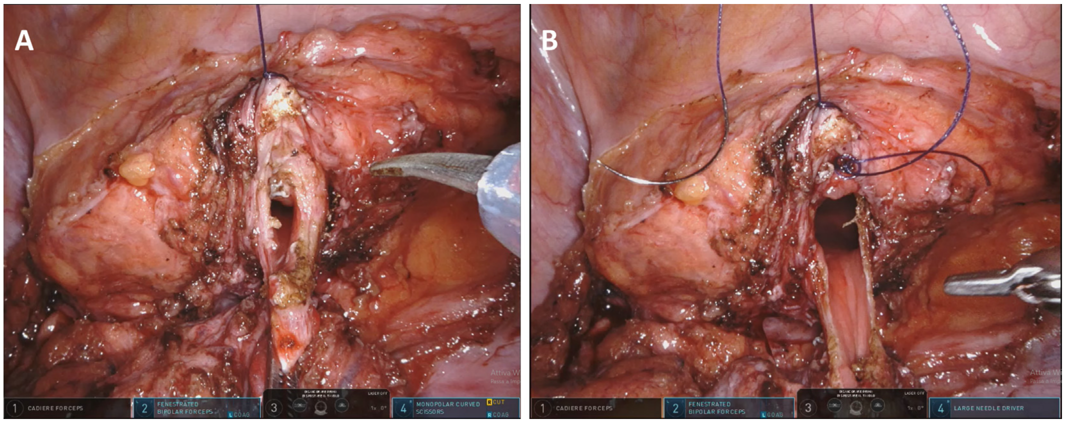

Fig. 3 – The bladder diverticulum neck is incised using monopolar scissor (A) starting from the anterior wall and (B) achieving partial dissection from the posterior bladder wall.

All patients underwent urinalysis and abdominal ultrasound examination at 1, 3, and 6 mo after surgery to evaluate any persistence of infection and BD presence, and to measure PVR. The IPSS questionnaire was administered at the 3-mo and 6-mo visits.

2.4. Statistical analyses

Considering the small number of cases included in the present analysis, continuous variables are reported as the median value with interquartile range (IQR). Categorical variables are reported as the frequency and percentage. Preoperative and postoperative IPSS and PVR results at 6-mo follow-up were compared using the Wilcox test for paired data. Clinical records were inserted in a dedicated database and analysed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA). All p values reported are two-sided, and statistical significance was set at $p < 0.05$.

3. Results

During the study period, 16 men with a median age of 68 yr (IQR 54–74) underwent RABD at our institution. Table 1 summarises the preoperative characteristics. In detail, all patients showed severe LUTS (median IPSS 25, IQR 21–30), elevated PVR (median 195 ml, IQR 140–210), and BOO/BPE. BD were located posteriorly in nine cases (56%) and posterolaterally in the remaining seven cases (44%). The median BD size was 69 mm (IQR 51–82). The indication for bladder diverticulectomy was high PVR in ten cases (63%), persistent lower urinary tract infections in five cases (31%), and BD stones in one case (6%).

The median prostate volume was 64 cm^3 (IQR 52–76), with no case exceeding 100 cm^3. Thus, all patients underwent bipolar TURP, which was performed 3 wk before RABD in seven cases (44%) and concomitant to RABD in the remaining nine cases (56%). No patient required preoperative ureteral catheter placement. BD were identified intraoperatively by filling the bladder via the indwelling catheter with saline solution in 12 cases (75%), while assistance via flexible cystoscopy and Firefly technology was needed in the remaining four cases (25%). A concomitant ureteric reimplantation was performed in only one case. This was because of severe inflammatory adhesions between the pelvic ureteric tract and the sac of a large posterolateral BD, for which dissection of the ureter out of the diverticulum was deemed at high risk of devascularisation and subsequent stricture.

Table 2 summarises the intraoperative and postoperative outcomes. The median OR time was 126 min (IQR 92–167) and median EBL was 20 ml (IQR 15–40). No intraoperative complications were recorded. The median indwelling catheter time was 5 d (IQR 5–7) and median LOS was 6 d (IQR 6–7). A cystogram performed on postoperative day 4 showed no urine leakage in all cases.

Table 1 – Clinical characteristics of the 16 patients undergoing robot-assisted bladder diverticulectomy

Parameter	Result
Median age, yr (interquartile range)	68 (54–74)
Median body mass index, kg/m^2 (interquartile range)	25.5 (24.8–28.4)
Charlson comorbidity score, *n* (%)	
0	9 (56)
1	5 (31)
2	2 (13)
American Society of Anesthesiologists score, *n* (%)	
2	10 (62)
3	6 (38)
Median International Prostate Symptom Score (interquartile range)	25 (21–30)
Median postvoid residual volume, ml (interquartile range)	195 (140–210)
Median prostate volume, cm^3 (interquartile range)	64 (52–76)
Median bladder diverticulum size, mm (interquartile range)	69 (51–82)
Bladder diverticulum location, *n* (%)	
Right posterolateral wall	4 (25)
Left posterolateral wall	3 (19)
Posterior wall	9 (56)

Table 2 – Intraoperative and postoperative outcomes for the 16 patients undergoing robot-assisted bladder diverticulectomy

Parameter	Result
Median operating room time, min (interquartile range)	126 (92–167)
Median estimated blood loss, ml (interquartile range)	20 (15–40)
Median catheter time, d (interquartile range)	5 (5–7)
Median length of stay, d (interquartile range)	6 (6–7)
Median postvoid residual volume at 6-mo follow-up, ml (interquartile range)	30 (28–40)
Median International Prostate Symptom Score at 6-mo follow-up (interquartile range)	5 (5–6)

Postoperative minor complications (persistent lower urinary tract infections requiring prolonged antimicrobial therapy) were recorded in two (13%) men. A 6-mo follow-up the median IPSS was 5 points (IQR 5–6) and median PVR was 30 ml (IQR 28–40), which were both significantly lower than at baseline ($p < 0.001$).

4. Discussion

Our data show that RABD is a safe and effective minimally invasive option for the treatment of acquired BD associated with BOO/BPE. The RABD technique is not yet standardised. Most authors perform the procedure using a lithotomy position [6,7]. In our experience, all procedures could be performed in a supine position using the Xi da Vinci platform to minimise potential complications related to the lithotomy and Trendelenburg position. The supine position allows for assistance via flexible cystoscopy for BD identification, if needed.

Different techniques for intraoperative identification of BD have been described. Moore et al. [12] described easy BD identification via injection of saline solution or methylene blue through an indwelling catheter. Alternatively, catheterisation of the diverticulum with fluid or balloon distension was also described [13,14]. In 2008, Macejko et al. [15] described an interesting method for intraoperative BD identification using flexible cystoscopy. More recently, Vedovo et al. [10] described the use of Firefly technology for intraoperative BD identification during a robot-assisted approach. In our series, we used injection of saline solution through the transurethral catheter in all cases. However, in some cases we also assistance via flexible cystoscopy and Firefly technology, mostly in cases in which the BD neck was close to the ureteric orifice.

Similar to traditional open surgery, the transvesical and extravesical approaches are the most frequently used by robotic surgeons [8,13,16]. In rare cases, some authors have proposed a transdiverticular approach for very large BD, whereby the sac can be opened, entered, and subsequently followed until the diverticular neck is found [7]. No study has compared the different approaches. Liu et al. [7] proposed the transvesical technique for posterior or posterolateral BD often located in close proximity to the ureteric orifice, and, vice versa, the extravesical approach for moderate to large BD located near the dome of the bladder or at the lateral wall. Develtere et al. [8] adopted the transvesical route for all their cases, claiming that this technique allows rapid identification of the BD neck and ureteral orifices, and facilitates concomitant simple prostatectomy or bladder stone removal when necessary. In our experience, the extravesical approach allowed appropriate treatment of all the posteriorly or posterolaterally located BD. In just one case the BD neck was close to the ureteric orifice and required an immediate ureteric reimplantation. Although we believe that the surgical approach should be chosen according to BD location, any need for concomitant prostate surgery, and the surgeon's preference, the extravesical route is associated with a minimal cystotomy that potentially lowers the risk of urinary leakage.

The type and timing of treatment to relieve BOO/BPE in patients undergoing RABD is not yet standardised, with 30–65% undergoing a concomitant procedure, either transurethral resection (or enucleation) of prostate adenoma or RASP [6–8,17,18]. In our series, 56% of patients underwent concomitant bipolar TURP, namely those with prostate volume <60 cm^3. Since prostate volume did not exceed 100 cm^3 for any of our patients, concomitant RASP was deemed not indicated according to our institutional policy. In the case of concomitant procedures, we always favour bipolar TURP (or RASP) as the first step. It might be argued that bleeding from the fresh TURP area would impair vision for the subsequent RABD. However, in our opinion this would not be an issue for smaller prostates, provided that haemostasis is meticulous, with little to no interference during diverticulectomy, especially when an extravesical approach is pursued. Furthermore, if de-obstructive prostate surgery were to be performed immediately after RABD, our concern would be that the intraoperative and/or postoperative continuous bladder irrigation might predispose to leakage through the fresh sutures used to close the bladder or prostate capsule. Combined procedures seem to be safe, with some authors reporting a few cases of RABD performed concomitant even to robot-assisted radical prostatectomy in patients with localised prostate cancer [7,8,19].

Table 3 summarises the most important clinical data from all these reports [6–8,12,13,17,20–22] and the present series. Perioperative outcomes confirmed that RABD is safe and effective. OR time is extremely variable, with a wide range between 63 and 386 min [7,13]. Obviously, OR time can be strongly influenced by the type and complexity of other associated surgical procedures. In our series, the median OR time was 126 min considering that only one case required a concomitant ureteric reimplantation.

Similar to our experience, EBL was very low with, a range between 0 and 200 ml [6,7]. There are very heterogeneous data for indwelling catheter time and LOS. The timing for catheter removal after RABD is not yet standardised. Data from the larger series in the literature showed a range between 7 and 29 d, with mean values between 5 and 11 d. In our experience, a cystogram performed on postoperative day 4 demonstrated a watertight bladder in all cases allowing for expedited catheter removal.

Patients were usually discharged after 1–11 d, with mean values between 2 and 7 d. We believe that different postoperative management pathways mainly depend on different health systems, which could explain this variability. According to our postoperative protocol, patients were discharged after catheter removal. Finally, no major postoperative complications after RABD were reported in the literature, confirming the good safety profile of the procedure.

While no study has compared RABD with pure laparoscopic bladder diverticulectomy, Liu et al. [7] compared their robotic series with a historical control group undergoing open diverticulectomy and found significant advantages in terms of EBL, indwelling catheter time, and major complications in favour of robotic surgery.

Similar to the finding in the present study, other authors have reported significant improvements in LUTS, a decrease in PVR, and resolution of lower urinary tract infections after

Table 3 – Robot-assisted bladder diverticulectomy series including at least five cases reported in the literature

Study	Cases	Maximum BD size (cm)	Approach	OR time (min)	EBL (ml)	Catheter time (d)	LOS (d)	Concomitant procedures (*n*)	90-d postoperative complications (*n*)
Myer 2007 [13]	5	10.8 (4.7–15.8)	Extravesical	83 (63–143)	–	–	3 (1–6)	URI (1)	–
Altunrende 2011 [20]	6	2.1–7.6	Extravesical/transvesical	233 (135–360)	100 (50–150)	7–12	3 (2–5)	PLND (1) URI (1) TURP (1)	Urosepsis (1) AUR (1)
Moore 2012 [12]	5[a]	2.5–11	Extravesical	216 (175–265)	45 (25–50)	7–8[b]	1[b]	–	AUR (1)
Abreu 2014 [17]	10	–	Transvesical	210	75	–	–	RARP (1) RASP (1) TURP (1)	–
Davidiuk 2015 [21]	16	7.2 (1–20)	Extravesical	184 (130–353)	50	11 (7–29)	2 (1–3)	URI (1)	–
Tufek 2016 [22]	9	–	Extravesical	186	70	8	5	–	–
Cacciamani 2018 [6]	6	7.1 (5.5–9.5)	Extravesical	112.5	25 (0–50)	5.3 (7–15)	7 (4.7–11)	TURP (2)	AUR (1)
Liu 2021 [7]	20	7.6 (3–14)	Extravesical/transvesical	184 (57–386)	100 (25–200)	12.3 (7–14)	2.1 (1–9)	RARP (5) RASP (4) PLND (2) URI (1) Bowel lesion repair (1)	– Bleeding (1) – – –
Develtere 2022 [8]	23[a]	7 (5.4–9.7)	Transvesical	140 (120–180)	250 (28–438)	2 (1–5)	3 (2–4)	RASP (12) RARP (1)	UTI (1) Urinary leakage (1)
Present series	16	69 (51–82)	Extravesical	126 (92–167)	20 (15–40)	5 (5–7)	6 (6–7)	URI (1) TURP (9)	UTI (2)

BD = bladder diverticulum; EBL = estimated blood loss; OR = operating room; PLND = pelvic lymph node dissection; RARP = robot-assisted radical prostatectomy; RASP = robot-assisted simple prostatectomy; TURP = transurethral resection of the prostate; URI = ureteric reimplantation; AUR = acute urinary retention; UTI = urinary tract infection.
[a] Including one woman.
[b] Data for four patients.

RABD with or without de-obstructive prostate surgery [6–8,12,20,21].

The main limitation of our study is the rather small, single-centre cohort with no control group.

5. Conclusions

Transperitoneal extravesical RABD is a safe and effective minimally invasive alternative to open surgery for the treatment of acquired posterior or posterolateral BD associated with BOO/BPE. In well-selected cases, TURP can be performed concomitant to RABD.

Our surgical technique seems to be easy to perform and is standardisable. In centres in which a robotic platform is available, RABD should be considered as the preferred treatment option for BD. Validation of our results in larger multicentre series with longer follow-up is warranted.

Author contributions: Vincenzo Ficarra had 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.

Study concept and design: Ficarra.
Acquisition of data: Rossanese, Macchione, Mucciardi, Crestani.
Analysis and interpretation of data: Ficarra.
Drafting of the manuscript: Giannarini.
Critical revision of the manuscript for important intellectual content: Ficarra, Giannarini.
Statistical analysis: Ficarra.
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Supervision: Ficarra.
Other: None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.euros.2022.08.016.

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