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ORIGINAL PAPER

Robotic bladder diverticulectomy in patients with bladder diverticulum neoplasia: A single-center study

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Summary *Purpose: The aim of this work is to present the clinical experience and outcomes in the management and follow up of bladder diverticular neoplasm.*
Methods: Following institutional board approval and informed consent obtained from each patient, a total of 10 patients, from January 2021 to December 2023, underwent robotic assisted bladder diverticulectomy with the preservation of the bladder. All the cases were performed with a four port transperitoneal approach plus two laparoscopic ports for the second surgeon, opting for an extravesical dissection of the diverticular neck. A tailored follow up for each patient was planned with cytological examination, cystoscopy and imaging. All patients were screened to confirm localized disease and to exclude obstructive disease and LUTS to avoid high post voiding volumes.
Results: To date, all patients involved in the study have adhered to the follow up protocol and remain alive and free of recurrent disease. Catheters were successfully removed in all ten patients, after a negative cystography for leakage at seven days. Pathological examination confirmed clear surgical margins in 100% of the cases. The average length of the procedure was 112 minutes, with minimal blood loss and a mean hospital stay of 3,7 days. No major complication occurred.
Conclusions: Our case series demonstrated the safety and feasibility of this approach, achieving favourable operative times, minimal blood loss and absence of leakage. The outcomes also highlight improvement in terms of reduction of catheterization duration, hospital stay and QoL of the patients.

KEY WORDS: *Bladder cancer; Bladder diverticulum; Diverticulectomy; Robotic surgery.*

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INTRODUCTION

The human bladder may be characterized by numerous pathological manifestations, including bladder tumor and diverticula. Bladder diverticula represent a herniation of the bladder mucosa through the muscular layer, in communication with the bladder lumen through their neck. The size of diverticula can vary from millimetric shapes to large diverticula (1). Diverticula can be acquired, e.g. following obstructive urinary pathologies, or congenital (1). Albeit most could be small and clinically insignificant, complications such as infections, stones and even neoplasms could occur (2, 3).
Patients with intradiverticular bladder tumors can be asymptomatic or show symptoms such as hematuria, recurrent urinary infections or difficulty in emptying the bladder. Primary diverticular tumors are rare, with an average frequency of 2% of all diagnosed bladder cancers (4, 5). The most common histological types are represented by urothelial carcinoma, followed by squamous cell carcinoma, small cell carcinoma, adenocarcinoma and sarcoma, in decreased order of frequency (5-8).
Their diagnosis is based on urinary cytology, imaging (ultrasound, computed tomography or magnetic resonance imaging), cystoscopy and subsequent endovesical resection which could result in a diagnostic or therapeutic option.
When the endoscopic resection could not be radical, major surgical approaches can be considered such as diverticulectomy, partial or total cystectomy.
Bladder diverticulectomy for intradiverticular bladder tumor is a surgical procedure used to treat bladder diverticula. Management becomes more complex and requires personalized treatment when diverticula harbor neoplasms. Different surgical techniques are proposed for diverticulectomy. Open diverticulectomy is, traditionally, the most common technique and allows for wide exposure and complete removal of the diverticulum with adequate margins. Minimally invasive laparoscopic/robotic surgery is an increasingly used approach due to the advantages of less invasiveness, reduced bleeding and faster recovery times. However, it requires advanced surgical experience, especially in the presence of malignant tumors.
Compared to traditional surgical approaches, long-term outcomes of robotic bladder diverticulectomy have shown significant improvements in voiding symptoms and diminished postvoid residuals, indicating the effectiveness of the procedure in addressing patient symptoms (9, 10).
In cases of malignancy, robotic bladder diverticulectomy has demonstrated clear margins in a high percentage of patients, highlighting its efficacy in addressing both benign and malignant indications for diverticulectomy (9, 11).

The use of a four-arm robotic system with a transperitoneal approach has facilitated precise dissection of bladder diverticula, contributing to improved perioperative outcomes and functional results (16).
In general , robotic bladder diverticulectomy can be performed using various techniques, including the transperitoneal extravesical approach, transperitoneal intravesical approach, and trans vesical approach (9-12) but, in case of bladder diverticulum cancer it would be preferable to perform a fully extravesical approach.
The extravesical dissection of the diverticular neck is a commonly utilized technique, which has been associated with successful outcomes in both benign and malignant cases (9-11).
The transperitoneal approach, with robot assistance, allows for precise dissection of adjacent structures and easier intracorporeal suturing, contributing to the effectiveness of the procedure (10, 13).
Robotic bladder diverticulectomy is generally associated with minor complications. Among minor issues could be included urinary tract infection, prolonged hospital stays and persistent urinary symptoms (9-11, 14, 15). However, these complications are generally well managed and tolerated, while no significant intraoperative or postoperative complications have been observed in several studies (9-11). Persistent urinary infection has been reported in a small percentage of cases, but overall, the procedure has been deemed safe with minimal surgical morbidity (10, 16).
The objective of our work is to evaluate the effectiveness and safety of the robotic approach to bladder diverticulectomy for diverticulum neoplasia, highlighting the advantages such as hospitalization time, catheterization time and the safety of the procedure.

Materials and methods

In our case series, a thorough assessment was conducted within all patients with bladder diverticulum cancer who underwent robotic assisted diverticulectomy between 2021 and 2023. The preoperative work-up included medical history, physical exam, cystoscopy, *post void residual* volume (PVR), CT-imaging (Figure 1) and *transurethral resection of the bladder* (TURB).
Baseline characteristic, including age, histology, position and dimensions of the bladder diverticulum, operative time and length of hospital stay were retrieved.
In all patients the disease was primary to the diverticulum in the absence of concomitant lesions in the rest of the bladder. In all selected patients the TURB was performed before major surgery.
Follow up was based on evaluations at catheter removal with cystography, at 1 month, 3 months, 6 and 12 months with routinary examinations (urinary cytology, cystoscopy and echography with PVR plus regular CT-imaging).
All patients were then subjected to a follow-up protocol according to guidelines with urinary cytology, cystoscopy and imaging at regular intervals and personalized based on the histology.
At 3, 6, and 12 months from the operation at visit, the patients showed negative cytology, imaging and cystoscopy. The control CT scans of the patients were negative for disease recurrence. To date, the ten patients are in follow-up without disease recurrence.

Step-by-step surgical technique

Our robotic approach includes:

- Patient positioning: Patients are typically positioned in a low dorsal lithotomy position (in low Trendelenburg), a Foley catheter is placed over a guide wire into the diverticulum with the balloon inflated at the diverticulum neck (13,17). In only two cases a double J-stent was prophylactically positioned due to the localization of the diverticulum to identify the ureter.
- Port placement a transperitoneal approach was performed using the Da Vinci Surgical System. Four robotic ports are placed together with two laparoscopic ports for the second surgeon. Camera was positioned 2 cm over the umbilicus level, two robotic ports are placed 1 cm over the midline between the umbilicus and anterior superior iliac spine, another robotic port 2 cm over the right anterior superior iliac spine. A 12 mm and a 5 mm ports for the assistant are placed respectively 2 cm over the left anterior superior iliac spine and 2 cm over the line between the camera port and the left robotic port. The preferred robotic instruments were monopolar scissors in the right robotic arm, a Maryland bipolar forceps in the left arm, a Prograsp in the fourth arm.
- Identification of bladder diverticulum (18), dissection and excision: The diverticulum is approached trans peritoneally after filling the bladder with saline solution, the identified diverticulum is mobilized and transected at its neck circumferentially with monopolar scissors. The bladder is then closed with Hem-o-lock or Endo-Gia depending on the dimension of the neck (17)[3]. The diverticulum is stored in Endo-Bag and extracted.
- At the end of the closure and resection, a bladder leak test is performed to exclude any urine leakage.

Figure 1.
Bladder diverticulum cancer with diverticulum localized in left anterior wall.

Results

In our center from 2021 to 2023 we performed 10 robotic diverticulectomy procedures in patients with a histological diagnosis of intradiverticular tumor confined to the diverticulum for whom the TURB was not radical. The ten patients had an average age of 68 years, and all underwent enhanced CT, urinary cytology, cystoscopy, ultrasound evaluation of the post-void residue and subsequent staging endoscopic resection with concomitant bladder mapping. Bladder mapping was negative in all cases undergoing diverticulectomy (Table 1).

Table 1.
Population data and follow-up time.

Patient	Age	Period	Follow-up
1	67	jan-21	47
2	70	apr-21	44
3	63	may-21	43
4	70	oct-21	38
5	68	feb-22	34
6	69	apr-22	32
7	72	sep-22	27
8	67	mar-23	21
9	69	jun-23	18
10	68	dec-23	12
Median	68.3		31.6

Of the ten histological examinations 3 reported a low-grade urothelial histology, 5 a high-grade urothelial histology, 2 high-grade squamous. All histological tests showed negative resection margins (Table 2).

Table 2.
Pathological data of patients at the time of TURB and diverticulectomy.

Patients	TURB histology	DIverticulectomy histology
1	G2 Ta	G3 Ta
2	G3 Ta	G3 T1
3	G2 Ta	G2 Ta
4	G3 T1	G3 ta
5	G2 T1	G3 T1
6	G3 T1	G3 Ta
7	G2 Ta	G2 Ta
8	G3 T1	G3 Ta
9	G3 Ta	G3 T1
10	G2 Ta	G2 Ta

Outcomes and efficacy

Four of the patients had an history of TURP, three others had non-significant PVR with adequate treatment, the others had good performances without therapy and no PVR.
All patients undergoing robotic-assisted bladder diverticulectomy report significant improvement in symptoms and minimal post-void residuals.
All of them began to eat the day after surgery and two days after started to ambulate. No patients reported major complications at 30 and 90 days.
After one week from the surgery, none of the patients had leakage at cystography and they had their catheter removed.
After one month, at imaging control, no significant PVR was found for each of the patients.
Based on these results we can consider the procedure generally safe and with minimal complications, with a median loss of blood of 130 cc.
Hospital Stay and Recovery: median length of hospital stay of our patients was around 4 days, with patients experiencing a swift recovery and minimal postoperative complications. This is comparable with the median hospital stay described in literature (16, 17, 19).
Catheter Management: Foley catheter was removed after a negative cystogram, which was usually performed around 7 days post-surgery, as also described in literature (19).
The average time for the procedures was 178 minutes from the time of anesthesia to skin closure.
After a median follow-up of 31.6 months no disease relapse was found.

Discussion

As highlighted in the available literature, although few articles focus on the subject, a well-defined relationship exist between bladder diverticula, intradiverticular bladder cancer and chronic inflammation. Chronic urinary stasis as well as continuous exposure to carcinogens have been considered as potential triggers of neoplastic mutations at the level of the bladder wall. The frequency of primary intradiverticular neoplasia varies from 1 to 10% with a higher rate in men than in women and in patients over 60 years of age (13). As with bladder tumors in general, the most frequent symptom is hematuria without *lower urinary tract symptoms* (LUTS). Some studies have also highlighted how intradiverticular tumors arise more often in the lateral walls rather than in the anterior or posterior wall (19, 18). For what concerns diagnostics, traditionally and according to current guidelines, an initial ultrasound approach can highlight more gross and easily identifiable lesions (13). However, ultrasound alone is not always decisive and in second level investigations such as cystoscopy and CT scan with contrast medium are often required.
Matkovic et al., in their review, highlighted that the most frequent histotype was urothelial carcinoma (72%) (21).
Baniel and Vishna (15) emphasized that a T1 carcinoma in a bladder diverticulum should be considered as a T2-3 carcinoma is considered in a normal bladder.
As for treatment, TURB is recommended for low-grade and T1 stage forms, followed by regular follow-up according to guidelines with imaging, cystoscopy and urinary cytology. However, the choice for endoscopic resection is not free from problems such as the presence of a very narrow diverticular neck that cannot be passed by the instrument, or the presence of a thin diverticular wall with the risk of creating a perforation and tumor dissemination (13).

Diverticulectomy is the preferred indication for large tumors with low histological grade when complete transurethral resection is not possible. Partial cystectomy may be proposed in the case in which the tumor reaches and exceeds the neck of the diverticulum and in the absence of concomitant carcinoma in situ. In this case, it may sometimes be useful to complete the procedure with lymphadenectomy and adjuvant treatment. Radical cystectomy is proposed in high-grade diverticular forms, in locally advanced forms and with concomitant additional endovesical lesions or carcinoma in situ or multifocal disease with concomitant poor bladder function.
Matkovic et al. underlined that the overall 5-year survival rate ranges between 63-72% and that factors of poor prognosis could be considered the lack of muscle layer, positive margins and extradiverticular extension and larger tumors. But they also underlined that there were no statistically significant difference between partial and radical cystectomy.
The surgical approach for diverticulectomy can be open, laparoscopic or robotic assisted surgery, with almost similar performances. Open diverticulectomy is the most common technique, although it has been used less and less recently and often in selected cases (22) in favor of minimally invasive techniques such as the laparoscopic and robotic approach, which guarantee less invasiveness with reduced bleeding and faster recovery times.
In our experience, all patients who underwent robot-assisted diverticulectomy reported significant improvement in symptoms and minimal post-void residuals.
The robotic approach we used ensured excellent closure of the neck of the diverticulum, allowing us obtaining a cystography negative for urinary leakage 7 days after surgery for all patients removing the bladder catheter
After a median follow up of 31,6 months no disease relapse was found.

Conclusions

In summary, in our experience, robotic technology in bladder diverticulectomy offers enhanced precision, better visualization, and improved patient outcomes, making it a preferred approach (17, 19, 20).
The robotic approach has proven to be crucial in ensuring free margins to reduce the risk of recurrence and reduce postoperative complications.
We are aware of the limits of our study due to the limited number of cases, and we acknowledge that larger studies with long-term data are needed to establish optimal guidelines, as most of the current literature is based on limited case series and retrospective reports.
In summary, robotic bladder diverticulectomy has emerged as a safe, effective, and reliable surgical intervention for both benign and malignant bladder diverticula. The procedure's potential for minimizing complications, improving long-term outcomes, and benefiting from advancements in robotic technology makes it a promising option for patients requiring bladder diverticulectomy.

Declarations

Ethical approval and consent for participate: *Not applicable.*

Consent for publication: *Informed consent was obtained from all subjects involved in the study.*

Availability of data and material: *The authors confirm that the data supporting the findings of this study are available within the article. Raw data that supports the findings are available, upon reasonable request to the authors.*

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