Review Article

Current status of robot-assisted total pelvic exenteration focusing on the field of urology: a clinical practice review

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Abstract: Total pelvic exenteration (TPE) is a highly invasive surgery associated with high rates of perioperative morbidity and mortality and is commonly performed for several types of locally advanced or recurrent pelvic cancers. It involves multivisceral resection, including the rectum, sigmoid colon, bladder, prostate, uterus, vagina, or ovaries, and urologists normally perform radical cystectomy or radical prostatectomy and urinary diversion in collaboration with colorectal surgeons and gynecologists. In the urological field, robot-assisted surgeries have been widely performed as one of the main minimally invasive procedures because of their superior perioperative or oncological outcomes compared to open or laparoscopic surgeries. In pelvic exenteration (PE) surgery, laparoscopic surgeries have shown superior rates of mortality, morbidity, and R0 resection compared to open surgeries. Robot-assisted TPE for the treatment of locally advanced rectal cancer was first reported in 2014, and reports of its safety and usefulness have gradually increased. Robot-assisted PE, in which multivisceral resection in a narrow pelvic space is easier, will eventually be a standard minimally invasive procedure, although evidence has been limited to date. This clinical practice review summarizes the indications for surgery, perioperative complications, and oncological outcomes of robot-assisted TPE and highlights the current status of robot-assisted TPE for patients with urological malignancies and its surgical technique, focusing on the manipulation of urological organs.

Keywords: Cystectomy; pelvic exenteration (PE); prostatectomy; robotic surgery

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Introduction

Pelvic exenteration (PE) is performed to treat several types of locally advanced or recurrent pelvic cancers or multiple genitourinary and colorectal cancers (1). It was first reported in 1948 for the treatment of advanced recurrent gynecological malignancies and has since been applied to other advanced cancers (2,3). In primary rectal cancer, one of the major malignancies performed PE, approximately 30% of patients were diagnosed with rectal cancer in locally advanced state, and it was estimated that about 6–10% of patients received PE in order to achieve R0 resection (4). PE is divided into three types depending on the tumor location, extent, and involvement of the pelvic compartments (5). Total PE (TPE) refers to the resection of the urinary tract, rectum, and internal reproductive organs. Posterior PE was defined as resection of the rectum and female reproductive organs without resection of the bladder or ureter. Anterior PE was described as resection of the lower urinary tract and

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female reproductive organs without resection of the rectum. TPE involves multivisceral resection, including the rectum, sigmoid colon, bladder, prostate, uterus, vagina, or ovaries, and urologists normally perform radical cystectomy or radical prostatectomy and urinary diversion in collaboration with colorectal surgeons and gynecologists.

There have long been concerns about the high complication and mortality rates of open PE because of the technical difficulties in handling several organs in the narrow pelvic space, even though open PE has been shown to prolong survival (1). A systematic review of 23 studies on open PE showed that the perioperative mortality rate (within 30 days) was 0–25% (median, 2.2%), with a complication rate of 37–100% (median, 57%) (6). Minimally invasive techniques for pelvic surgery have several advantages in manipulating organs and vessels in the narrow and deep pelvis, with clear visualization; laparoscopic PE was first reported in 2003 for the treatment of locally advanced cervical cancer (7). Several studies have reported the safety and efficacy of laparoscopic PE, with low mortality and morbidity rates and high R0 resection rates compared to open PE (8-11). In contrast, laparoscopic manipulation to dissect pelvic vessels and multivisceral resections requires high skill. A robot-assisted approach is expected to overcome the problems of the laparoscopic approach with superior three-dimensional high-definition vision and a more ergonomically stable platform (12). The first report on robot-assisted PE for the treatment of locally advanced rectal cancer was published in 2014. Studies demonstrating the safety and usefulness of robot-assisted TPE for the treatment of several pelvic malignancies, including urological tumors, have been gradually increasing (12,13).

This review article provides the current status of robot-assisted TPE and surgical techniques for TPE, focusing on the association with urological malignancies and the manipulation of urological organs.

Current status of robot-assisted TPE

Patient selection

The most common indication for TPE is locally advanced or recurrent colorectal cancer (4,14). Locally advanced or recurrent cervical cancer was dominant for indication for TPE in non-rectal pelvic malignancy, although all gynecological neoplasms (cervical, endometrial, vulvar, or ovarian carcinoma) and lower urinary tract neoplasms (bladder or prostate cancer) are also candidates for TPE as reported in previous literatures (15,16). Moreover, TPE is indicated in patients with both urological and colorectal cancer occurring at the same time (8,17-19). Indication for TPE depends on various factors, including previous treatments and presence of unresectable metastasis and invasion of the pelvic wall, sciatic nerve, or sacral nerve plexus. Additionally, nutritional status or general health conditions tolerable to extended surgery and acceptance of reduced quality of life because of permanent stoma management or complications, including bladder bowel dysfunction, are crucial in identifying the indications for TPE.

The extent of the resected organs was determined based on the extent of the tumor lesion. In cases of preservation of sphincter function with colorectal or coloanal anastomosis, supralevator exenteration was performed, and the levator ani and anus were preserved. In cases with tumor invasion to the prostate but not to the bladder neck or trigone, bladder-sparing prostatectomy and vesicourethral anastomosis can be performed.

Current status of robot-assisted TPE for patients involving urological malignancies

Previous reports on TPE for locally advanced or recurrent urological malignancies are fewer than on those for locally advanced or recurrent colorectal or gynecological malignancies, and information about the surgical outcomes of TPE for urological malignancies is limited (14,16,20). *Table 1* shows a summary of previous reports of robot-assisted TPE involving urological malignancies (17-19,21-24). Many cases receiving robot-assisted TPE for urological malignancies had synchronous rectal and prostate cancer, and cases with locally advanced or recurrent bladder or prostate cancer are few (21-24). It may be important to note that the concept of R0 resection or *en bloc* extended resection including urinary diversion and decision of the extent of resection can be different between Robot-assisted TPE for synchronous localized rectal and prostate cancer and those for locally advanced urological malignancies or colorectal or gynecological malignancies.

The long-term oncological outcomes of robot-assisted TPE for locally advanced bladder or prostate cancer remain unclear; however, the reduced risk of perioperative complications from minimally invasive surgery (MIS) and improvement of perioperative adjuvant chemotherapies for urological cancers these days may expand the indications for extended surgery for

Table 1 Previous reports on robot-assisted TPE for urological malignancies

Authors, year	Cases	Primary urological tumor	Simultaneous tumor	Type of surgery	Mean operating time [range]	Mean blood loss [range]	Intraoperative complication	Postoperative complications (Clavien-Dindo classification)	Perioperative mortality	Margin of resection	Recurrence
Castillo *et al.*, 2015, (21)	1	Locally recurrent prostate cancer	None	APR + radical cystectomy	249	600	None	None	None	Negative	Biochemical recurrence
Winters *et al.*, 2015, (22)	2 (with another case of primary rectal cancer)	Locally recurrent prostate cancer (n=1), locally advanced bladder cancer (n=1)	None	APR + RCP (n=1), APR + RP (n=1)	597 [530–660]	550 [350–800]	None	Pelvic abscess and pyelonephritis (II, n=1)	None	Negative (n=2)	Negative (n=2)
Kamiyama *et al.*, 2016, (17)†	1	Prostate cancer	Rectal cancer	APR + RP (n=1)	545	170	None	None	None	Negative	N/A
Peng *et al.*, 2020, (23)	1 (with 4 other cases of primary rectal cancer)	Locally advanced prostate cancer	None	APR + RCP	N/A	N/A	N/A	N/A	None	Negative	N/A
Maeda *et al.*, 2022, (19)	1 (with 4 other cases of primary rectal cancer)	Prostate cancer	Rectal cancer	ISR + RP	N/A	N/A	N/A	N/A	None	Negative	N/A
Williams *et al.*, 2021, (24)	5 (with other 2 cases with primary rectal cancer)	Prostate cancer (n=5) (including 2 cases with cT4 cancer)	Primary rectal cancer (n=2), recurrent rectal cancer (n=1), none (n=2)	APR + RCP (n=2), ultra-low anterior resection + RP (n=2), APR + RP (n=1)	485 [200–670]	563 [150–1,000]	None	Vesicourethral anastomotic leak and sepsis (IIIa, n=1), ileus and perineal wound infection (II, n=1), urinary tract infection (I, n=1), ileus (I, n=1)	None	Negative (n=5)	Negative (n=3), internal iliac node and thoracic vertebrae (n=1), pelvic, ling, femoral neck (n=1)
Fukata *et al.*, 2022, (18)	5	Prostate cancer (n=5)	Rectal cancer (n=5)	APR + RP (n=2), ISR + RP (n=2), high anterior resection + RP (n=1)	505 [431–764]	139 [20–345]	N/A	Colorectal anastomotic leakage (IIIb, n=1), vesicourethral anastomotic leakage (IIIa, n=2)	None	Negative (n=5)	Negative (n=4), bone metastasis of prostate cancer (n=1)

†, abdominoperineal resection performed laparoscopically. TPE, total pelvic exenteration; APR, abdominoperineal resection; RCP, radical cystoprostatectomy; RP, radical prostatectomy; N/A, not available; ISR, intersphincteric resection.

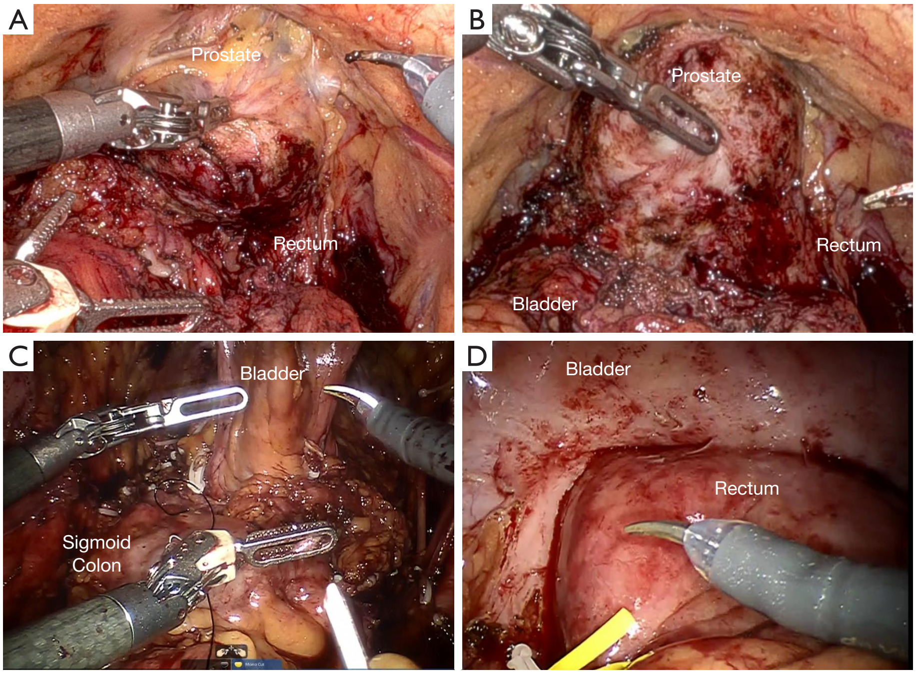

Figure 1 Representative intraoperative images of robot-assisted TPE. (A) After dissection of the bladder neck and seminal vesicles and (B) during dissection of the bladder neck in prostatectomy in TPE for locally advanced rectal cancer invading the prostate. (C) After ureteric isolation and ligation in cystectomy in TPE for locally advanced rectal cancer invading the bladder neck. (D) The finding of rectovesical excavation in a case with large rectal tumor and narrow pelvic space. In this case, it was hard to dissect the dorsal side of rectum because dilated rectum by tumor occupying pelvic space. TPE, total pelvic exenteration.

urological malignancies in the near future.

Surgical technique of robot-assisted TPE focusing on the manipulation of urological organs

The patients were placed in the lithotomy position, and the robot was docked in the Trendelenburg position after four robot ports and two assistant ports were placed. Representative port placements for robot-assisted TPE using the Da Vinci Xi surgical system have been described in the literature (18,19). The same robot ports can be used in rectal and urologic surgery using the Da Vinci Xi surgical system; however, robot or assistant ports can be replaced or added for colorectal surgeons and urologists to operate with the port placement to which they are usually accustomed. Further, combining laparoscopic and robotic surgery was allowed, depending on the type of MIS in which the colorectal surgeons or urologists specialized in each institute (17).

Generally, rectal resection is performed first, followed by radical cystectomy or prostatectomy (*Figure 1*). Initially, after dividing the inferior mesenteric artery and vein, colorectal surgeons mobilize the rectum by dissecting its dorsal side. After dividing the sigmoid colon, radical prostatectomy or cystectomy was performed. To obtain *en bloc* specimens, prostatectomy in robot-assisted TPE differed from ordinal robot-assisted radical prostatectomy (RARP) in not dissecting the Denonvilliers' fascia or ligating the lateral pedicles (*Figure 1A*). It should be noted that the dorsal tissue moved more easily when dissecting the bladder neck compared to standard RARP because the rectum was already dissected (*Figure 1B*). During cystectomy in robot-assisted TPE, retrovesical dissection, developing the rectovesical space, and lateral dissection were not performed to resect the bladder with rectal specimen (*Figure 1C*).

After urethral resection, the rectum was dissected, and *en bloc* specimen was obtained (*Figure 2*). Finally, urinary diversion or vesicourethral anastomosis and sigmoid-end colostomy or coloanal anastomosis were performed.

In cases of large rectal tumors in narrow pelvic spaces, dissection of the dorsal side of the rectum is sometimes

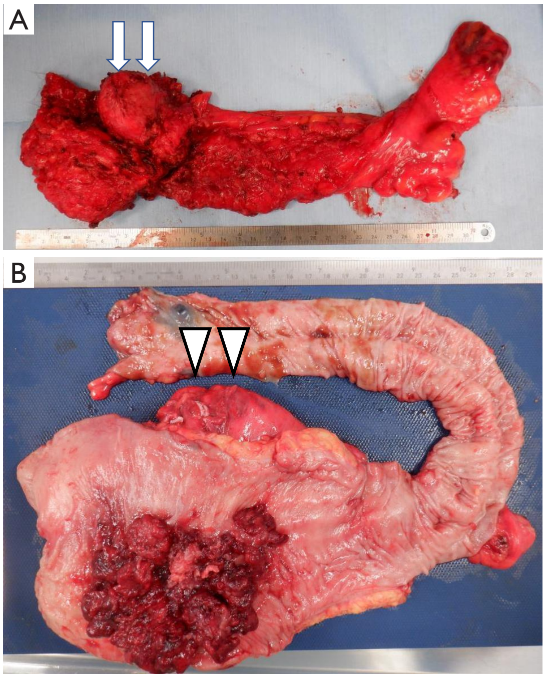

Figure 2 Macroscopic findings of specimen of locally advanced rectal cancer with (A) abdominoperineal resection with *en bloc* prostatectomy and (B) total mesorectal resection with *en bloc* cystoprostatectomy. The arrows and arrowheads indicate the prostate and bladder, respectively.

difficult, and it would be better to perform radical cystectomy procedure earlier in order to increase the range of motion of the bladder and rectum (*Figure 1D*).

Complications and oncological outcomes of robot-assisted TPE for urological malignancies

In the field of urological surgery, several robotic surgeries, including radical prostatectomy, radical cystectomy, and partial nephrectomy, have revealed the superiority of perioperative outcomes and postoperative complications over open surgeries (25,26). In addition, several studies have reported that the oncological outcomes of RARP are equivalent or superior to those of open or laparoscopic radical prostatectomy, with superior perioperative safety, continence, and erectile dysfunction recovery (27-31). The oncological outcomes of robot-assisted radical cystectomy for invasive bladder cancer are also equivalent to those of open or laparoscopic radical cystectomies (32-34). In contrast, the safeties and treatment efficacy of robot-assisted TPE for urological malignancies with large cohort have not yet been reported in the literature, and information about the perioperative or oncological outcomes of robot-assisted TPE compared with open or laparoscopic TPE is scarce.

Limited information for previous reports suggested that perioperative complications of robot-assisted TPE for urological malignancies have been tolerable and oncological outcomes have also been well preserved (*Table 1*) (17-19,21-24). A recent case series has summarized fourteen cases of robot-assisted TPE for locally advanced rectal and/or prostate cancers, including three literature reviews, and compared the perioperative and oncological outcomes to those in the literature of a large cohort or meta-analysis data of open TPE (21,22,24,35-37). The study reported higher rates of Clavien-Dindo grade III–IV complications, return to the operating room and intensive care unit (ICU) in open TPE than in robot-assisted TPE, and the tendency of less blood loss and prolonged median operating time in robot-assisted TPE (not statistically analyzed). Therefore, the perioperative complications about urinary tract and the oncological outcomes of urological cancer in robot-assisted TPE for synchronous rectal and urological malignancies or locally advanced urological malignancies are expected to be better or at least equivalent than in open TPE. Further studies with large cohort studies will be needed.

Complications and oncological outcomes of robot-assisted TPE for colorectal and gynecological malignancies (Table 2)

The PelvEx Collaborative summarized a meta-analysis comparing minimally invasive (robotic or laparoscopic) and open PE, concluding that MIS reduced intraoperative blood loss (550 *vs.* 2,300 mL, P<0.001), prolonged the median operation time by 83 minutes (P<0.001), and shortened hospital stay (22 *vs.* 28 days, P=0.04) compared to open PE. The overall morbidity rate in the MIS group showed reduced tendency (56.7% *vs.* 88.5%) but not statistically significant [relative risk rate, 1.17 (95% confidence interval, 0.93–1.48, P=0.172)] (40). Moreover, another retrospective study comparing perioperative outcomes between MIS and open PE for primary colorectal cancer has shown longer operative time (630 *vs.* 432 minutes, P<0.01) and less blood loss (900 *vs.* 1,550 mL, P<0.01) in MIS; however, the overall morbidity was not significantly reduced (60% *vs.* 49%, P=0.306) in the MIS group (38).

A retrospective single-center study comparing perioperative outcomes between laparoscopic and robot-assisted PE in gynecological malignancies has reported that robot-assisted PE significantly shortened operative time

Table 2 Perioperative and oncological outcomes of minimally invasive TPE including robot-assisted procedures in the literature

Authors, year	Design	Sample size	Primary malignancies	Median operating time (min)	Median blood loss (mL)	30-day morbidity (%)	Median ICU stay (days)	Mean length of stay (days)	R0 resection (%)	Recurrence (%)
Kumar *et al.*, 2020, (38)	MIS *vs.* open	95 (23 *vs.* 72)	Primary colorectal cancer	640 *vs.* 432 (P<0.01)	900 *vs.* 1,550 (P<0.01)	60 *vs.* 49 (P=0.306)	N.E.	11 *vs.* 12 (P=0.63)	87 *vs.* 89 (P=0.67)	N.E.
Kazi *et al.*, 2021, (39)	MIS *vs.* open	158 (61 *vs.* 97)	Locally advanced rectal cancer	640 *vs.* 450 (P<0.0001)	900 *vs.* 1,600 (P<0.0001)	39 *vs.* 46 (P=0.15)	N.E.	11 *vs.* 12 (P=0.62)	89 *vs.* 92 (P=0.49)	51.9 *vs.* 47.8 (3 years recurrence-free survival; P=0.922)
PelvEx Collaborative, 2018, (40)	MIS *vs.* open, meta-analysis	170 (37 *vs.* 133)	Mixed	Prolonged 83 min in MIS (median)	550 *vs.* 2,300 (P<0.001)	56.7 *vs.* 88.5 (P=0.17)	N.E.	22 *vs.* 28 (P=0.04)	21.7 *vs.* 23.0 (P=0.96)	N.E.
Winters *et al.*, 2015, (22)	Robotic *vs.* open	12 (3 *vs.* 9)	Robotic: recurrent prostate 1, locally advanced bladder 1, locally advanced rectal 1. Open: mixed	600 *vs.* 690 (P=0.18)	575 *vs.* 2,300 (P=0.01)	33.3 *vs.* 44 (P=0.74)	1 *vs.* 3 (P=0.01)	7 *vs.* 13 (P=0.01)	N.E.	N.E.
Bizzarri *et al.*, 2019, (41)	Robotic *vs.* laparoscopic	23 (11 *vs.* 12)	Cervical 10, endometrial 9, vaginal 3, urothelial 1	500 *vs.* 660 (P=0.04)	235 *vs.* 250 (P=0.298)	0 *vs.* 16.7 (P=0.47)	N.E.	9 *vs.* 11.5 (P=0.10)	63.6 *vs.* 83.3 (P=0.37)	N.E.

TPE, total pelvic exenteration; ICU, intensive care unit; MIS, minimally invasive surgery (laparoscopic or robot-assisted surgery); N.E., not evaluated.

(500 *vs.* 660 minutes, P=0.04), with equivalent outcomes of blood loss (235 *vs.* 250 mL, P=0.298), major postoperative complications (0 *vs.* 16.7%, P=0.47), and hospital stay (9 *vs.* 11.5 days, P=0.10) (41). A meta-analysis in colorectal surgeries has reported that the perioperative outcomes and postoperative complications in robotic surgeries were similar to those in laparoscopic surgeries, although there was little evidence of the safety of robot-assisted TPE in colorectal cancers compared with laparoscopic TPE (42).

In addition to safety and perioperative outcomes, there is little evidence of the superiority of oncological outcomes of robot-assisted TPE over open or laparoscopic TPE in a large cohort not only in urological malignancies but also in colorectal or gynecological malignancies.

Robot-assisted rectal cancer surgery has shown similar oncological outcomes to those of open surgery or laparoscopic surgery for colorectal cancer (43-45). Therefore, the oncological outcomes of robot-assisted TPE are expected to be equivalent or superior to those of open or laparoscopic TPE for colorectal malignancies; however, limited evidence has been established regarding the difference in oncological outcomes, especially long-term outcomes. A recent retrospective study at a single institute has revealed that recurrence-free survival and 3-year overall survival for locally advanced rectal cancer in minimally invasive (robotic or laparoscopic) TPE were not statistically different from those in open TPE (51.9% *vs.* 47.8%, P=0.922, 79.4% *vs.* 60.2%, P=0.251, respectively) (39). In gynecological malignancies, the rate of negative resection margins (R0) in robot-assisted PE was similar to that in laparoscopic PE (63.6% *vs.* 83.3%, P=0.37) (41). To clarify the superiority of the oncological outcomes of robot-assisted TPE, large multicenter cohort studies with long-term observations are required.

Limitations and further prospective

Currently, most reports on robot-assisted TPE are case reports or studies with small cohorts, and no previous studies have compared the treatment outcomes of robot-assisted TPE to open or laparoscopic TPE in large cohorts or randomized control trials. In addition, information on the long-term oncological outcomes, late complications, and cost-effectiveness of robot-assisted TPE is insufficient. In contrast, several robotic pelvic surgeries in the urological, gynecological, and colorectal fields have demonstrated superior or at least similar safety and oncological outcomes compared to open and laparoscopic surgeries, and robot-assisted pelvic surgeries could replace open or laparoscopic surgeries as the primary technique. Robot-assisted TPE may be a favorable standard MIS for locally invasive or recurrent pelvic malignancies requiring multivisceral resection, and cumulative evidence is warranted.

Conclusions

Robot-assisted TPE is a feasible, safe, and minimally invasive surgical procedure for the treatment of locally invasive or recurrent pelvic malignancies. More high-quality evidence revealing the superiority of robot-assisted TPE in perioperative and long-term oncological outcomes is required to establish robot-assisted TPE as a standard procedure.

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