ORIGINAL PAPER

Postoperative complications following simple cystectomy for radiation-induced bladder dysfunction compared to radical cystectomy: A matched cohort study

Paweł Lipowski[1*], Adam Ostrowski[1], Jan Adamowicz[1,2], Anastazja Zaigrajewa[1], Przemysław Jasiewicz[3], Filip Kowalski[1], Tomasz Drewa[1], Kajetan Juszczak[1*]

[1]Department of Urology and Andrology, Collegium Medicum, Nicolaus Copernicus University, Bydgoszcz, Poland
[2]Department of Regenerative Medicine, Collegium Medicum, Nicolaus Copernicus University, Bydgoszcz, Poland
[3]Department of Anesthesiology and Intensive Care, Collegium Medicum, Nicolaus Copernicus University, Bydgoszcz, Poland

Citation: Lipowski P, Ostrowski A, Adamowicz J, et al. Postoperative complications following simple cystectomy for radiation-induced bladder dysfunction compared to radical cystectomy: A matched cohort study. Cent European J Urol. 2026; doi: 10.5173/ceju.2025.0163

Article history
Submitted: Jul. 14, 2025
Accepted: Dec. 22, 2025
Published online: Feb. 22, 2026

Corresponding author
Paweł Lipowski
Department of Urology and Andrology,
Collegium Medicum,
Nicolaus Copernicus University,
9 M. Curie Skłodowskiej St.,
85-094 Bydgoszcz, Poland,
pavelipovsky@gmail.com

Introduction Simple cystectomy (SC) for radiation-induced bladder dysfunction (RIBD) is occasionally performed, yet data regarding perioperative outcomes are limited. This study aimed to compare perioperative complications following SC for RIBD with radical cystectomy (RC) for bladder cancer.

Material and methods We conducted a retrospective single-center analysis of patients who underwent laparoscopic cystectomy with ureterocutaneostomy between 2016 and 2024. Propensity score matching (PSM) was applied separately for cT1–cT2 stage tumors, cT3–cT4 stage tumors, and for SC group vesicoenteric fistula patients. Outcomes were assessed using the Clavien-Dindo (CD) classification at 30 and 90 days.

Results In total, 257 patients were included in the study: 25 SC for RIBD and 232 RC for BC. Prior to matching, SC patients had significantly higher rates of CD grade ≥3 complications at 30 days (44% vs 22.4%, p <0.001), higher reoperation rates (47.8% vs 11.6%, p <0.001), and prolonged hospital stays (15 vs 9 days, p = 0.002). After matching, SC patients continued to demonstrate more severe complications, especially compared to cT1–T2 RC patients (CD ≥3 complications: 47.1% vs 11.8%, p = 0.057; reoperations: 56.2% vs 5.9%, p = 0.002). In patients with vesicoenteric fistula after matching, CD complication rates at 30 days did not differ significantly between groups (p = 0.130), 90-day complication rates were comparable (p = 0.968), and reoperations occurred significantly more often in the SC group (61.5% vs 6.7%; p = 0.004). Study limitations include the retrospective single-center design, small SC group size and urinary diversion type.

Conclusions Due to high morbidity, non-oncological cystectomy for RIBD should be limited to selected cases and managed in experienced, multidisciplinary centers. Urinary diversion without cystectomy may be a safer alternative.

Key Words: simple cystectomy ‹› radical cystectomy ‹› radiotherapy ‹› vesicoenteric fistula ‹› bladder dysfunction

INTRODUCTION

Radiation-induced bladder dysfunction is a rare complication observed in patients who have undergone pelvic radiotherapy [1]. Although often delayed, long-term complications following pelvic radiotherapy can be severe and commonly necessitate surgical management, accounting for a notable share of emergency urological admissions in high-volume centers [2]. For instance, radiation-induced hemorrhagic cystitis may affect more than 5% of patients at a median of 43.9 months following radiotherapy, with up to half of those cases requiring invasive treatment [3]. Fistulas represent one

of the most severe and uncommon toxicities of radiotherapy, occurring in approximately 0.2% of patients undergoing pelvic irradiation due to prostate cancer [4]. It constitutes a strong indication for definitive surgical management [5].

Ionizing radiation initiates a cascade of biological responses including oxidative stress, endothelial dysfunction, and dysregulation of fibroblast activity. This results in persistent inflammation, vascular rarefaction, and excessive extracellular matrix deposition, which collectively impair tissue regeneration and contribute to late-onset complications such as fibrosis, impaired wound healing and tissue fragility [6].

Bladder cancer is managed according to tumor stage and risk stratification. Non-muscle-invasive bladder cancer (NMIBC) is typically treated with transurethral resection followed by intravesical immunotherapy such as Bacillus Calmette–Guérin (BCG) instillations, whereas muscle-invasive bladder cancer (MIBC) often requires radical cystectomy or bladder-sparing approaches [5, 6]. While cystectomy is most commonly performed for oncological indications, it may also be necessary in selected cases of severe non-malignant bladder dysfunction, such as bladder fistulas, perforations, or treatment-resistant hematuria, which is the focus of the present study [9].

There is evidence that cystectomy performed for non-oncological reasons carries significant perioperative risks [10]. Additionally, procedures performed in a previously irradiated surgical field may be associated with significant difficulties in wound healing and infections [9, 10].

Although simple cystectomy due to radiation-induced changes is performed in clinical practice, available data on outcomes and complication risks of this procedure are limited. Most publications focus on radical cystectomies performed for oncological indications or salvage procedures due to bladder cancer recurrence following prior radiotherapy [11–13].

The aim of this study was to compare postoperative complications between patients undergoing simple cystectomy for radiation-induced bladder dysfunction and patients undergoing radical cystectomy for bladder cancer.

MATERIAL AND METHODS

Population

A retrospective analysis was conducted on 257 patients who underwent laparoscopic cystectomy at a single center between 2016 and 2024. The study group included 25 patients who underwent simple cystectomy (SC) due to radiation-induced bladder dysfunction and 232 patients who underwent radical cystectomy (RC) for bladder cancer. In the SC group, radiotherapy had been performed for prior oncological indications such as prostate cancer, cervical cancer, endometrial cancer, or rectal cancer.

All procedures were performed laparoscopically by one experienced surgeon. In the SC group, unilateral right-side ureterocutaneostomy (UCS) was the standard method of urinary diversion; therefore, to ensure consistency and reduce selection bias, only patients from the RC group with UCS urinary diversion were included in the analysis. Patients who underwent salvage cystectomy were excluded from the study. Because many patients were treated in external institutions, radiotherapy documentation was incomplete or unavailable in several cases. Therefore, standardized extraction of RT dose, field, and modality was not feasible.

Study design

The primary aim was to evaluate complications using the Clavien–Dindo (CD) scale at 30 and 90 days postoperatively. Additionally, demographic, clinical, and perioperative parameters, blood transfusions, and length of hospital stay were analyzed.

To minimize differences between groups, propensity score matching was applied. Three separate analyses were conducted. Patients in the SC group were matched with RC patients with clinical tumor stage cT1–cT2 to form the organ-confined disease group (17 vs 17 patients), and separately with RC patients with clinical tumor stage cT3–cT4 for form the advanced disease group (19 vs 19 patients). Additionally, patients with vesicoenteric fistula from the SC group were matched with RC patients regardless of tumor stage.

Statistical analysis

Statistical significance was set at a two-sided alpha level of 0.05. Propensity score matching was conducted using the cardinality matching method to optimize the matched sample size while ensuring covariate balance. The Average Treatment Effect on the Control (ATC) estimand was employed to evaluate the effect of SC compared to RC in patients. Propensity scores were estimated via logistic regression, incorporating ten covariates selected for their clinical relevance as confounders influencing both cystectomy type and postoperative complications: sex, age, BMI, chemotherapy, hypertension, diabetes mellitus, chronic heart failure, chronic kid-

ney disease, American Society of Anesthesiologists (ASA) Physical Status, and Charlson Comorbidity Index (CCI). The rationale and suitability of each covariate are detailed in Suppl. Table A.1. Covariate balance was assessed using standardized mean differences (SMD), with SMD <0.1 indicating good balance, and empirical cumulative distribution function (eCDF) metrics.

The matching procedure was performed separately for two RC subgroups based on clinical tumor stages: cT1–cT2 (n = 73) and cT3–cT4 (n = 159), compared to SC (n = 25).

Continuous variables of matching were summarized using medians and interquartile ranges (IQR) due to non-normal distributions, as assessed by Shapiro-Wilk tests. Categorical variables were reported as counts and percentages. Descriptive statistics were calculated for the overall matched cohort and separately for SC and RC groups within each tumor stage subgroup (cT1–cT2 and cT3–cT4) to characterize baseline, treatment, and outcome variables.

Group differences in clinical characteristics and CD grades were assessed using appropriate statistical tests based on variable type and distribution. For continuous variables (e.g., age, BMI, operation time), the Wilcoxon rank-sum test was used due to non-normality. For categorical variables (e.g., sex, CD grades), Pearson's χ^2 test or Fisher's exact test was applied, with the latter used when expected cell counts were less than 5 (e.g., for specific CD grades).

Logistic regression with a logit link function was employed to estimate the effect of group (SC vs RC as reference) on CD 3+ incidence at 1-month and 3-month follow-ups. The model effects were reported as odds ratios (ORs) with 95% confidence intervals (CIs) and p-values. Model fit was evaluated using Tjur's R^2 to measure explained variation in binary outcomes.

The statistical analysis adheres to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational studies (von Elm et al. 2007 [16]) and the RECORD (Reporting of Studies Conducted Using Observational Routinely-Collected Data) guidelines for studies using observational data (Benchimol et al. 2015 [17]), ensuring transparency, reproducibility, and methodological rigor.

Analyses were conducted using R (v4.3.3) with packages for matching, regression, balance diagnostics, and visualization (details in Appendix F).

Bioethical standards

The study protocol was approved by the institutional review board at Nicolas Copernicus University in Torun Collegium Medicum in Bydgoszcz (number approval: KEWL 2/2025).

RESULTS

A total of 257 patients were included in the analysis, comprising 25 patients undergoing simple cystectomy (SC) for radiation-induced bladder dysfunction and 232 patients undergoing radical cystectomy (RC) for bladder cancer. Demographic and clinical characteristics of both groups are presented in Table 1.

The SC group had a significantly higher proportion of females compared to the RC group (48% vs 22%, p = 0.004). There were no significant differences between groups in terms of age (p = 0.35) or body mass index (BMI). Both groups were comparable regarding comorbidities, including hypertension, diabetes mellitus, chronic kidney disease (defined as eGFR < 60 ml/min calculated using the Cockcroft-Gault formula), and chronic heart failure (diagnosed by a cardiologist).

The Charlson Comorbidity Index was significantly higher in the RC group (median: 5 vs 3; p < 0.001), primarily due to the inclusion of malignancy in the scoring system. Patients in the RC group were also more frequently classified as malnourished according to the Nutritional Risk Screening (NRS) scale (median: 3 vs 2; p < 0.001). Neoadjuvant chemotherapy was administered to 37 patients (15.9%) in the RC group.

In the SC group, the median time from completion of radiotherapy to cystectomy was 6 years. A vesico-intestinal fistula was diagnosed in 17 patients (68%), 20 patients (75%) had bilateral nephrostomies, and 11 patients (44%) had previously undergone creation of a single-barrel intestinal stoma. The most common indications for radiotherapy were prostate cancer (48%) and cervical cancer (36%). In the remaining patients, radiotherapy was administered due to endometrial cancer and rectal cancer (8% each). In the SC group, 11 patients (44%) received chemotherapy during primary cancer treatment.

Perioperative outcomes and complications before matching

Operation time, blood loss, and intraoperative blood transfusions did not differ significantly between groups (p = 0.075; p = 0.165; p = 0.175, respectively).

The incidence of complications according to the Clavien-Dindo (CD) scale within 30 days reached statistical significance. Patients in the RC group

more frequently experienced mild Grade 1 complications (46.1% vs 12%, p <0.001), whereas severe Grade 3 complications occurred more frequently in the SC group (44% vs 22.4%, p <0.001). No differences were observed in complication rates between 30 and 90 days after cystectomy. However, notably, three patients (12%) from the SC group died within 90 days after surgery compared to eleven patients from RC group (4.7%).

Among patients in the SC group who experienced Clavien-Dindo grade 3 complications, gastrointestinal complications were the most prevalent, reported in 8 cases: adhesive small bowel obstruction (n = 3), enteric fistula or small bowel perforation (n = 6), and small bowel necrosis (n = 1). Additional complications included evisceration (n = 3), pelvic abscess (n = 4), and ureteral necrosis at the site of ureterocutaneostomy (n = 2). Some patients experienced a combination of those complications. In 7 cases, two or more reoperations were required to manage postoperative morbidity.

Patients in the RC group more often required postoperative transfusions of packed red blood cells (77.5% vs 52%, p <0.001). Nonetheless, a higher percentage of SC patients required massive transfusions (≥3 units RBC: 36% vs 6.1%, p <0.001). SC patients were more likely to require total parenteral nutrition (TPN) during hospitalization (36% vs 9.9%, p = 0.001). SC patients more frequently underwent reoperation defined as any subsequent surgical procedure performed in the operating room to address complications within 30 days (47.8% vs 11.6%, p <0.001). SC group patients more

Table 1. *Demographics and patient characteristics before matching*

Characteristic	SC (N = 25)	RC (N = 232)	p
Demographics			
Sex, n (%) Female Male	 12 (48) 13 (52)	 51 (22) 181 (78)	0.004
Age, years, median (IQR)	67 (62, 72)	69 (64, 74)	0.354
BMI, kg/m², median (IQR)	25.3 (22.7, 29.7)	26.7 (24.2, 30.1)	0.219
Medical history			
CCI, median (IQR)	3.0 (2, 5)	5.0 (4, 6)	< 0.001
Hypertension, n (%)	20 (80)	156 (67.2)	0.192
Diabetes mellitus, n (%)	3 (12)	56 (24,1)	0.170
Heart failure, n (%)	4 (16)	45 (19.4)	0.795
Chronic kidney disease, n (%)	7 (28)	68 (29.3)	0.891
ASA score, median (IQR)	3 (3, 3)	3 (3, 3)	0.531
NRS score, median (IQR)	2 (2, 3)	3 (2.8, 3)	<0.001
Treatment and clinical history			
Chemotherapy, n (%)	11 (44)	37 (15.9)	0.002
Radiotherapy, n (%)	25 (100)	–	–
Time from radiotherapy to cystectomy, years, median (IQR)	6 (3, 16)	–	–
Presence of stoma, n (%)	11 (44)	–	–
Vesicoenteric fistula, n (%)	17 (68)	4 (1.7)	<0.001
Primary diagnosis, n (%) Rectal cancer Cervical cancer Uterine cancer Prostate cancer Bladder cancer	 2 (8) 9 (36) 2 (8) 12 (48) 0 (0)	 0 (0) 0 (0) 0 (0) 0 (0) 232 (100)	<0.001

P-values were calculated using Pearson's χ^2 test, Wilcoxon rank-sum test, or Fisher's exact test, as appropriate.
ASA – American Society of Anesthesiologists; BMI – body mass index; CCI – Charlson Comorbidity Index; NRS – Nutritional Risk Screening

Table 2. *Clavien-Dindo complications and perioperative outcomes before propensity score matching*

Characteristic	SC (N = 25)	RC (N = 232)	p
Surgical details			
Operation time, minutes, median (IQR)	215 (180, 245)	190 (165, 220)	0.075
Blood loss, ml, median (IQR)	220 (100, 300)	250 (150, 350)	0.165
Intraoperative RBC transfusion (%)	0(0)	17(7.3)	0.175
Postoperative outcomes			
Postoperative red blood cell transfusion, units, n (%)[b] 0 1 2 ≥3	 13 (52) 2 (8) 1 (4) 9 (36)	 179 (77.5) 10 (4.3) 28 (12.1) 14 (6.1)	<0.001
TPN, n (%)	9 (36)	23 (9.9)	0.001
Reoperation, n (%)	11 (47.8)	27 (11.6)	<0.001
Intensive care unit admission, n (%)	7 (30.4)	10 (4.3)	<0.001
Length of hospital stay, days, median (IQR)	15 (9, 27)	9 (8, 13)	0.002
Clavien-Dindo complications at 30 days, n (%) Grade 1 Grade 2 Grade 3 Grade 4	 3 (12) 5 (20) 11 (44) 0 (0)	 107 (46.1) 60 (25.9) 52 (22.4) 6 (2.6)	<0.001
Clavien-Dindo complications at 90 days, n (%) Grade 1 Grade 2 Grade 3 Grade 4 Grade 5	 3 (12) 2 (8) 2 (8) 0 (0) 3 (12)	 42 (18.1) 60 (25.9) 24 (10.3) 1 (0.4) (4.7)	0.119

p-values were calculated using Pearson's χ^2 test, the Wilcoxon rank-sum test, or Fisher's exact test, as appropriate.
RBC – red blood cell; TPN – total parenteral nutrition

often required admission to the Intensive Care Unit (30.4% vs 4.3%, p <0.001). Hospital length of stay was significantly longer in the SC group (median: 15 days vs 9 days, p = 0.002). A detailed comparison of perioperative outcomes and complication rates between SC and RC groups is presented in Table 2. Between 90 and 180 days of follow-up in the RC group, no new complications were observed in 86% of patients. Clavien–Dindo grade II complications occurred in 8.4% of cases, and no grade III or IV events were recorded. Ten patients died during this period (4.3%). In the SC group, no new complications were observed in 57.9% of patients. Three patients experienced grade II complications (13.6%), and two patients experienced grade III complications (9%). One patient died between 90 and 180 days of follow-up.

Table 3. *Perioperative outcomes and Clavien-Dindo complications after propensity score matching (SC vs RC, cT1–cT2 cohort)*

Characteristic	SC (N = 17)	RC (N = 17)	p
Surgical details			
Operation time, median (IQR), minutes	220 (180, 245)	180 (170, 220)	0.105
Blood loss, median (IQR), ml	250 (100, 300)	200 (150, 350)	0.626
Intraoperative RBC transfusion, n (%)	0(0)	3(18.6)	0.227
Postoperative outcomes			
Postoperative RBC transfusion, n (%)			0.020
0 units	8 (47.1)	15 (88.2)	0.026
1 unit	1 (5.9)	1 (5.9)	1.000
2 units	1 (5.9)	0 (0)	1.000
≥3 units	7 (41.2)	1 (5.9)	0.039
TPN, n (%)	7 (41.2)	1 (5.9)	0.039
Reoperation, n (%)	9 (56.2)	1 (5.9)	0.002
Intensive care unit admission, n (%)	5 (33.3)	1 (5.9)	0.076
Length of hospital stay, median (IQR), days	18 (12, 33)	8.0 (7, 9)	<0.001
Clavien-Dindo complications at 30 days, n (%)			<0.001
Grade 1	0 (0,0)	9 (52,9)	0.001
Grade 2	4 (23.5)	6 (35.3)	0.708
Grade 3	8 (47.1)	2 (11.8)	0.057
Clavien-Dindo complications at 90 days, n (%)			
Grade 1	2 (11.8)	3 (17.6)	0.805
Grade 2	2 (11.8)	2 (11.8)	
Grade 3	2 (11.8)	2 (11.8)	
Grade 5	2 (11.8)	0 (0)	

p-values were calculated using Pearson's χ^2 test, the Wilcoxon rank-sum test, or Fisher's exact test, as appropriate.
RBC – red blood cell; TPN – total parenteral nutrition

Outcomes after propensity score matching for cT1–cT2 tumors

Cardinality matching resulted in 17 matched pairs. The groups were well balanced in all clinical variables (SMD <0.05). Suppl. Table B1 and Suppl. Figure B1 in the Supplementary Materials section summarize balance before and after matching.
The primary outcome, Clavien-Dindo grades, revealed significant differences in postoperative complication severity between SC and RC patients at 30 days (p <0.001). Patients from the SC group more often experienced severe Grade 3 complications (47.1% vs 11.8%, p = 0.057). Differences in complications at 90 days were not statistically significant (p = 0.805).
Patients from the SC group more frequently required reoperation (56.2% vs 5.9%, p = 0.002) and more commonly received total parenteral nutrition (TPN) (41.2% vs 5.9%, p = 0.039). RC patients more frequently required packed red blood cell transfusions (88.2% vs 44.1%, p = 0.026), although SC patients received massive transfusions (≥3 units RBC) more frequently (41.2% vs 5.9%, p = 0.039). Patients in the SC group required significantly longer hospitalization (18 days vs 8 days, p <0.001). Detailed data are presented in Table 3. Figure 1 illustrates transitions in Clavien-Dindo categories (0–5) at 1-month and 3-month follow-ups.

Outcomes after propensity score matching for cT3–cT4 tumors

Cardinality matching resulted in 19 matched pairs. The groups were well balanced for all clinical variables (SMD <0.05). Suppl. Table C1 and Suppl. Figure C1 in the Supplementary Materials section summarize the balance before and after matching.
No statistically significant differences in complica-

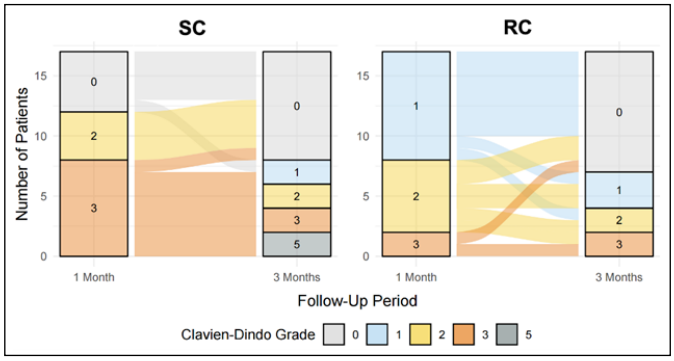


Figure 1. *Transitions in Clavien-Dindo categories (0–5) at 1-month and 3-month follow-ups in SC and RC patients (cT1–cT2) after propensity score matching.*

tions between groups were noted at either 30 days (p = 0.06) or 90 days (p = 0.773) postoperatively. However, operation time was significantly longer in the SC group (220 min vs 180 min, p = 0.039). Patients in the SC group underwent reoperation more frequently (50% vs 10.5%, p = 0.009), and hospital length of stay was significantly longer (17 days vs 8 days, p = 0.013). There were no statistically significant differences regarding the use of TPN (p = 0.141) or blood transfusions (p = 0.592). Detailed data are presented in Table 4. Figure 2 illustrates transitions in Clavien-Dindo categories (0–5) at 1-month and 3-month follow-ups.

Table 4. *Perioperative outcomes and Clavien-Dindo complications after propensity score matching (SC vs RC, cT3–cT4 cohort)*

Characteristic	SC (N = 19)	RC (N = 19)	p
Surgical details			
Operation time, median (IQR), minutes	220 (182.5, 242.5)	180 (167.5, 190)	0.039
Blood loss, median (IQR), ml	250 (125, 300)	200 (150, 275)	0.667
Intraoperative RBC transfusion, n (%)	0(0)	4(21.1)	0.105
Postoperative outcomes			
Postoperative RBC transfusion, n (%)			0.203
0 units	10 (52.6)	13 (68.4)	0.508
1 unit	1 (5.3)	1 (5.3)	1.000
2 units	1 (5.3)	3 (15.8)	0.340
≥3 units	7 (36.8)	2 (10.5)	0055
TPN, n (%)	7 (36.8)	3 (15.8)	0.141
Reoperation, n (%)	9 (50.0)	2 (10.5)	0.009
Intensive care unit admission, n (%)	5 (29.4)	1 (5.3)	0.081
Length of hospital stay, median (IQR), days	17 (11, 28)	8 (8, 11)	0.013
Postoperative outcomes			
Clavien-Dindo grade at 30 days, n (%)			0.060
1	2 (10.5)	8 (42.1)	
2	4 (21.1)	5 (26.3)	
3	8 (42.1)	4 (21.1)	
4	0 (0)	1 (5.3)	
Clavien-Dindo grade at 90 days, n (%)			0.773
1	2 (10.5)	4 (21.1)	
2	2 (10.5)	3 (15.8)	
3	2 (10.5)	2 (10.5)	
5	2 (10.5)	3 (15.8)	

p-values were calculated using Pearson's χ^2 test, the Wilcoxon rank-sum test, or Fisher's exact test, as appropriate.
RBC – red blood cell; TPN – total parenteral nutrition

Outcomes after propensity score matching for patients with vesicoenteric fistula

Cardinality matching resulted in 15 matched pairs. The groups were well balanced in all clinical variables (SMD range: -0.04 to 0.01). Suppl. Table D1 and Suppl. Figure D1 in the Supplementary Materials section summarize balance before and after matching.

The primary outcome, Clavien-Dindo grades at 30 days, showed no significant overall difference (p = 0.130). However, the SC group had a higher proportion of Grade 3 complications (53.3% vs 40.0%). Differences in complications at 90 days were not statistically significant (p = 0.968).

Reoperation rates were significantly higher in the SC group (61.5% vs 6.7%; p = 0.004), and intensive care unit (ICU) admission rates were higher but not significantly (30.8% vs 6.7%; p = 0.153). Total parenteral nutrition (TPN) use was higher in the SC group (40.0% vs 13.3%; p = 0.215), though not statistically significant. Postoperative RBC transfusion rates were significantly higher in the SC group (60% vs 20% p = 0.027). The median length of hospital stay was longer in the SC group (18.0 days vs 10.0 days), though this difference was not significant (p = 0.244).

DISCUSSION

Radical cystectomy remains the gold standard of muscle invasive bladder cancer treatment. Despite the development of minimally invasive techniques (laparoscopic, robotic-assisted), RC is associated with many complications (18). The most common complications were gastrointestinal complications (20%), infectious complications (17%), and ileus (14%). The majority of complications occurring were Clavien-Dindo I–II (45%) [19].

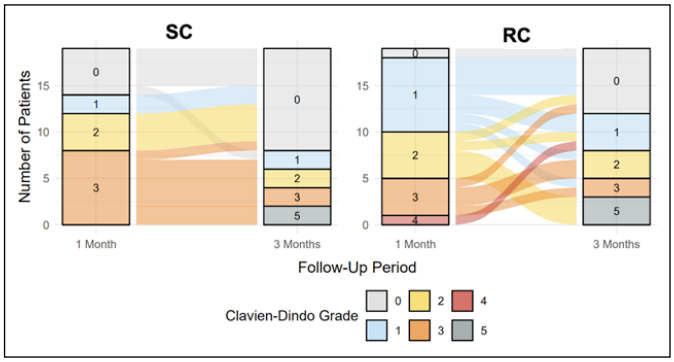


Figure 2. *Transitions in Clavien-Dindo categories (0–5) at 1-month and 3-month follow-ups in SC and RC patients (cT3–cT4) after propensity score matching.*

Non-surgical therapies remain the first-line management for radiation-induced bladder dysfunction (RIBD), particularly in cases of chronic radiation cystitis. Available interventions such as bladder irrigation, intravesical instillations, hyperbaric oxygen therapy, and arterial embolization have demonstrated varying degrees of efficacy and safety [20]. However, when conservative measures fail, surgical intervention in the form of simple cystectomy (SC) may be required.

The results of this study demonstrate that simple cystectomy performed for radiation-induced bladder dysfunction is associated with a higher risk of severe postoperative complications within 30 days compared to radical cystectomy performed for bladder cancer. This observation is likely attributable to the profound tissue damage caused by prior radiotherapy – namely fibrosis, vascular rarefaction, and impaired regenerative capacity [6]. Patients in the SC group more frequently required reoperation and experienced longer hospital stays.

Table 5. *Perioperative outcomes and Clavien-Dindo complications after propensity score matching for patients with viesocenteric fistula*

Characteristic	SC (N = 15)	RC (N = 15)	p[a]
Intraoperative parameters			
Operation time, median (IQR), minutes	230 (200, 250)	185 (165, 195)	0.017
Blood loss, median (IQR), ml	200 (100, 300)	200 (100, 300)	0.949
Intraoperative RBC transfusion, n (%)	0 (0%)	4 (27.7%)	0.100
Postoperative outcomes			
Postoperative RBC transfusion, units	9 (60%)	3 (20%)	0.027
TPN, n (%)	6 (40%)	2 (13.3%)	0.215
Reoperation, n (%)	8 (61.5%)	1 (6.7%)	0.004
Intensive care unit admission, n (%)	4 (30.8%)	1 (6.7%)	0.153
Length of hospital stay, days	18 (8, 33)	10 (8, 17)	0.244
Clavien-Dindo grade at 30 days, n (%) 1 2 3 4	 1 (6.7%) 4 (26.7%) 8 (53.3%) 0 (0.0%)	 6 (40%) 1 (6.7%) 6 (40%) 1 (6.7%)	0.130
Clavien-Dindo grade at 90 days, n (%) 1 2 3 5	 2 (13.3%) 2 (13.3%) 2 (13.3%) 1 (6.7%)	 2 (13.3%) 4 (26.7%) 2 (13.3%) 1 (6.7%)	0.968

[a] p-values were calculated using Pearson's chi-squared test or Fisher's exact test for categorical variables and the Wilcoxon rank-sum test for continuous variables. RBC – red blood cell; TPN – total parenteral nutrition

This difference remained evident after applying propensity score matching, particularly when compared with patients diagnosed with cT1–cT2 bladder cancer. Although the difference in Clavien-Dindo grade ≥3 complications for this group did not reach statistical significance ($p = 0.057$), the markedly higher reoperation rate in the SC group ($p = 0.002$) suggests that the lack of significance was likely due to the limited sample size rather than the absence of a true clinical difference. The vesicoenteric fistula subgroup showed similar 30- and 90-day Clavien-Dindo distributions and markedly higher reoperation rates ($p = 0.0004$).

Available literature presents conflicting findings; however, direct comparisons with our results are limited due to differences in study populations.

Ramani et al. [14] did not observe differences in complication rates between patients undergoing radical cystectomy and those undergoing salvage cystectomy after radiotherapy. However, all patients in that study underwent surgery for oncological indications. Moreover, the median time from radiotherapy to cystectomy was significantly shorter (483 days), which may have influenced the degree of tissue fibrosis and healing capacity.

Nguyen et al. [21] analyzed patients who underwent radical cystectomy for bladder cancer following prior radiotherapy. The median interval between radiotherapy and cystectomy was 8.6 years. This study found no difference in 30-day complications compared to patients who had not received radiotherapy. As in the previous study, it is important to note that the indication for surgery was oncological, rather than functional damage caused by radiation, which may imply a lesser degree of radiation-related tissue injury in that population.

In a large ACS-NSQIP database analysis using propensity score matching, Titus et al. [13] found that patients with a history of radiotherapy undergoing radical cystectomy had an increased risk of intraoperative rectal injury, 30-day readmissions, and infectious complications. While this study included over 5,000 patients and is methodologically comparable, the procedures were likewise performed for oncological rather than functional indications.

Similar observations have also been confirmed in other surgical disciplines. For example, Onoda et al. [11] found that radiation-induced changes increased complication rates and impaired wound healing in head and neck reconstructive procedures, while Potkrajcic et al. [12] reported that prior radiotherapy was associated with higher rates of wound infections after soft tissue carcinoma resection.

According to meta-analytic data, surgery for vesicoenteric fistulas is associated with a 22.2% complication

rate and a 4.9% mortality rate [22]. However, evidence on bladder resection for radiation-induced fistulas remains very limited. Some reports suggest that prior radiotherapy does not significantly affect surgical outcomes of cystectomy with urinary diversion compared to urinary diversion alone in a high-volume center [23]. It should be noted, however, that data on reoperation rates in this subgroup may be biased due to the small sample sizes of available cohorts.

Our cohort did not include patients treated with urinary diversion alone, as this procedure was not performed in our center during the study period. Therefore, direct comparison was not feasible. However, published data suggest that diversion alone may carry lower morbidity in selected benign conditions, which supports considering it as an alternative in RIBD [23].

Our findings suggest that patients with radiation-induced bladder dysfunction should be carefully selected for non-oncological cystectomy. They should be explicitly informed about the high risk of postoperative complications. If surgery is deemed necessary, it should be performed in a high-volume center with access to multidisciplinary support, including an experienced clinical nutrition team. Whenever feasible, isolated urinary diversion without the ablative component should be considered.

It must be acknowledged that this is a single-center, retrospective study, which introduces the potential for systematic bias. Secondly, the small number of patients in the SC group, further reduced by propensity score matching, raises the risk of type II error. Consequently, some clinically relevant differences may not have reached statistical significance. A power calculation was not performed because the study included all available SC and RIBD patients treated during the study period. Detailed radiotherapy parameters (dose, field, modality) were inconsistently documented in historical records and therefore could not be analyzed. Furthermore, we included only patients undergoing a single type of urinary diversion and a single surgical approach, which limits the generalizability of our findings.

CONCLUSIONS

Despite its limitations, this study clearly demonstrates that simple cystectomy performed for radiation-induced bladder dysfunction carries a substantial risk of perioperative complications, including severe adverse events. This risk is either greater than or at least comparable to that observed in patients undergoing radical cystectomy for bladder cancer. The findings highlight the need for careful patient selection and comprehensive multidisciplinary perioperative care. Multicenter studies are needed to generate higher-quality evidence.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

ETHICS APPROVAL STATEMENT

The study protocol was approved by the institutional review board at Nicolas Copernicus University in Torun Collegium Medicum in Bydgoszcz (number approval: KEWL 2/2025).

SUPPLEMENTARY MATERIALS

Appendix A. List and justification of covariate selection for matching procedure

Suppl. Table A.1. *Rationale and suitability of covariates for matching*

Covariate	Rationale	Suitability
Sex	Influences surgical choice (e.g., anatomical differences) and complication risk (e.g., infection)	Appropriate; baseline demographic confounder
Age	Affects surgical candidacy and complication risk due to physiological reserve	Highly appropriate; strong confounder
BMI	Impacts surgical complexity and complication risk (e.g., wound infections)	Appropriate; surgical risk indicator
Chemotherapy	Pre-treatment history affects tissue healing and complication risk	Appropriate; pre-exposure oncologic factor
HT	Common comorbidity increasing cardiovascular and surgical risks	Appropriate; baseline comorbidity
DM	Increases infection and healing complications	Appropriate; baseline comorbidity
HF	Elevates perioperative morbidity and mortality risk	Appropriate; baseline comorbidity
CKD	Common in urological patients, affecting surgical outcomes	Appropriate; baseline comorbidity
ASA	Standardized measure of preoperative health, predicting complications	Highly appropriate; surgical risk indicator
CCI	Quantifies comorbidity burden, influencing surgical choice and outcomes	Highly appropriate; comprehensive confounder

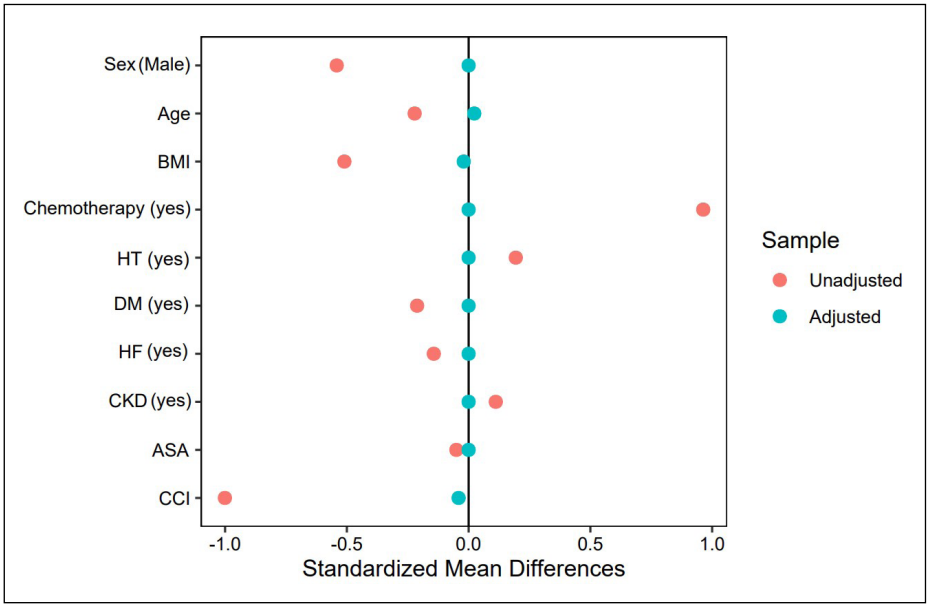
ASA – American Society of Anesthesiologists; BMI – body mass index; CCI – Charlson Comorbidity Index; CKD – chronic kidney disease; DM – diabetes mellitus; HF – heart failure; HT – hypertension

Appendix B. Results of propensity score matching procedure for SC and RC in patients with clinical stages cT1–cT2

Suppl. Table B.1. *Balance of covariates before and after cardinality matching for SC vs RC (cT1–cT2)*

Covariate	Type	Means Treated (SC)	Means Control (RC)	SMD (Unmatched)	SMD (Matched)	eCDF Max (Matched)
Sex (Female)	Binary	0.48	0.27	0.54	0	0
Sex (Male)	Binary	0.52	0.75	–0.54	0	0
Age	Continuous	67.52	69.21	–0.22	0.02	0.18
BMI	Continuous	25.71	28.12	–0.51	–0.02	0.18
Chemotherapy (yes)	Binary	0.44	0.12	0.96	0	0
Chemotherapy (no)	Binary	0.56	0.88	–0.96	0	0
HT (yes)	Binary	0.80	0.71	0.19	0	0
HT (no)	Binary	0.20	0.29	–0.19	0	0
DM (yes)	Binary	0.12	0.22	–0.21	0	0
DM (no)	Binary	0.88	0.79	0.21	0	0
HF (yes)	Binary	0.16	0.22	–0.14	0	0
HF (no)	Binary	0.84	0.78	0.14	0	0
CKD (yes)	Binary	0.28	0.23	0.11	0	0
CKD (no)	Binary	0.72	0.77	–0.11	0	0
ASA	Continuous	2.76	2.78	–0.05	0	0
CCI	Continuous	3.64	5.07	–1.00	–0.04	0.18

ASA – American Society of Anesthesiologists; BMI – body mass index; CCI – Charlson Comorbidity Index; CKD – chronic kidney disease; DM – diabetes mellitus; HF – heart failure; HT – hypertension



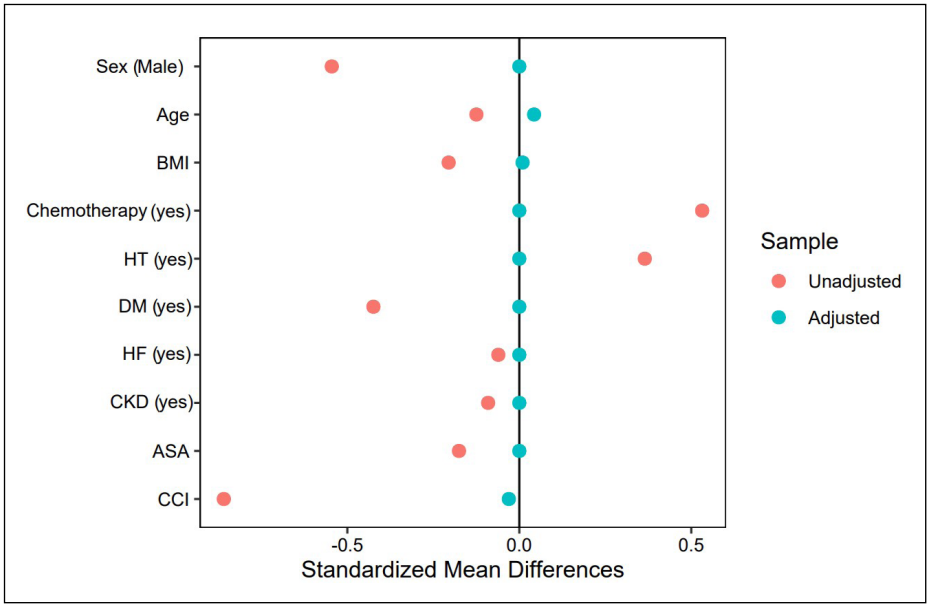
Suppl. Figure B.1. *Covariate balance for unadjusted (SC, n = 25 vs RC, n = 73) and adjusted (SC, n = 17 vs RC, n = 17) samples.*

Appendix C. Results of propensity score matching procedure for SC and RC in patients with clinical stages cT3–cT4

Suppl. Table C.1. *Balance of covariates before and after cardinality matching for SC vs RC (cT3–cT4)*

Covariate	Type	Means Treated (SC)	Means Control (RC)	SMD (Unmatched)	SMD (Matched)	eCDF Max (Matched)
Sex (Female)	Binary	0.48	0.21	0.55	0	0
Sex (Male)	Binary	0.52	0.79	–0.55	0	0
Age	Continuous	67.52	68.44	–0.12	0.04	0.26
BMI	Continuous	25.71	26.65	–0.21	0.01	0.16
Chemotherapy (yes)	Binary	0.44	0.18	0.53	0	0
Chemotherapy (no)	Binary	0.56	0.82	–0.53	0	0
HT (yes)	Binary	0.8	0.65	0.36	0	0
HT (no)	Binary	0.2	0.35	–0.36	0	0
DM (yes)	Binary	0.12	0.26	–0.42	0	0
DM (no)	Binary	0.88	0.74	0.42	0	0
HF (yes)	Binary	0.16	0.18	–0.06	0	0
HF (no)	Binary	0.84	0.82	0.06	0	0
CKD (yes)	Binary	0.28	0.32	–0.09	0	0
CKD (no)	Binary	0.72	0.68	0.09	0	0
ASA	Continuous	2.76	2.84	–0.18	0	0
CCI	Continuous	3.64	5.13	–0.86	–0.03	0.16

ASA – American Society of Anesthesiologists; BMI – body mass index; CCI – Charlson Comorbidity Index; CKD – chronic kidney disease; DM – diabetes mellitus; HF – heart failure; HT – hypertension



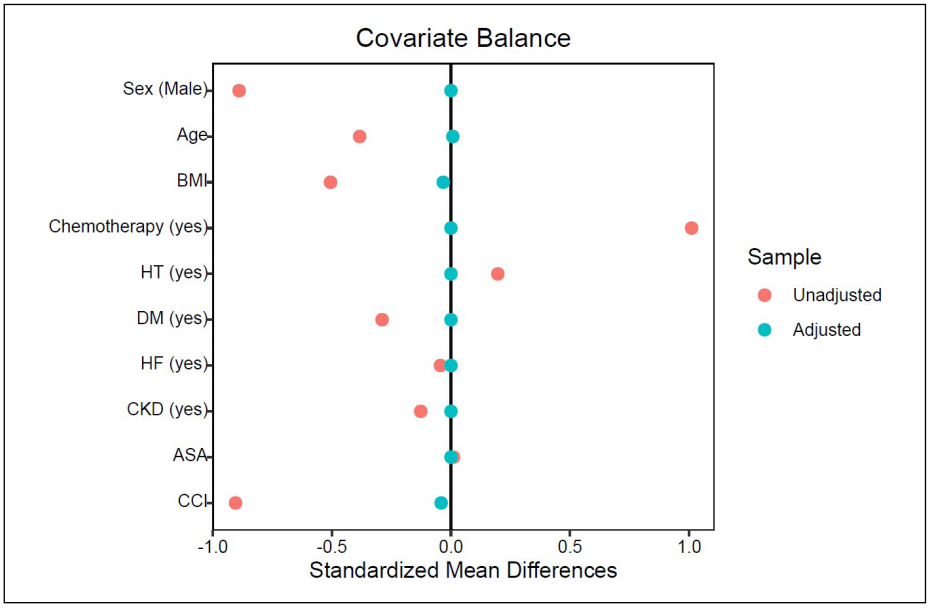
Suppl. Figure C.1. *Covariate balance for unadjusted (SC, n = 25 vs RC, n = 140) and adjusted (SC, n = 19 vs RC, n = 19) samples.*

Appendix D. Results of propensity score matching procedure for SC group patients with vesico-enteric fistula and RC group

Suppl. Table D1. Covariate balance in unmatched and matched cohorts

Covariate	Unmatched						Matched						
	Means Treated	Means Control	SMD	Var. Ratio	eCDF Mean	eCDF Max	Means Treated	Means Control	SMD	Var. Ratio	eCDF Mean	eCDF Max	Adj. Diff.
Sex (male)	0.41	0.78	–0.89	.	0.37	0.37	0.47	0.47	0.00	.	0.00	0.00	0.00
Age	65.35	68.68	–0.38	0.55	0.09	0.26	66.13	66.07	0.01	0.28	0.09	0.20	0.01
BMI	24.84	27.11	–0.51	1.19	0.13	0.25	24.91	25.06	–0.03	1.97	0.12	0.27	–0.03
Chemotherapy (yes)	0.53	0.16	1.01	.	0.37	0.37	0.47	0.47	0.00	.	0.00	0.00	0.00
HT (yes)	0.76	0.67	0.20	.	0.09	0.09	0.80	0.80	0.00	.	0.00	0.00	0.00
DM (yes)	0.12	0.24	–0.29	.	0.12	0.12	0.13	0.13	0.00	.	0.00	0.00	0.00
HF (yes)	0.18	0.19	–0.04	.	0.02	0.02	0.20	0.20	0.00	.	0.00	0.00	0.00
CKD (yes)	0.24	0.29	–0.13	.	0.06	0.06	0.27	0.27	0.00	.	0.00	0.00	0.00
ASA	2.82	2.82	0.01	0.84	0.01	0.02	2.80	2.80	0.00	1.00	0.00	0.00	0.00
CCI	3.65	5.11	–0.90	1.39	0.15	0.39	3.93	4.00	–0.04	2.13	0.06	0.13	–0.04

Adj. Diff. – adjusted difference (Treated – Control); ASA – American Society of Anesthesiologists; BMI – body mass index; CCI – Charlson Comorbidity Index; CKD – chronic kidney disease; DM – diabetes mellitus; eCDF – empirical cumulative distribution function (mean and maximum differences; lower values indicate better distributional balance); HF – heart failure; HT – hypertension; SMD – standardized mean difference (values below 0.1 indicate adequate balance); Var. Ratio – variance ratio (values close to 1 indicate similar variability)



Suppl. Figure D1. *Covariate balance for unadjusted (SC, n = 17 vs RC, n = 232, red color) and adjusted (SC, n = 15 vs RC, n = 15, blue color) samples.*

Appendix F. Statistical software and packages used

Analyses were conducted using the R statistical programming language (version 4.3.3) on Windows 11 Pro 64 (build 26100), using the packages *ggalluvial* (version 0.12.5), *rio* (version 1.2.1), *cobalt* (version 4.5.5), *MatchIt* (version 4.5.5), *sjPlot* (version 2.8.15), *report* (version 0.5.8), *gtsummary* (version 1.7.2), *glmtoolbox* (version 0.1.12), *ggplot2* (version 3.5.0), *Rglpk* (version 0.6.5.1), *Rsymphony* (version 0.1.33), and *dplyr* (version 1.1.4).

References

1. Spratt DE, Pei X, Yamada J, Kollmeier MA, Cox B, Zelefsky MJ. Long-term survival and toxicity in patients treated with high-dose intensity modulated radiation therapy for localized prostate cancer. Int J Radiat Oncol Biol Phys. 2013; 85: 686-692.
2. Ma JL, Hennessey DB, Newell BP, Bolton DM, Lawrentschuk N. Radiotherapy-related complications presenting to a urology department: a more common problem than previously thought? BJU Int. 2018; 121 Suppl 3: 28-32.
3. Sanguedolce F, Sancho Pardo G, Mercadé Sanchez A, et al. Radiation-induced haemorrhagic cystitis after prostate cancer radiotherapy: factors associated to hospitalization and treatment strategies. Prostate Int. 2021; 9: 48-53.
4. Sadighian M, Hakam N, Amend G, et al. Radiation-induced Fistulas in Patients With Prior Pelvic Radiotherapy for Prostate Cancer: A Systematic Review and Meta-analysis. Urology. 2023; 176: 121-126.
5. Chrouser KL, Leibovich BC, Sweat SD, et al. Urinary fistulas following external radiation or permanent brachytherapy for the treatment of prostate cancer. J Urol. 2005; 173: 1953-1957.
6. Dormand EL, Banwell PE, Goodacre TEE. Radiotherapy and wound healing. Int Wound J. 2005; 2: 112-127.
7. Bursiewicz W, Złotkiewicz M, Krajewski W, et al. Long-term efficacy and safety of intravesical Bacillus Calmette-Guerin Moreau Polish substrain in the treatment of non-muscle invasive bladder cancer. Cent European J Urol. 2024; 77: 196-202.
8. Zaytoun O, Tillu N, Kolanukuduru K, et al. Thulium laser en bloc resection is a safe and efficacious alternative to conventional bipolar transurethral resection of bladder tumors. Cent European J Urol. 2024; 77: 466-471.
9. Mendenhall WM, Henderson RH, Costa JA, et al. Hemorrhagic radiation cystitis. Am J Clin Oncol. 2015; 38: 331-336.
10. Chong JT, Dolat MET, Klausner AP, Dragoescu E, Hampton LJ. The role of cystectomy for non-malignant bladder conditions: A review. Can J Urol. 2014; 21: 7433-7441.
11. Onoda S, Kimata Y, Sugiyama N, Onoda T, Mizukawa N. Effects of radiation therapy on postoperative complications and adverse events in patients with head and neck reconstruction with flaps. Microsurgery. 2014; 34: 516-521.
12. Potkrajcic V, Kolbenschlag J, Sachsenmaier S, et al. Postoperative complications and oncologic outcomes after multimodal therapy of localized high risk soft tissue sarcoma. Radiation Oncology. 2022; 17: 1-11.
13. Titus RS, Xu J, Mundra V, et al. IP24-23 The association between prior pelvic radiotherapy for cancer and surgical

outcomes in patients undergoing radical cystectomy for bladder cancer: An analysis of national surgical quality improvement program targeted cystectomy database. Urol Oncol. 2026; 44: 62.e9-62.e16.

14. Ramani VAC, Maddineni SB, Grey BR, Clarke NW. Differential complication rates following radical cystectomy in the irradiated and nonirradiated pelvis. Eur Urol. 2010; 57: 1058-1063.

15. Murthy PB, Lone Z, Corrigan D, et al. Survival outcomes following radical cystectomy in patients with prior pelvic radiation for prostate cancer: A matched cohort analysis. Urol Oncol. 2022; 40: 10.e13-10.e19.

16. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008; 61: 344-349.

17. Benchimol EI, Smeeth L, Guttmann A, et al. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. PLoS Med. 2015; 12: e1001885.

18. Rahota RG, Beauval JB, Gautier JR, et al. Impact of outcomes and costs for implementation of robotic radical cystectomy with full intracorporeal urinary diversion. Cent European J Urol. 2023; 76: 305-310.

19. Katsimperis S, Tzelves L, Tandogdu Z, et al. Complications After Radical Cystectomy: A Systematic Review and Meta-analysis of Randomized Controlled Trials with a Meta-regression Analysis. Eur Urol Focus. 2023; 9: 920-929.

20. Datseris N, Gkazis T, Nikas S, Memmos D, Zoumpanioti E, Sountoulides P. Safety and efficacy of non-surgical treatments for chronic post-radiation cystitis: a systematic review. Cent European J Urol. 2024; 77: 472-482.

21. Nguyen DP, Al Hussein Al Awamlh B, Faltas BM, et al. Radical Cystectomy for Bladder Cancer in Patients With and Without a History of Pelvic Irradiation: Survival Outcomes and Diversion-related Complications. Urology. 2015; 86: 99-106.

22. Granieri S, Sessa F, Bonomi A, et al. Indications and outcomes of enterovesical and colovesical fistulas: systematic review of the literature and meta-analysis of prevalence. BMC Surg. 2021; 21: 265.

23. Vetterlein MW, Buhné MJ, Yu H, et al. Urinary Diversion With or Without Concomitant Cystectomy for Benign Conditions: A Comparative Morbidity Assessment According to the Updated European Association of Urology Guidelines on Reporting and Grading of Complications. Eur Urol Focus. 2022; 8: 1831-1839. ■