Research Article

Role of a spray-type anti-adhesion barrier (AdSpray®) in post-operative outcomes following robot-assisted radical cystectomy for bladder cancer

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Abstract

Background: Despite advances in robot-assisted radical cystectomy (RARC) for bladder cancer and enhanced recovery protocols, post-operative gastrointestinal complications—particularly ileus and bowel obstruction—remain a significant clinical problem. **Objective:** We investigated whether intraoperative AdSpray® (TERUMO) during RARC is associated with fewer post-operative complications and improved recovery, with a focus on gastrointestinal events. **Methods:** We retrospectively reviewed consecutive patients who underwent RARC with urinary diversion at a single tertiary hospital between June 2019 and March 2025. The primary endpoint was any post-operative complication within 90 days. Prespecified gastrointestinal complications included paralytic ileus, intestinal obstruction, anastomotic leak, and anastomotic stricture. Additional outcomes were time to first liquid intake, time to resumption of a normal diet, and time to discharge. Intestinal obstruction was defined as a computed tomography-demonstrated transition point with compatible clinical findings, and paralytic ileus as radiographic ileus without obstruction. One-to-one propensity score matching (PSM) was used to balance baseline characteristics between the AdSpray and non-AdSpray groups. Post-matching logistic regression was used to estimate associations with binary outcomes, and time-to-event outcomes were analyzed using Kaplan–Meier methods. **Results:** Among 71 patients, 17 (24%) received AdSpray, and 54 (76%) did not; PSM yielded two comparable cohorts (n = 17 each). AdSpray use was significantly associated with a lower 90-day incidence of intestinal obstruction in the matched cohorts (odds ratio = 0.15, 95% confidence interval = 0.02–0.88, p = 0.032). Times to resumption of oral intake and discharge were similar between groups (before PSM, log-rank p = 0.64; after PSM, log-rank p = 0.42). **Conclusion:** These retrospective findings are hypothesis-generating and suggest that intraoperative AdSpray use during RARC may be associated with a reduced 90-day incidence of intestinal obstruction; however, they should not be interpreted as definitive evidence of a causal relationship.

Keywords: Bladder cancer, Robot-assisted radical cystectomy, AdSpray, Intestinal obstruction, Post-operative complications

1. Introduction

Robot-assisted radical cystectomy (RARC) is currently a standard surgical option for muscle-invasive bladder cancer, offering potential reductions in blood loss and length of stay without compromising oncologic outcomes compared with open surgery.[1,2] Nevertheless, post-operative morbidity remains substantial and clinically meaningful to patients and health systems, with gastrointestinal complications, particularly ileus and adhesive small bowel obstruction, being prominent contributors to prolonged recovery and readmission.[3] Reported small bowel obstruction rates after urinary diversion range approximately from 0.7% to 11%, highlighting the need for strategies that specifically address

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adhesion-related bowel morbidity in patients undergoing radical cystectomy (RC).[4]

Several large studies have highlighted the burden of post-operative bowel dysfunction after cystectomy. In a nationwide analysis of more than 40,000 patients who underwent RC, small bowel obstruction occurred in approximately 2–3% of patients and post-operative ileus in nearly 27%, both of which were strongly associated with prolonged length of stay and higher inpatient costs (ileus: odds ratio [OR] = 5.6; small bowel obstruction: OR = 19.6).[5] Similar findings have been reported in contemporary RARC cohorts, in which gastrointestinal complications remain common despite minimally invasive techniques and enhanced recovery protocols.[2,3,6,7] Together, these data underscore the need for additional strategies specifically targeting the adhesive and mechanical components of post-operative bowel dysfunction in cystectomy patients.[5]

Enhanced Recovery After Surgery (ERAS) pathways have become the standard perioperative framework for RC and are supported by several guidelines; these pathways reduce unwarranted variation in analgesia, mobilization, nutrition, and fluid therapy.[6] While ERAS can accelerate recovery and decrease complications, it may also attenuate the measurable impact of any single intraoperative adjunct on global endpoints such as length of stay or time to diet advancement, underscoring the value of targeting discrete complications such as mechanical obstruction.[6]

The prevention of bowel adhesions has long been pursued using barrier technologies; however, evidence for sheet-type barriers has been inconsistent with respect to obstruction outcomes. For example, reductions in adhesion scores have not consistently translated into fewer post-operative bowel obstructions and have raised safety concerns in some settings.[8,9] In contrast, sprayable hydrogels offer rapid, conformable coverage within confined pelvic spaces and have shown a favorable safety profile and feasibility in clinical series outside urologic oncology, with supportive preclinical data comparing spray and sheet barriers in complex anatomy.[10-13] Recent advances in materials science continue to refine sprayable systems to improve handling and tissue targeting.[12] However, robust domain-specific evidence in urologic oncology remains limited.

AdSpray® is a spray-type bioabsorbable adhesion barrier composed of a dextrin hydrogel that polymerizes *in situ* when two precursor solutions are mixed at the spray tip.[13] The resulting thin, translucent film conforms to complex pelvic surfaces, remains in place for several days, and is gradually resorbed without leaving permanent foreign material.[13] Preclinical studies in porcine laparoscopic models have shown that this dextrin hydrogel barrier significantly reduces adhesion scores compared with no barrier, with no residual material observed macroscopically after approximately 4 weeks.[14] Clinical series in hepatobiliary surgery and gynecology have further suggested that spray-type adhesion barriers can be applied safely in minimally invasive procedures and may reduce the severity of adhesions encountered during subsequent surgeries.[10,15] More recently, a pediatric laparoscopic cohort treated with AdSpray® reported no device-related allergic or infectious complications and no recurrence of adhesive ileus during midterm follow-up.[16] These data support the biological plausibility and cross-disciplinary safety of AdSpray®, but its impact on bowel-related outcomes in urologic oncology has not been clarified.

From a methodological standpoint, evaluating the clinical impact of anti-adhesion strategies is challenging because adhesions are rarely directly observable outside reoperative settings.[17] Numerous prior studies have relied on intraoperative adhesion scores at subsequent surgeries, which provide pathophysiological insight but are not routinely available in contemporary practice and may not fully capture the patient's experience.[17,18] As a result, investigators frequently use indirect but clinically meaningful surrogates such as radiologically confirmed intestinal obstruction, obstruction-related readmission, or the need for reoperation.[19] Computed tomography (CT) is widely employed to investigate suspected post-operative intestinal obstruction and allows discrimination between mechanical obstruction and paralytic ileus in many cases; however, its diagnostic accuracy is imperfect, and misclassification can occur.[20] Against this background, we selected CT-defined mechanical obstruction and paralytic ileus within 90 days as pragmatic clinical endpoints to explore the potential impact of AdSpray in the RARC setting.[21]

Here, we evaluated whether the intraoperative use of a spray-type anti-adhesion hydrogel (AdSpray®) during RARC is associated with fewer post-operative complications and improved recovery, with particular attention to gastrointestinal morbidity.

2. Methods

2.1. Study design, data collection, and definitions

This retrospective observational study was conducted at the Department of Urology of Nara Medical University. The study protocol was approved by the Ethics Committee of Nara Medical University (approval no. 2891). Between June 2019 and March 2025, we screened 84 consecutive adults with histologically confirmed bladder cancer who underwent RC at our institution. Inclusion criteria required RARC with urinary diversion and the availability of 90-day follow-up data. We excluded non-robotic approaches (open, $n = 10$; conventional laparoscopic surgery, $n = 3$). The final analytical cohort included 71 patients, of whom 17 received intraoperative AdSpray, and 54 did not (Figure 1).

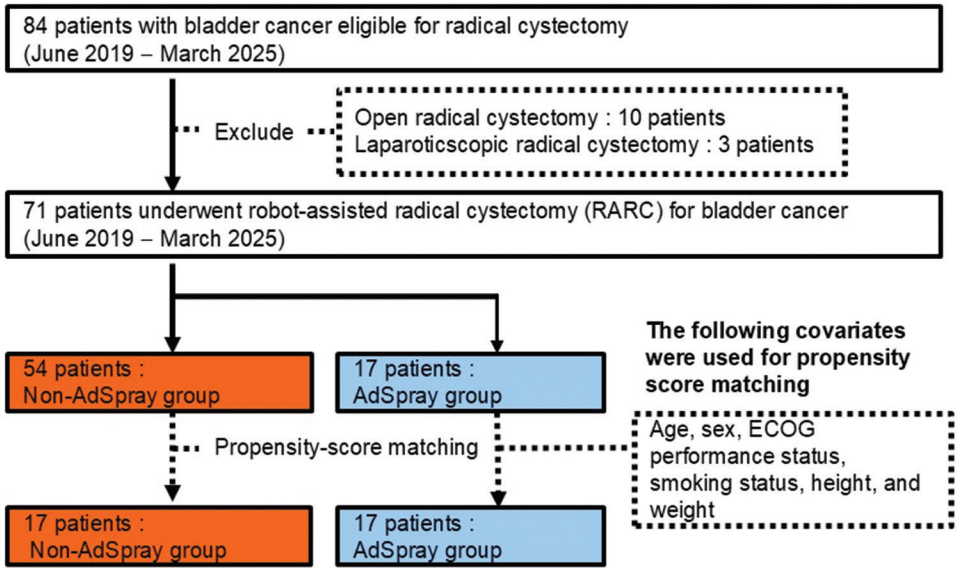

Figure 1. Flowchart of patient dataset creation. The primary endpoint was any 90-day post-operative complication, and prespecified gastrointestinal events were recorded as additional outcomes.
Abbreviation: ECOG: Eastern Cooperative Oncology Group.

Demographic, perioperative, and post-operative data were retrieved from electronic medical records. Preoperative variables included age, sex, performance status (PS), smoking history, height, and weight. Surgical variables included operative time, estimated blood loss, diversion type (intracorporeal or extracorporeal urinary diversion), and AdSpray use. Post-operative complications were recorded within 90 post-operative days (PODs), capturing events during the index admission and any readmissions to our or referring hospitals, and were graded according to the Clavien–Dindo classification.[22] Prespecified gastrointestinal events comprised intestinal obstruction, defined as CT-demonstrated obstruction or a transition point with compatible clinical findings; paralytic ileus, defined as the absence of mechanical obstruction with radiographic evidence of ileus on plain abdominal radiography or CT together with compatible clinical findings; and anastomotic leak or stricture, diagnosed by imaging and/or endoscopy as documented by the treating team. CT was chosen as the primary imaging modality because it is routinely used at our institution to evaluate suspected post-operative intestinal obstruction and facilitates differentiation between mechanical obstruction and paralytic ileus in daily practice. We acknowledge that CT has imperfect sensitivity and specificity for bowel obstruction; the potential implications of this limitation are discussed below. Perioperative management followed our institutional ERAS pathway. Patients were considered ready for discharge when they were afebrile for at least 24 h without hemodynamic instability; tolerated an oral diet without persistent nausea or vomiting; demonstrated adequate stoma care (patient and/or caregiver trained) and satisfactory urine output; had pain controlled with oral analgesics alone; and were independently ambulatory or ambulatory with their usual aids, with no unresolved grade ≥ III complications requiring in-hospital intervention. Transfer to another acute care or rehabilitation facility before meeting these criteria was recorded as a transfer rather than a discharge event. Time-to-event variables (time to first liquid intake, time to normal diet, and time to discharge) were measured as PODs from the date of surgery (POD 0) and abstracted from routine nursing and physician documentation.

2.2. Surgical procedures of RARC

All procedures were performed using the da Vinci Surgical System under standard institutional protocols previously described.[23] Extended pelvic lymph node dissection included removal of the obturator, external iliac, common iliac, and presacral lymph nodes, and the ureters were mobilized to the level of the aortic bifurcation. The urinary diversion approach—intracorporeal or extracorporeal—was selected by the operating surgeon according to patient factors, intraoperative findings, and institutional logistics, consistent with contemporary evidence that either approach is acceptable following RARC.[24] Diversion types included ileal conduit, orthotopic ileal neobladder, and cutaneous ureterostomy.

For ileal conduit reconstruction, standard Bricker principles were followed using a terminal ileal segment with ureteroenteric anastomosis, as described in a contemporary reference.[25]

For orthotopic neobladder construction, the technique depended on the diversion setting. When intracorporeal urinary diversion was performed, a U-shaped ileal neobladder was constructed according to previously published methods.[26] When extracorporeal urinary diversion was performed, an

orthotopic neobladder was fashioned in accordance with Studer principles.[27,28]

As a general policy, cutaneous ureterostomy was performed as a bilateral single-stoma diversion whenever feasible; the ureteral ends were spatulated and matured to a single cutaneous stoma without bowel reconstruction.[29,30]

Reconstruction and stenting were standardized across all diversion types. For the ileal conduit and neobladder, ureteroenteric anastomoses were fashioned with absorbable monofilament sutures, and bilateral single-J ureteral stents were placed across each anastomosis and externalized according to the institutional routine. For cutaneous ureterostomy, a single-J stent was placed in each ureter and secured externally. In all diversion types, stents were typically removed 2 weeks postoperatively unless clinically indicated. All procedures were performed by experienced surgeons using a standardized program.

In the AdSpray group, an anti-adhesion barrier was applied after completion of urinary diversion and before peritoneal closure. As illustrated in Figure 2, AdSpray was sprayed over (i) the pelvic peritoneal cavity, (ii) lymph node dissection regions, (iii) bowel anastomoses, and (iv) other peritoneal defect areas.

2.3. Statistical analysis

Descriptive statistics were used to summarize patient characteristics. Continuous variables are reported as mean ± standard deviation or the median (interquartile range), as appropriate, and were compared using Welch's *t* test or the Wilcoxon rank-sum test. Categorical variables were compared using Fisher's exact tests.

To adjust for baseline differences between the AdSpray and non-AdSpray groups, propensity score matching (PSM) was performed using 1:1 nearest-neighbor matching without replacement. Covariates included in the propensity model were age, sex, PS, smoking history, height, and weight. Standardized mean differences (SMDs) were calculated to assess the covariate balance.

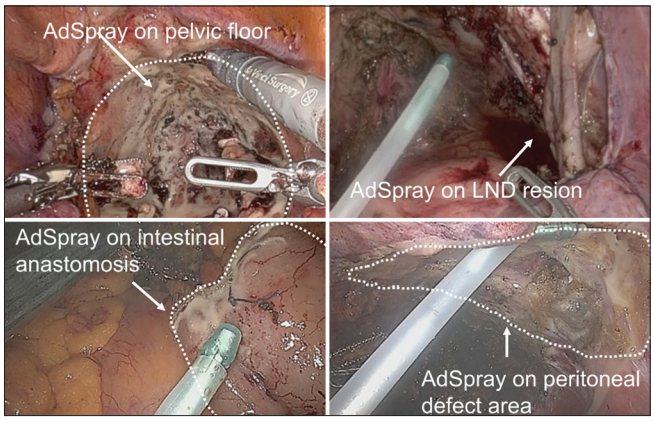

Figure 2. Representative images of AdSpray use during robot-assisted radical cystectomy with urinary diversion
Abbreviation: LND: lymph node dissection.

After matching, logistic regression was used to estimate the association between AdSpray use and the endpoint of any 90-day complication, with results reported as ORs with 95% confidence intervals (CIs). The Kaplan–Meier method was used to analyze time-to-event outcomes. The time of origin was the date of surgery (POD 0). For time to liquid and normal diet intake, observations were censored at death, transfer, or POD 90, whichever occurred first.

Discharge from the index hospitalization was treated as an event. In-hospital death or transfer before discharge was prespecified as a competing event; however, no such events occurred in this cohort, and Fine–Gray estimates were therefore not applicable. Cause-specific Cox models were used to treat competing events as censoring at their occurrence to characterize the instantaneous rate of discharge among patients who remained at risk. Patients who were still hospitalized on POD 90 were censored on POD 90. All tests were two-sided, and a $p<0.05$ was considered statistically significant. Analyses were conducted using R software (version 4.3.2, R Foundation for Statistical Computing, Austria) with the MatchIt, survival, survminer, and ggplot2 packages.

3. Results

3.1. Patient characteristics

A total of 71 patients were analyzed: 17 received AdSpray, and 54 did not. The baseline demographic and clinical characteristics before and after PSM are summarized in Table 1.

Before PSM, the AdSpray group tended to be older ($p=0.16$) and had higher PS scores ($p=0.036$), whereas sex distribution, smoking history, height, and weight were comparable between the groups.

After 1:1 nearest-neighbor PSM, 17 matched pairs ($n = 34$) were identified. Covariate balance improved compared with the pre-matching cohort, with several variables achieving SMDs < 0.20. Residual imbalances remained for age (SMD = 0.41), sex (SMD = 0.45), height (SMD = 0.30), and ECOG PS (SMD = 0.80) (Table 1). For example, after PSM, the mean ages of the AdSpray and non-AdSpray groups were 76.8 and 74.4 years ($p=0.42$), respectively, and the PS distributions were similar in hypothesis tests, although the SMD indicated residual imbalance. In light of these residual imbalances, particularly SMDs > 0.4 for age and ECOG PS, the matched analyses should be interpreted with caution.

Table 1. Patients' baseline characteristics before and after propensity score matching

Variable	Categories	Before PSM cohorts				After PSM cohorts			
		Non-AdSpray group (%)	AdSpray group (%)	*p*-value	SMD	Non-AdSpray group (%)	AdSpray group (%)	*p*-value	SMD
Patients (*n*=71)	-	54 (76)	17 (24)	-	-	17	17	-	-
Age (mean [SD])	-	74 (7.5)	77 (7.8)	0.16	0.39	74 (5.4)	77 (7.8)	0.246	0.41
Sex	Male	46 (85)	15 (88)	1	0.09	12 (71)	10 (88)	0.4	0.45
	Female	8 (15)	2 (12)			5 (29)	2 (12)		
Height (mean [SD])	-	162 (7.18)	162 (8.45)	0.96	-	159 (9.1)	161.83 (8.5)	0.38	0.3
Weight (mean [SD])	-	59 (10.7)	59.6 (11.6)	0.85	-	58.9 (13.4)	59.6 (11.6)	0.87	0.06
ECOG-PS	0	47 (87)	10 (59)	0.036	0.74	14 (82.4)	10 (58.8)	0.2	0.8
	1	3 (5.6)	5 (29)			1 (5.9)	5 (29.4)		
	2	3 (5.6)	1 (5.9)			2 (11.8)	1 (5.9)		
	3	1 (1.9)	1 (5.9)			0 (0.0)	1 (5.9)		
Smoking	Never	9 (17)	3 (18)	0.9	0.25	4 (23.5)	3 (17.6)	0.77	0.25
	Former	35 (65)	12 (71)			10 (58.8)	12 (70.6)		
	Current	9 (17)	2 (12)			3 (17.6)	2 (11.8)		
	Unknown	1 (1.9)	0 (0.0)			0 (0.0)	0 (0.0)		
Diabetes mellitus	Yes	2 (4)	1 (6)	1	0.1	1 (5.9)	1 (5.9)	1	<0.01
	No	52 (96)	16 (94)			16 (94.1)	16 (94.1)		
Cardiovascular disease	Yes	5 (9.3)	2 (11.8)	1	0.1	1 (5.9)	2 (11.8)	1	0.21
	No	49 (90.7)	15 (88.2)			16 (94.1)	15 (88.2)		
T stage at diagnosis	1	7 (13)	0 (0.0)	0.28	0.74	1 (5.9)	0 (0.0)	0.69	0.53
	2	26 (48)	13 (76)			12 (70.6)	13 (76.5)		
	3	13 (24)	2 (12)			3 (17.6)	2 (11.8)		
	4	4 (7.4)	1 (5.9)			1 (5.9)	1 (5.9)		
	Tis	4 (7.4)	1 (5.9)			0 (0.0)	1 (5.9)		
N stage at diagnosis	0	52 (96)	15 (88)	0.51	0.31	16 (94)	15 (88)	1	0.21
	2	2 (3.7)	2 (12)			1 (6)	2 (12)		
M stage at diagnosis	0	52 (96)	17 (100)	1	0.28	16 (94)	17 (100)	1	0.35
	1	2 (3.7)	0 (0.0)			1 (6)	0 (0.0)		
Neoadjuvant chemotherapy	Yes	36 (67)	8 (47)	0.24	0.4	12 (71)	8 (47)	0.296	0.49
	No	18 (33)	9 (53)			5 (29)	9 (53)		
History of abdominal surgery	Yes	25 (46)	9 (53)	0.84	0.13	8 (47)	9 (53)	1	0.12
	No	29 (54)	8 (47)			9 (53)	8 (47)		
History of abdominal radiation therapy	Yes	3 (5.6)	3 (18)	0.29	0.38	2 (12)	3 (18)	1	0.17
	No	51 (94)	14 (82)			15 (88)	14 (82)		
Urinary diversion	Ileal conduit	42 (78)	12 (71)	0.7	0.23	12 (71)	12 (71)	1	0.17
	Cutaneous ureterostomy	4 (7.4)	1 (5.9)			1 (6)	1 (6)		
	Neobladder	8 (15)	4 (24)			4 (24)	4 (24)		
ICUD	Yes	37 (69)	15 (88)	0.2	0.49	14 (82)	15 (88)	1	0.17
	No	17 (32)	2 (12)			3 (18)	2 (12)		
Blood loss, ml (mean [SD])	-	360 (483)	276 (296)	0.5	0.21	242 (303)	276 (296)	0.74	0.11
Operation time, min (mean [SD])	-	461 (103)	438 (71)	0.36	0.28	466 (106)	438 (71)	0.37	0.31
T stage at RC	0	16 (30)	5 (29)	0.85	0.46	9 (52.9)	5 (29.4)	0.655	0.66
	1	3 (5.6)	1 (5.9)			2 (11.8)	1 (5.9)		
	2	8 (15)	1 (5.9)			1 (5.9)	1 (5.9)		
	3	15 (28)	5 (29)			2 (11.8)	5 (29.4)		
	4	2 (3.7)	2 (12)			1 (5.9)	2 (11.8)		
	Ta	1 (1.9)	0 (0.0)			0 (0.0)	0 (0.0)		
	Tis	9 (17)	3 (18)			2 (11.8)	3 (17.6)		

(Cont'd...)

Table 1. ***(Continued)***

Variable	Categories	Before PSM cohorts				After PSM cohorts			
		Non-AdSpray group (%)	AdSpray group (%)	*p*-value	SMD	Non-AdSpray group (%)	AdSpray group (%)	*p*-value	SMD
N stage at RC	0	51 (94)	13 (77)	0.08	0.53	16 (94.1)	13 (76.5)	0.08	
	1	1 (2)	2 (12)			1 (5.9)	2 (11.8)		
	2	2 (3.7)	2 (12)			0 (0.0)	2 (11.8)		
LVI	Yes	22 (42)	7 (41)	1	0.03	5 (29.4)	7 (41.2)	0.72	0.25
	No	31 (59)	10 (59)			12 (70.6)	10 (58.2)		
RM	Yes	2 (3.7)	4 (24)	0.04	0.6	2 (11.8)	4 (23.5)	0.653	0.31
	No	52 (96)	13 (77)			15 (88.2)	13 (76.5)		
LND	Yes	46 (85)	14 (82)	1	0.08	13 (76.5)	14 (82.4)	1	0.15
	No	8 (15)	3 (18)			4 (23.5)	3 (18.6)		

Abbreviations: ECOG-PS: Eastern Cooperative Oncology Group performance status; ICUD: Intracorporeal urinary diversion; LND: Lymph node dissection; LVI: Lymphovascular invasion; PSM: Propensity score matching; RC: Radical cystectomy; RM: Resection margin; SD: Standard deviation; SMD: Standardized mean difference.

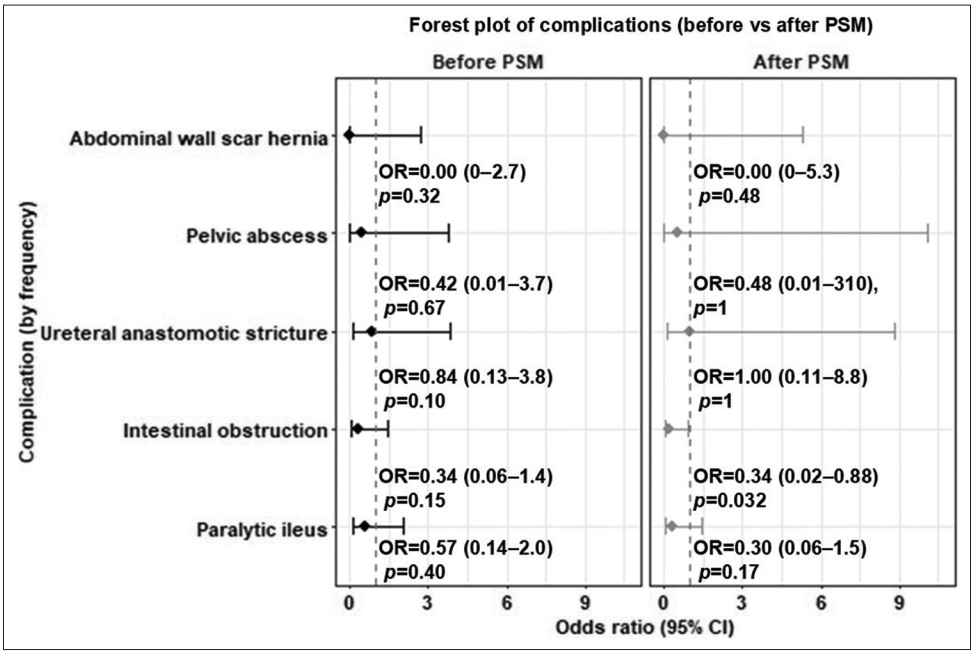

Figure 3. Comparison of post-operative outcomes between AdSpray and non-AdSpray groups, showing forest plots of post-operative complications before and after propensity score matching. Odds ratios were calculated as the odds of each complication in the AdSpray group divided by those in the non-AdSpray group.
Abbreviation: CI: Confidence interval.

3.2. Post-operative complications

Before PSM, no significant differences were observed between the groups: pelvic abscess (OR = 0.00, 95% CI = 0.00–2.68, *p*=0.32), ureteral anastomotic stricture (OR = 0.42, 95% CI = 0.01–3.74, *p*=0.67), abdominal wall scar hernia (OR = 0.84, 95% CI = 0.13–3.85, *p*=1.0), intestinal obstruction (OR = 0.34, 95% CI = 0.06–1.44, *p*=0.14), and paralytic ileus (OR = 0.56, 95% CI = 0.14–2.04, *p*=0.40) (Figure 3, "Before PSM").

After PSM (*n* = 17 each), intestinal obstruction occurred less frequently in the AdSpray group (OR = 0.15, 95% CI = 0.02–0.88, *p*=0.032). Other complications showed no significant differences: pelvic abscess (OR = 0.00, 95% CI = 0.00–5.3, *p*=0.49), ureteral anastomotic stricture (OR = 0.47, 95% CI = 0.01–10.1, *p*=1.00), abdominal wall scar hernia (OR = 1.00, 95% CI = 0.11–8.82, *p*=1.0), and paralytic ileus (OR = 0.29, 95% CI = 0.06–1.47, *p*=0.17) (Figure 3, "After PSM").

AdSpray was associated with lower odds of intestinal obstruction and may represent a potential preventive adjunct after RARC, pending confirmation in larger prospective cohorts.

3.3. Time-to-event and recovery outcomes

3.3.1. Time to discharge

Kaplan–Meier analysis showed no significant difference in the time to hospital discharge between the AdSpray and non-AdSpray groups before (log-rank p=0.64) or after matching (log-rank p=0.42) (Figure 4A). The discharge trajectories largely overlapped, and the median discharge time was similar.

For reference, the cumulative incidence of discharge on POD 14 was 5.9% vs. 1.9% (AdSpray vs. non-AdSpray) before PSM and 5.9% vs. 5.9% after PSM (Figure 4A).

3.3.2. Dietary recovery

Post-operative dietary progression was assessed by the number of days to liquid intake and normal diet. Before PSM, the median time to liquid diet was 3.0 days (interquartile range [IQR] = 2.5–4.0) in the non-AdSpray group and 3.0 days (IQR = 3.0–4.0) in the AdSpray group (p=0.61). The median time to normal diet was 10.0 days (IQR = 8.0–14.0) vs. 9.0 days (IQR = 8.0–14.0), respectively (p=0.33).

After PSM, both groups required a median of 3.0 days to resume a liquid diet (IQR 1.0 in non-AdSpray; IQR 3.0 in AdSpray; p=0.96). The time to normal diet was 11.0 days (IQR = 10.0) in the non-AdSpray group and 10.0 days (IQR = 4.0) in the AdSpray group (p=0.70). These distributions are shown as box plots in Figure 4B.

4. Discussion

In this retrospective cohort of patients who underwent RARC, the intraoperative application of AdSpray was not associated with a reduction in the overall post-operative complication rate, earlier dietary progression, or shorter time to discharge. However, after PSM, AdSpray use was associated with a lower 90-day incidence of intestinal obstruction, indicating

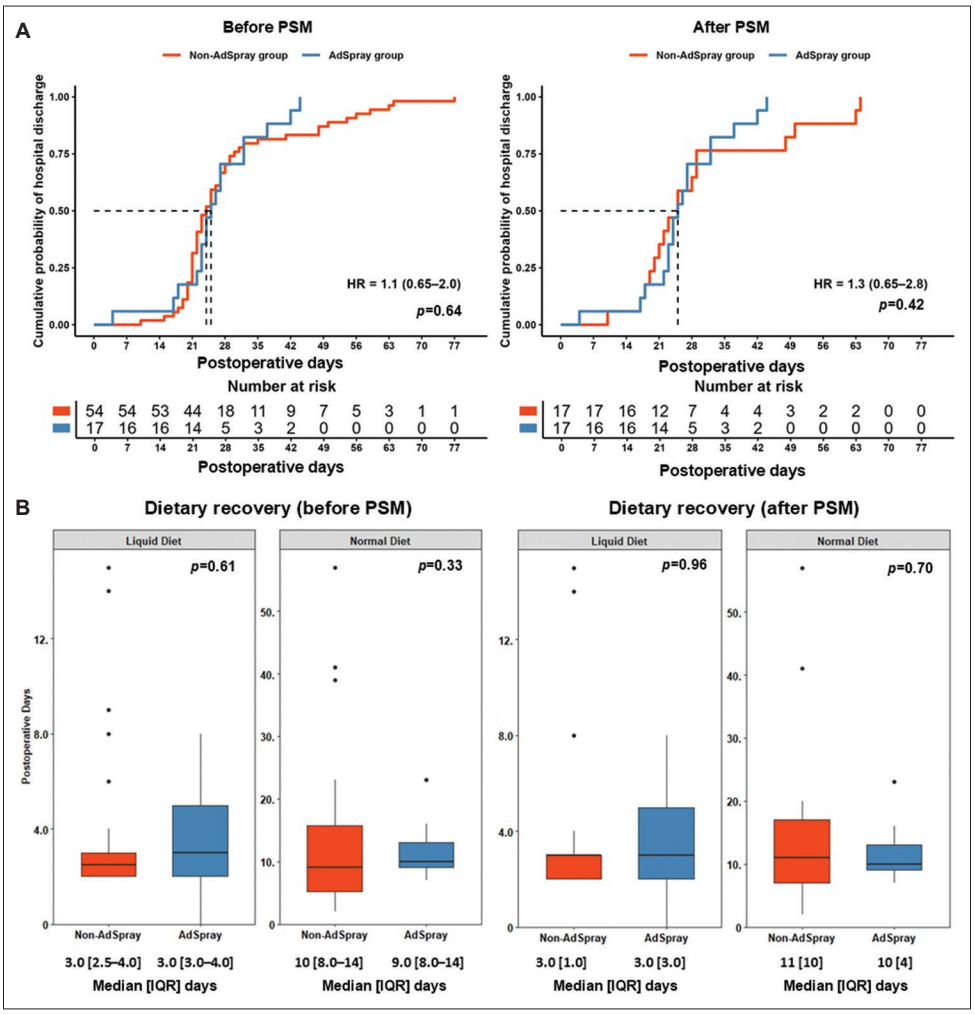

Figure 4. Time to hospital discharge and dietary recovery after robot-assisted radical cystectomy. (A) Kaplan–Meier curves for time from surgery day to hospital discharge, comparing AdSpray and non-AdSpray groups (before and after propensity score matching [PSM]). (B) Box plots showing the distribution of post-operative days to first liquid intake and normal diet in the AdSpray and non-AdSpray groups before and after PSM. The y-axis represents the number of days since surgery.
Abbreviations: HR, hazard ratio; IQR: Interquartile range.

a focused benefit on adhesion-related morbidity rather than a broad effect on global recovery endpoints. This selective reduction is directionally consistent with an anti-adhesive mechanism and provides a clinically meaningful signal in contemporary cystectomy care pathways. However, given the retrospective single-center design, modest sample size, and the fact that PSM can only adjust for measured covariates, these observations should be viewed as hypothesis-generating rather than definitive evidence of a causal effect.[31-33] Therefore, unmeasured or incompletely captured confounders may have influenced both the use of AdSpray and the risk of post-operative intestinal obstruction.[31,34]

Biologically, peritoneal adhesions arise from mesothelial injury, fibrin deposition, and impaired fibrinolysis, followed by fibroblastic ingrowth and collagen formation, which can tether bowel loops and cause mechanical obstruction. A temporary hydrogel interface may limit direct tissue apposition during the critical early phase of healing, thereby reducing adhesion formation.[8,35] Randomized and clinical evidence from non-urologic contexts further supports the plausibility that barrier technologies can lessen adhesive small bowel obstruction after abdominal surgery, even when global morbidity metrics change little.[8] Within this framework, our observation of fewer mechanical obstructions without measurable acceleration of discharge is consistent with the expected mechanism-based scope of the benefits.

Contextual factors specific to RARC also help to explain the observed pattern of results. RARC involves extensive pelvic dissection, prolonged pneumoperitoneum, bowel handling, and urinary diversion, all of which increase the risk of adhesion-related complications.[3,36] Simultaneously, ERAS programs standardize analgesia, mobilization, nutrition, and fluid strategies, reducing variation in length of stay and feeding milestones.[11,37] As a result, the detectable impact of a single intraoperative adjunct on global recovery may be attenuated, even if a specific adhesion-driven event such as mechanical obstruction is reduced. Taken together, these findings suggest that any effect of AdSpray is likely to be selective and mechanism-based, consistent with the intended function of bioabsorbable adhesion barriers designed to provide temporary separation of injured peritoneal surfaces.[9,13,14]

Accordingly, any potential benefit would be expected to primarily target adhesion-related mechanical obstruction rather than uniformly accelerate multifactorial recovery endpoints such as dietary progression or hospital discharge, which are strongly influenced by perioperative care pathways, including ERAS in RC.[6-8] In addition, technical choices, such as intracorporeal versus extracorporeal urinary diversion, can affect the extent and location of bowel manipulation and, therefore, the risk of adhesion. These practice patterns vary across centers and may act as effect modifiers that warrant prospective stratification.[14,15,18,20] Consistent with this, we observed no between-group differences in other complications, including paralytic ileus, abdominal wall hernia, or anastomotic events, underscoring that AdSpray's potential benefit is targeted rather than global.

Our findings are consistent with those of previous studies on spray-type hydrogel barriers. A prospective clinical series in hepatobiliary surgery reported the acceptable safety and feasibility of AdSpray,[10] and preclinical comparisons suggested favorable anti-adhesion profiles versus sheet barriers in confined spaces.[38] Gynecologic experience further supports reduced adhesions in subsequent procedures.[15] Beyond individual series, the surgical literature recognizes the substantial burden of adhesions in repeat operations and complex abdominal care.[39] Although robust data in urologic oncology remain limited, focusing on a hard endpoint, mechanical obstruction, rather than surrogate adhesion scores, helps bridge this evidence gap and provides an actionable clinical context for RARC. Beyond urologic oncology, accumulated experience with dextrin hydrogel barriers provides a broader safety framework for interpreting our results. Prospective and retrospective series of minimally invasive hepatectomy have reported that AdSpray™ can be applied safely without increasing major abdominal complications while potentially facilitating repeat abdominal surgery by limiting dense adhesions around the liver.[10,38,39] Similarly, in pediatric laparoscopic surgery, AdSpray® was used in infants and children without device-related allergic reactions, inflammatory complications, or deterioration of hepatic or renal function, and no recurrence of adhesive ileus was observed during midterm follow-up.[16] These data, together with preclinical uterine horn and pericardial adhesion models, suggest that dextrin hydrogel barriers can provide temporary physical separation of serosal surfaces without impairing wound healing or causing long-term foreign body reactions.[14] Our study extends this evidence base to the setting of RARC, indicating that such barriers may selectively mitigate adhesive intestinal obstruction within contemporary cystectomy care pathways.[10]

Clinically, preventing mechanical obstruction is important, even when it does not translate into earlier discharge. From a surgeon's and health system perspective, time to discharge is an attractive hard endpoint that integrates many aspects of post-operative recovery, and earlier discharge in patients without intestinal complications is desirable.[6,7] In our small matched cohort, however, the absolute number of obstruction events was limited, and discharge timing was strongly influenced by other factors—including non-gastrointestinal complications, rehabilitation needs, and social or logistical considerations—which likely diluted any incremental effect of reducing obstruction alone. Adhesive small bowel obstruction

is a relatively infrequent but clinically important event, and even a modest absolute reduction may translate into fewer reinterventions, readmissions, and episodes of prolonged hospitalization at the population level.[5,19] Adhesive obstruction often necessitates imaging, nasogastric decompression, and sometimes reoperation, with downstream effects on resource utilization, cost, and quality of life.[19,40] In contrast, earlier recovery of bowel motility and timely discharge are multifactorial endpoints influenced by baseline comorbidities, perioperative fluid management, opioid exposure, and institution-specific enhanced recovery protocols.[41,42] Previous observational studies on open and RARC have identified fluid balance and other systemic factors as key determinants of post-operative ileus and length of stay, suggesting that barrier-based strategies alone are unlikely to normalize these outcomes.[7,41] Within this context, the selective association between AdSpray use and reduced intestinal obstruction, in the absence of a measurable effect on time to diet or discharge, is consistent with a mechanism-based, targeted scope of benefit for adhesion-related bowel obstruction rather than a global improvement in post-operative recovery.[9,35]

From a value-based care perspective in the ERAS era of cystectomy, a selective, risk-stratified application of AdSpray—particularly in patients with anticipated extensive bowel handling or prior laparotomy—appears reasonable until higher-level evidence is available.[6,7] Safety also warrants consideration: in our cohort, we observed no device-attributable adverse events, and the barrier was applied after meticulous hemostasis and irrigation, consistent with recommended principles of adhesion prevention. Current guidelines emphasize timely diagnosis and tailored surgical decision-making for adhesive small bowel obstruction, and standardizing application sites and doses may further enhance reproducibility across surgeons and centers.[19,40]

The strengths of this study include consecutive case ascertainment, explicit differentiation between intestinal obstruction and paralytic ileus, and matched analyses. However, several limitations should be acknowledged. The retrospective single-center design limits generalizability, and despite PSM, substantial residual imbalances remained for several covariates, including age and ECOG PS. Moreover, propensity score methods can only account for measured variables and cannot eliminate the influence of unmeasured or poorly captured confounding factors.[31-33] The matched sample size also reduced the power to detect modest differences in infrequent secondary outcomes. Adhesion severity was not directly graded, and follow-up was restricted to 90 days, which is relatively short for capturing adhesion-related morbidity. [19,43] In clinical practice, the most substantial burden of adhesions may manifest as late intestinal obstruction and reoperation occurring months or years after cystectomy, rather than within the first 90 days.[44] Consequently, we were unable to systematically assess late adhesive events, recurrent obstruction, or reoperations that may occur beyond the early post-operative period. The surgeon's learning curve and institutional practice patterns, including urinary diversion techniques, could contribute to unmeasured confounding.[36] These factors necessitate cautious interpretation and motivate confirmatory research in the future. In addition, our primary gastrointestinal endpoints relied on CT-based diagnosis of bowel obstruction and paralytic ileus.[20] Although CT is the standard imaging modality for suspected post-operative obstruction, its diagnostic performance is not perfect, and misclassification of bowel events is possible.[19,43] Such misclassification would generally be expected to bias associations toward the null if non-differential between groups, although more complex patterns cannot be excluded.

Future studies should be multicenter and randomized, incorporate standardized application protocols (sites, dose, and timing), and predefine risk-stratified analyses based on prior abdominal surgery, anticipated bowel handling, and diversion technique.[23,24,28] Given ERAS standardization, trials should prioritize hard endpoints (mechanical obstruction requiring intervention) over global recovery timelines.[6,7] In addition, incorporating patient-centered measures, such as days alive and out of the hospital, durable discharge home without readmission, and long-term health-related quality of life, would better capture the global impact of adhesion prevention strategies.[45-47] Longer follow-up is needed to quantify recurrent obstruction and reoperation and to evaluate cost-effectiveness within bundled payment frameworks.[48,49] Together, such data would clarify whether selective intraoperative use of AdSpray should become routine in RARC and in which patient subsets it provides the greatest value.

5. Conclusion

Among patients who underwent RARC for bladder cancer, intraoperative AdSpray was associated with fewer post-operative intestinal obstructions but did not accelerate recovery, as measured by diet advancement or hospital discharge. AdSpray may serve as a selective adjunct to reduce adhesion-related complications in high-risk patients; however, confirmation in prospective multicenter studies is required. Accordingly, these results should be interpreted as hypothesis-generating and not as definitive evidence of a causal relationship.

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Conflict of interest

The authors declare that they have no competing interests.

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Writing–review & editing: All authors

Ethics approval and consent to participate

This retrospective study was approved by the Institutional Review Board (IRB) of Nara Medical University (Approval No. 2891). Given the retrospective design using de-identified clinical data, the requirement for individual informed consent was waived by the IRB.

Consent for publication

Written informed consent to publish patients' images was obtained from all patients whose images are included in this study.

Data availability statement

Clinical data were obtained from patients' electronic medical records at Nara Medical University. Due to privacy and institutional policies, the datasets are not publicly available but can be obtained from the corresponding author upon reasonable request and with approval from the Institutional Review Board of Nara Medical University.

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