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ARTICLE

Clinical Research

Regular vs. selective use of closed suction drains following robot-assisted radical prostatectomy: results from a regional quality improvement collaborative

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Abstract

Background Closed suction drain (CSD) placement is common in robot-assisted radical prostatectomy (RARP). Our goal is to quantify outcomes of RARP for patients undergoing RARP by surgeons who regularly or selectively use CSDs.

Methods Patients undergoing RARP (4/2014−7/2017) were prospectively entered into the Michigan Urological Surgery Improvement Collaborative (MUSIC) registry. Outcomes included length of stay (LOS) >2 days, >16-day catheterization, 30-day readmission, and clinically significant urine leak or ileus. Retrospective analysis of each adverse event was performed comparing groups using chi-square tests.

Results In all, 6746 RARPs were performed by 115 MUSIC surgeons. CSDs were used in 4451 RARP (66.0%), with wide variation in surgeon CSD use (median: 94.7%, range: 0–100%, IQR: 45–100%). The cohorts of patients treated by surgeons with regular vs. selective CSD usage were similar. CSD use pattern was not associated with rates of prolonged catheterization (4.6% vs. 3.9%, $p = 0.17$) or readmission (4.5% vs. 4.0%, $p = 0.35$) and multivariable analysis confirmed these findings (each $p > 0.10$). Regular CSD use was associated with LOS >2 days (8.4% vs. 6.3%, $p = 0.001$) and multivariable analyses indicated an odds ratio (OR) of 1.42 (95% CI: 1.12–1.79; $p = 0.017$) and increased likelihood of clinically significant ileus (OR: 1.64; CI: 1.14–2.35; $p = 0.008$).

Conclusions Although there are specific situations in which CSDs are beneficial, e.g. anastomotic leak or observed lymphatic drainage, regular CSD use during RARP was associated with a greater likelihood of LOS >2 days and clinically significant ileus. Our data suggest that CSD should be placed selectively rather than routinely after RARP.

Introduction

Robot-assisted radical prostatectomy (RARP) is a common mode of surgical intervention for clinically localized prostate cancer (PCa) [1, 2]. The continued refinement of the technique of RARP has yielded excellent disease control, improved continence and potency, and acceptable early postoperative outcomes [2]. RARP is frequently accompanied by pelvic lymph node dissection (PLND) to stage the cancer, with some increase in the risk of bleeding and lymphocele formation [3–9]. Placement of a surgical drain as a conduit for removal of urine, blood, and lymphatic fluid from the pelvis has been used during RARP and a variety of other urological surgeries for many years [10–12]. Use of a closed-suction drain with bulb (CSD), also commonly known as a Jackson−Pratt drain, to facilitate postoperative pelvic drainage is not without controversy. Past studies have indicated that CSD usage may be associated with increased pain, elevated morbidity, infection occurrence, increased length of hospital stay, and higher treatment cost [13–18]. Removal of the CSD requires an additional bedside (or office) procedure that can rarely result in drain breakage and retained drain material [19]. Although several prior research

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studies have supported the safety of CSD omission [13, 16, 17, 20–23], the routine practice of many urologic surgeons still is to always place a CSD following RARP.

The Michigan Urological Surgery Improvement Collaborative (MUSIC) is a statewide, physician-led quality improvement consortium that prospectively collects data regarding prostate cancer outcomes. MUSIC established the Notable Outcomes and Trackable Events after Surgery (NOTES) system to assess factors that contribute to adverse outcomes after RARP [24]. These include both post-operative complications and events that are not generally accounted for in other grading systems. In the present study, we sought to understand the use of CSDs during RARP for patients treated at the diverse practices compromising MUSIC. Our goals are to analyze the outcomes of patients undergoing RARP with or without CSD placement to better inform clinicians regarding the association of selective vs. regular CSD placement with perioperative outcomes of RARP.

Methods

Michigan Urological Surgery Improvement Collaborative (MUSIC)

Established in 2011, MUSIC is a collaborative funded by Blue Cross Blue Shield of Michigan (BCBSM) and representing approximately 90% of Michigan urologists from 45 participating practices. Patient data are entered prospectively from the time of prostate biopsy by trained data abstractors into the MUSIC clinical registry, which currently includes more than 40,000 patients, including more than 20,000 with PCa. Participating practices represent a broad spectrum of academic and community practices. Each site obtains regulatory exemption from local institutional review boards to participate in MUSIC and its quality improvement focused goals.

Study population and Notable Outcomes and Trackable Events after Surgery (NOTES)

In this analysis we included all men who underwent an RARP at 35 MUSIC practices from April 2014 to October 2017. This comprised all patients for which clinical data (age, race, preoperative prostate-specific antigen (PSA), clinical T stage, biopsy Gleason grade, etc.) and pathological data were collected and having at least 30 days of follow-up. NOTES were recorded for each patient, with attribution of events to specific causes when documented in the medical record [24]. MUSIC began recording NOTES in April 2014 to track and improve the short-term recovery outcomes after RARP, marking the earliest included patients for this study. These actionable data points collectively reflect practice patterns and resource utilization, technical complications, and coordination of care. NOTES aims to raise the quality of perioperative care for men in Michigan, as well as reduce adverse events and their associated costs following radical prostatectomy.

Statistical analysis

Surgical, pathological and perioperative outcomes were summarized and compared between those with and without CSD using chi-squared test for categorical variables and Wilcoxon rank-sum test for continuous measures. Stratified analysis based on surgeon's pattern of CSD use was also conducted, where the sample was divided into two groups, one from the surgeons who use CSDs regularly (>90%) and the other from the surgeons who more selectively use CSDs (≤90%). To ensure reliability of classification, only surgeons with at least ten cases were included in the stratified analysis. To identify factors associated with CSD usage, multivariable logistic regression model was used. Variables included for evaluation were patient's age, race, body mass index (BMI), comorbidity, PSA, clinical T stage, biopsy Gleason grade, percentage of cores positive and cancer involvement at biopsy, and performance and result of CT/MRI. Surgical characteristics that could impact the decision to place a CSD at the end of surgery, such as estimated blood loss (EBL), PLND, nerve-sparing, pathological T and N stage, and margin status, were also included as potential predictors.

Because of the significant selection bias identified in selecting patients for CSD placement for the surgeons not placing them routinely, additional analyses were performed using surgeon pattern of CSD use (regular vs. selective). To compare the outcomes between patients with and without CSDs, and between patients operated on by surgeons with regular vs. selective CSD use, separate multivariable logistic regression models were constructed. The models included as primary predictor either an indicator variable for CSD placement or regular CSD use, and controlled for all the covariates mentioned above. Further analyses of the characteristics and outcomes for these two groups of surgeons were performed to evaluate for potential associations with this trait. All statistical analyses were performed in SAS version 9.4, and statistical significance was set at 0.05.

Results

Characteristics of patients undergoing RARP by a surgeon with regular or selective CSD use

A total of 6746 men were included in the analysis. Among them, PLND was performed in 5225 cases (77.5%) and a

bilateral nerve-sparing approach was performed in 4188 cases (62.1%). CSD was utilized during 4451 RARP (66.0%), 94.7% of these CSDs ($n = 4217$) were removed on postoperative day 1 or 2. RARP were performed by 115 surgeons in this study, including 87 with data from at least 10 RARPs during the study period. Of these surgeons, 44 used a CSD in >90% of surgeries (median: 100%, interquartile range (IQR): 97.3–100%; $n = 3544$ RARP) and 43 used a CSD in between 0 and 90% of their surgeries (median: 36.6%, IQR: 7.2–67.1%; $n = 3112$ RARP) (Supplementary Fig. 1).

There were no clinically relevant differences between the cohorts of patients undergoing RARP by a surgeon that regularly or selectively placed CSD in terms of age, BMI, preoperative PSA, clinical T stage or Gleason grade (Table 1). In addition, the surgeons in both groups appeared comparable according to characteristics such as RARP volume, practice setting, year completed training, and fellowship training. Early postsurgical endpoints were comparable as well. For example, EBL > 400 ml occurred in 3.0% and 3.5% of RARP performed by regular and selective CSD placers ($p = 0.24$) and positive surgical margin rates for organ-confined disease (pT2) were 21.3% and 23.7% in these same groups ($p = 0.056$), respectively. Biochemical recurrence occurred in 10.6% and 10.7% of patients undergoing RARP by regular and selective CSD users, respectively ($p = 0.87$). In addition, continence outcomes at 3 months were comparable in the subset of patients ($n = 1347$) participating in Michigan Urological Surgery Improvement Collaborative—Patient Reported Outcomes (MUSIC-PRO). The OR for use of 0 or 1 pad per day was 1.19 (95% CI: 0.86, 1.65, $p = 0.298$) for surgeons who regularly placed CSDs. There were, therefore, no observed clinically significant differences between these two cohorts of surgeons and patients.

Table 1 Patient and surgeon characteristics according to surgeons' pattern of CSD use

	Regular CSD use	Selective CSD use	*p*
Patient-level characteristics			
Total No. RARP	3544	3112	
Age, years (IQR)	63.5 (58–68)	63.4 (58–68)	0.72
BMI, units (IQR)	28.7 (26–32)	28.5 (26–32)	0.23
Charlson comorbidity index ≥1	872 (24.6%)	857 (27.5%)	0.007
Preoperative PSA, ng/ml (IQR)	5.9 (4.4–8.5)	5.9 (4.4–8.6)	0.88
Clinical stage T1c	2582 (73.3%)	2200 (70.9%)	0.031
Pathologic grade group (Gleason score)			<0.001
1 (3 + 3)	490 (14.2%)	393 (12.8%)	
2 (3 + 4)	1686 (49.0%)	1596 (52.1%)	
3 (4 + 3)	766 (22.3%)	664 (21.7%)	
4 (8)	235 (6.8%)	139 (4.5%)	
5 (9–10)	265 (7.7%)	269 (8.8%)	
EBL >400 ml	98 (3.0%)	103 (3.5%)	0.24
PLND	2739 (77.3%)	2424 (77.9%)	0.25
Nerve-sparing performed	2505 (70.7%)	2457 (78.9%)	<0.001
Adverse pathology[a]	1692 (48.8%)	1579 (51.3%)	0.044
Positive surgical margins (overall)	1064 (30.0%)	1011 (32.5%)	0.030
Positive surgical margins (for pT2 patients)	521 (21.3%)	470 (23.7%)	0.056
Biochemical recurrence[b]	352 (10.6%)	311 (10.7%)	0.87
Median f/u since surgery, median (IQR)	16.2 (6.6–26.6)	18.0 (7.8–28.5)	<0.001
Surgeon-level characteristics[c]			
No. surgeons	44	43	
Volume of RARP, median (IQR)	21.4 (10.0–40.0)	12.7 (6.7–35.4)	0.16
Year completed training			0.73
Before 2000	21 (48.8%)	18 (42.9%)	
2000–2009	11 (25.6%)	14 (33.3%)	
2010 or later	11 (25.6%)	10 (23.8%)	
Fellowship trained	20 (51.3%)	17 (41.5%)	0.38
Academic center	7 (15.9%)	9 (20.9%)	0.55
Resident used as assistant	18 (60.0%)	20 (66.7%)	0.59

CSD closed suction drain, *RARP* robot-assisted radical prostatectomy, *BMI* body mass index, *EBL* estimated blood loss, *PSA* prostate-specific antigen, *PLND* pelvic lymph node dissection

[a]Adverse pathology is defined as pT3/T4 or pN1 or predominant Gleason pattern 4/5 cancer

[b]Detectable PSA between 1 and 12 months after RP

[c]Data were not available for year completed training ($n = 2$), fellowship trained ($n = 7$), resident used as assistant ($n = 24$)

Characteristics of patients undergoing RARP with or without CSD placement

Table 2 indicates the clinical, perioperative, and pathologic features of patients undergoing RARP with or without CSD placement for the selective CSD cohort. Preoperative characteristics displaying a significant association with omission of CSD included lower age ($p = 0.001$), lower PSA ($p = 0.006$), and clinical stage T1 ($p = 0.0001$). Surgical pathologic features associated with omission of CSD included organ-confined disease (pT2) ($p < 0.0001$) and Gleason grade ($p = 0.020$) in univariable models. Patients that did not have a CSD placed were more likely to have had bilateral nerve-sparing surgery (80.4% vs. 53.3%, $p < 0.0001$) and less likely to have had EBL >400 ml (2.6% vs. 5.7%, $p < 0.0001$), than those having a CSD placed. Multivariable logistic regression models were also performed to identify the contributions of various factors to the association with CSD use (Supplementary Table 1). The odds of CSD placement were four times less with bilateral nerve-sparing surgery (OR: 0.25, IQR: 0.20–0.31) and were significantly correlated with EBL as well ($p < 0.0001$ for both). For those who routinely used a CSD during RARP, no patient factors were significantly associated with CSD usage (as expected).

Table 2 Clinical, pathologic and perioperative data according to CSD use in surgeons with selective use of CSDs*

	Total	CSD	No CSD	*p*
No. patients	3112 (46.1%)	897 (28.8%)	2215 (71.2%)	
Preoperative characteristics				
Age, years (IQR)	63.4 (58–68)	64.2 (59–69)	63.1 (58–68)	0.001
African-American	485 (17.1%)	139 (16.7%)	346 (17.2%)	0.93
BMI, units (IQR)	28.5 (26–32)	28.7 (26–32)	28.4 (26–31)	0.23
Charlson comorbidity index ≥1 index	857 (27.5%)	245 (27.3%)	612 (27.6%)	0.86
Preoperative PSA, ng/ml (IQR)	5.9 (4.4–8.6)	6.2 (4.6–9.3)	5.8 (4.3–8.4)	<0.0001
Clinical stage T2 or higher	901 (29.1%)	258 (33.4%)	603 (27.3%)	0.001
Biopsy complication	68 (3.1%)	18 (2.5%)	50 (3.4%)	0.22
Perioperative outcomes				
Nerve-sparing				<0.0001
Bilateral	2142 (72.6%)	456 (53.3%)	1686 (80.4%)	
Unilateral	315 (10.7%)	149 (17.4%)	166 (7.9%)	
None/Partial	495 (16.8%)	251 (29.3%)	244 (11.6%)	
Pelvic lymph node dissection	2424 (79.7%)	676 (79.1%)	1748 (79.9%)	0.078
Estimated blood loss, ml (IQR)	100 (50–200)	110 (70–225)	100 (50–150)	<0.0001
EBL >400 ml	103 (3.5%)	48 (5.7%)	55 (2.6%)	<0.0001
Pathologic features				
Surgical grade group (Gleason score)				0.23
1 (3 + 3)	393 (12.8%)	107 (12.1%)	286 (13.1%)	
2 (3 + 4)	1596 (52.1%)	443 (50.3%)	1153 (52.9%)	
3 (4 + 3)	664 (21.7%)	196 (22.2%)	468 (21.5%)	
4 (8)	139 (4.5%)	43 (4.9%)	96 (4.4%)	
5 (9–10)	269 (8.8%)	92 (10.4%)	177 (8.1%)	
Extraprostatic extension	1091 (35.1%)	290 (32.3%)	801 (36.2%)	0.042
Seminal vesical invasion	336 (10.8%)	104 (11.6%)	232 (10.5%)	0.36
Positive lymph nodes	181 (5.8%)	45 (5.0%)	136 (6.1%)	0.23

EPE extraprostatic extension, *SVI* seminal vesical invasion, *PLND* pelvic lymph node dissection, *EBL* estimated blood loss

*Surgeons with <10 RARP were not included in the multivariate analysis of these cohorts after stratification

Outcomes of patients following RARP with or without CSD placement

In total, 1042 (15.4%) patients experienced some adverse outcome either during or after surgery; patients with CSDs accounted for 787 (75.5%) of those cases. Overall, patients with CSDs had a higher rate of NOTES deviations than those that did not (17.7% vs. 11.1%, $p < 0.0001$). In univariate analysis (Table 3), a greater proportion of those with CSDs had LOS >2 days (9.2% vs. 4.0%, $p < 0.0001$) or catheterization >16 days (5.2% vs. 2.8%, $p < 0.0001$). No other adverse events were found to be different between the two groups. Controlling for multiple patient characteristics in multivariable regression models (Supplementary Table 2), CSD use was significantly associated with catheterization >16 days (OR = 1.72, 95% CI: 1.21, 2.44, $p = 0.002$), LOS >2 days (OR = 2.40, 95% CI: 1.79, 3.21, $p < 0.0001$), clinically significant urine leak (OR = 3.05, $p < 0.001$), and clinically significant ileus (OR = 1.76, $p = 0.008$).

Outcomes of patient cohorts following RARP by a surgeon that regularly or selectively places a CSD during surgery

To minimize the effects of the selection bias of placing a CSD when poorer outcomes might be expected, outcomes were next analyzed according to surgeon pattern of CSD usage. In stratified univariate analysis (Table 3), patients of surgeons that used CSDs >90% of the time had LOS >2 days more often (8.4%) than patients of surgeons that used CSDs less frequently (6.3%). There were no other observed differences in NOTES deviations between the selective and regular CSD usage cohorts. Multivariable analysis was performed to identify whether pattern of CSD use was significantly associated with adverse outcomes after RARP (Table 4). Usage pattern was not a predictor of readmission within 30 days ($p = 0.38$), catheter replacement ($p = 0.28$), or occurrence of any NOTES deviation ($p = 0.40$). Regular CSD usage was significantly associated with

Table 3 Rate of adverse outcomes by CSD use

	CSD	No CSD	*p*	Regular CSD use	Selective CSD use	*p*
No. RARP	4451	2295		3544	3112	
NOTES deviations						
LOS >2 days	410 (9.2%)	91 (4.0%)	<0.0001	298 (8.4%)	197 (6.3%)	0.001
Prolonged catheterization	229 (5.2%)	63 (2.8%)	<0.0001	138 (3.9%)	142 (4.6%)	0.169
Catheter replacement	126 (3.4%)	47 (2.5%)	0.069	102 (3.4%)	69 (2.8%)	0.197
Rectal Injury	13 (0.3%)	4 (0.2%)	0.361	7 (0.2%)	8 (0.3%)	0.609
30-day readmission	186 (4.2%)	98 (4.3%)	0.860	143 (4.0%)	140 (4.5%)	0.350
30-day mortality	7 (0.2%)	2 (0.1%)	0.455	7 (0.2%)	2 (0.1%)	0.140
Any deviation	787 (17.7%)	255 (11.1%)	<0.0001	570 (16.1%)	455 (14.6%)	0.099
Clinically significant urine leak[a]	167 (3.8%)	27 (1.2%)	<0.0001	115 (3.2%)	73 (2.3%)	0.027
Clinically significant ileus[b]	155 (3.5%)	42 (1.8%)	<0.0001	120 (3.4%)	73 (2.3%)	0.014

NOTES Notable Outcomes and Trackable Events after Surgery, *LOS* length of stay

[a]Urine leak as the reason for any of the NOTES listed above

[b]Ileus as the reason for any of the NOTES listed above

prolonged (>2 day) length of stay (OR: 1.42, 95% CI: 1.12, 1.79, $p = 0.004$) and was inversely associated with prolonged (>16 day) catheterization (OR: 0.69, 95% CI: 0.51, 0.94, $p = 0.017$). Interestingly, although the risk of clinically significant urine leak was not associated with CSD usage pattern ($p = 0.14$), the risk of clinically significant ileus was higher with routine CSD usage (OR: 1.64, 95% CI: 1.14, 2.35, $p = 0.008$).

Discussion

The use of a CSD, such as a Jackson−Pratt or JP drain, is common at the time of RARP. In fact, despite multiple scientific investigations reported during the last 15 years suggesting that CSDs can be safely omitted during prostatectomy [13, 16, 17, 20–23, 25], we found usage in 66% of RARP in the MUSIC registry. Surgical drains serve as conduits for removal of bodily fluids such as urine, blood, and lymph from the abdominopelvic regions; they have been used in a variety of urological surgical interventions for many years [10–12, 25, 26]. Surgeons likely place a CSD to limit the consequences of urinoma, hematoma or lymphocele, which can compromise the urethrovesical anastomosis or lead to pelvic pain. Although prior studies, including randomized prospective trials, have shown no quantifiable benefits of regular CSD placement after prostatectomy [13, 20, 27], this remains the routine practice of many surgeons performing this operation. We investigated the associations between CSD usage and outcomes after RARP, in order to quantify the impact on undesired outcomes. While placing a CSD appears sensible in specific situations, such as with demonstrated or suspected anastomotic leak or to manage ongoing lymphatic drainage at case end, omission of CSD for uncomplicated cases may be associated with some benefits. We observed that regular CSD was associated with a greater risk of prolonged hospitalization and ileus after consideration of other factors in robust multivariable analyses. Considering the findings from our present study, in the setting of numerous prior studies (Table 5), selective CSD placement may be the preferred approach.

In this multi-institutional, retrospective study of outcomes of 6746 RARP performed by 115 surgeons, a CSD was placed 66.0% of the time; 17.7% of these patients experienced adverse postoperative outcomes compared with only 11.1% of those patients that did not have a CSD installed. The most common adverse outcome was increased length of stay (defined as >2 days), which occurred in 9.2% of patients that had a drain placed and only 4.0% of those that did not. The finding of increased NOTES deviations with patients that underwent CSD placement does not indicate a causative relationship, but rather is strong evidence supporting appropriate selection bias. In an attempt to account for the significant selection bias of placement in patients when the surgeon felt CSD placement was necessary, we analyzed outcomes according to pattern of CSD usage. Here, the difference in NOTES deviations was reversed, with a lower rate in the selective use cohort.

The advantages associated with selective CSD placement appear both statistically and clinically significant, with decreased risk of prolonged hospitalization and ileus. Potential explanations for the decreases in the observed rate of clinically

Table 4 Multivariable analysis of associations with adverse outcomes after RARP

Variable	Length of stay >2 days			Prolonged catheterization			Readmission within 30 days		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
Regular (vs. selective) CSD use[a]	1.42	(1.12, 1.79)	0.004	0.69	(0.51, 0.94)	0.017	0.88	(0.65, 1.17)	0.375
Age	1.02	(1.01, 1.04)	0.010	1.03	(1.01, 1.05)	0.003	1.01	(0.99, 1.03)	0.401
BMI	1.02	(1.00, 1.04)	0.119	1.02	(0.99, 1.04)	0.301	1.04	(1.01, 1.07)	0.008
African-American (vs. Caucasian)	2.36	(1.81, 3.09)	<0.0001	1.65	(1.14, 2.38)	0.008	1.32	(0.90, 1.92)	0.153
Charlson comorbidity index									
1 (vs. 0)	1.06	(0.80, 1.41)	0.688	0.91	(0.62, 1.32)	0.614	1.14	(0.80, 1.61)	0.466
≥2 (vs. 0)	1.47	(1.06, 2.05)	0.022	1.28	(0.83, 1.95)	0.261	1.16	(0.74, 1.80)	0.516
Biopsy grade group									
3 + 4 (vs. 6)	1.30	(0.93, 1.81)	0.122	1.14	(0.73, 1.79)	0.572	0.97	(0.64, 1.47)	0.890
4 + 3 (vs. 6)	1.45	(0.98, 2.15)	0.062	1.29	(0.76, 2.17)	0.347	1.16	(0.71, 1.88)	0.552
8 (vs. 6)	2.10	(1.32, 3.33)	0.002	1.84	(1.02, 3.30)	0.042	0.93	(0.51, 1.69)	0.803
9–10 (vs. 6)	1.83	(1.04, 3.21)	0.035	1.53	(0.76, 3.07)	0.230	1.46	(0.77, 2.78)	0.244
Bilateral nerve-sparing (vs. non-NS)	0.64	(0.51, 0.80)	<0.0001	0.79	(0.58, 1.06)	0.120	0.96	(0.71, 1.29)	0.781
Pathologic stage T3−T4 (vs. pT2)	0.89	(0.68, 1.16)	0.401	0.74	(0.53, 1.04)	0.085	1.02	(0.73, 1.42)	0.906
Positive margin (vs. negative)	1.47	(1.16, 1.86)	0.001	1.27	(0.94, 1.73)	0.125	1.08	(0.80, 1.47)	0.616
EBL, logarithm	1.34	(1.15, 1.55)	<0.0001	1.45	(1.20, 1.76)	<0.0001	1.04	(0.87, 1.25)	0.663

Variable	Any NOTES deviation[b]			Clinically significant urine leak[c]			Clinically significant ileus[d]		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
Regular (vs. selective) CSD use[a]	1.07	(0.91, 1.27)	0.402	1.31	(0.91, 1.88)	0.144	1.64	(1.14, 2.35)	0.008
Age	1.02	(1.01, 1.03)	0.004	1.03	(1.00, 1.05)	0.036	1.02	(1.00, 1.05)	0.100
BMI	1.02	(1.00, 1.03)	0.028	1.03	(1.00, 1.07)	0.045	1.01	(0.98, 1.05)	0.466
African-American (vs. Caucasian)	1.70	(1.38, 2.10)	<0.0001	1.00	(0.60, 1.68)	0.991	1.79	(1.17, 2.74)	0.007
Charlson comorbidity index									
1 (vs. 0)	1.05	(0.86, 1.29)	0.623	0.89	(0.56, 1.41)	0.619	0.88	(0.56, 1.39)	0.591
≥2 (vs. 0)	1.33	(1.04, 1.70)	0.021	1.21	(0.72, 2.03)	0.470	1.08	(0.63, 1.82)	0.788
Biopsy grade group									
3 + 4 (vs. 6)	1.05	(0.83, 1.32)	0.679	1.09	(0.64, 1.84)	0.749	0.83	(0.52, 1.32)	0.425
4 + 3 (vs. 6)	1.18	(0.89, 1.56)	0.242	1.47	(0.81, 2.67)	0.199	1.17	(0.68, 2.04)	0.567
8 (vs. 6)	1.53	(1.10, 2.11)	0.011	1.60	(0.80, 3.21)	0.184	1.24	(0.63, 2.43)	0.539
9–10 (vs. 6)	1.40	(0.95, 2.06)	0.093	1.27	(0.54, 2.99)	0.588	1.04	(0.45, 2.40)	0.929
Bilateral nerve-sparing (vs. non-NS)	0.75	(0.63, 0.88)	0.001	0.64	(0.45, 0.91)	0.013	0.73	(0.52, 1.04)	0.084
Pathologic stage T3−T4 (vs. pT2)	0.91	(0.75, 1.10)	0.312	0.65	(0.43, 0.99)	0.043	0.65	(0.43, 0.99)	0.044
Positive margin (vs. negative)	1.25	(1.05, 1.48)	0.011	1.22	(0.84, 1.77)	0.288	1.52	(1.07, 2.18)	0.021
EBL, logarithm	1.18	(1.06, 1.31)	0.002	1.27	(1.01, 1.59)	0.039	1.09	(0.87, 1.36)	0.471

Variables without significant association with any of the above endpoints included initial PSA, clinical T stage, percent of positive cores, PLND, pathologic N stage

OR odds ratio, *95% CI* 95% confidence interval, *NS* nerve-sparing

[a]Surgeons with <10 RARP were not included in the analysis of regular vs. selective CSD usage

[b]Documentation of any of the following NOTES: prolonged LOS, prolonged catheter, catheter replacement, readmission, mortality, rectal injury

[c]Urine leak as the reason for any of the NOTES listed above

[d]Ileus as the reason for any of the NOTES listed above

Table 5 Reported outcomes according to CSD use for pelvic surgery

Study	No. patients	Surgery	Study design	Findings/author conclusions
Patsner [14]	120	Radical hysterectomy with PLND	Prospective; single-surgeon series	· First 60 patients had CSD (Complication rate: 18.3%, LOS: 5.5 days) · Next 60 patients had CSD omitted (Complication rate: 5.5%, LOS: 4.5 days) · "Routine CSD following radical hysterectomy and PLND may be safely omitted."
Merad et al. [15]	319	Colon resection	Prospective; randomized clinical trial	· Complications: 9% w/ CSD and 8% w/o CSD (p = NS) · One patient had fistula directly imputable to CSD · "Routine abdominal drainage after colonic resection and immediate anastomosis decreases neither the rate nor the severity of anastomotic leakage. It can, occasionally, be detrimental."
Savoie et al. [16]	116	Retropubic RP	Retrospective; single-surgeon series	· CSD was not placed in 85 patients (73%) · Reasons for CSD placement: anastomotic leakage ($n = 30$) or rectal injury ($n = 1$) · LOS: 2 days for all except one patient, who had CT-guided drain placement for a urinoma and stayed 4 days · "In properly selected cases, morbidity is not increased by omitting a drain from the pelvic cavity after RRP."
Araki et al. [13]	552	Retropubic RP	Retrospective; single-surgeon series	· CSD was not placed in 419 patients (76%) · Complications: 6% w/ CSD and 5% w/o CSD ($p = 0.6$) · "Four-year experience indicates that morbidity is not increased by omitting drain from the pelvic cavity after RRP in properly selected cases"
Sharma et al. [17]	325	Retropubic RP ($n = 225$) and Robotic RP ($n = 100$)	Retrospective, observational	· CSD was not placed in 255 patients (78%) when, after successful bladder neck preservation and standard anastomosis, there was no urine leak detected · Complication rate: 11% w/ CSD and 6% w/o CSD · Frequency of complications in RRP vs. RARP and CSD vs. no CSD groups were similar ($p > 0.05$) · LOS: 2 days w/o CSD; 3.1 days w/ CSD · "Drain omission may contribute to shortened hospital stays and reduced costs without added complications."
Canes et al. [22]	208	Laparoscopic RP	Retrospective, single-surgeon series	· CSD was not placed in 157 patients (75%) · Anastomotic leak rate: 11% w/ CSD and 6% w/o CSD · Frequency of complications in RRP vs. LRP and the CSD vs. no CSD groups were similar (p = NS) · "Routine placement of CSD after LRP with a running urethrovesical anastomosis is not necessary, unless the anastomotic integrity is suboptimal intraoperatively."
Sachedina et al. [27]	846	Robotic RP	Retrospective, single-surgeon series	· CSD was not placed in 624 patients (74%) · Complications: 6% w/ CSD and 4% w/o CSD ($p = 0.25$) · "When the urethrovesical anastomosis is watertight and hemostasis is assured, CSD may be omitted without compromising patient safety and efficacy."
Danuser et al. [21]	331	Retropubic RP ($n = 205$) or Robotic RP ($n = 126$)	Randomized clinical trial and prospective, observational series	· RCT of CSD for 7 days vs. 1 day after RRP with extended PLND ($n = 132$) · Symptomatic lymphocele rate was 0% vs. 7.6% ($p = 0.06$) · Then, investigators omitted CSD for subsequent RRP ($n = 73$) and RARP ($n = 126$) · Symptomatic lymphocele rate was 6.8% after RRP and 0.8% after RARP ($p = 0.03$) · "Patients after RRP without CSD develop significantly more symptomatic lymphoceles than patients after RARP without CSD."
Musser et al. [23]	651	Robotic RP	Single surgeon. Non-randomized	· First 407 patients (2008–2010) had CSD (Complication rate: 8.4%; LOS > 1 day: 37%) · Next 230 patients (2011–2012) had CSD routinely omitted, except 6 (2.6%) with anastomotic leak (Complication rate: 7.4%,

Table 5 (continued)

Study	No. patients	Surgery	Study design	Findings/author conclusions
				p = NS; LOS > 1 day: 8.7%, $p < 0.0001$); · IR drainage of pelvic fluid collection performed in 1.6% of those with CSD and 1.8% of those without CSD (p = NS) · Sensitivity analysis: adjusted risk of grade 3–5 complications without CSD was −2.3% (−4.7% to 0.5%), p = NS · "While the present study lacks randomization, we report on a consecutive series of RARPs in which a drain was systematically omitted, thereby lessening potential selection bias. We believe that in the majority of cases any potential benefit of drain placement may be outweighed by the risks and that omission of drains may have advantages in terms of patient comfort and early hospital discharge."
Chenam et al. [20]	189	Robotic RP	Prospective; randomized clinical trial	· Non-inferiority trial comparing no CSD with CSD · Patients ($n = 5$) with inadequate hemostasis, intraoperative injury, or anastomotic leak were excluded (CSD placed in each) · Study halted by regulatory entities, did not reach accrual goal · Complications: 26.8% w/ CSD and 17.4% w/o CSD (not inferior at $p < 0.001$) · Major complications: 5.2% w/ CSD and 5.4% w/o CSD (not inferior at $p = 0.007$) · "In properly selected patients, CSD placement after RARP can be safely withheld without significant additional morbidity."
Kirmiz et al. (Current study)	6746	Robotic RP	Prospective, observational series of 115 surgeons	· CSD was not placed in 2295 patients (34%) · Regular CSD use (vs. selective) was associated with increased likelihood of LOS > 2 days (odds ratio: 1.42, $p = 0.017$) and ileus (odds ratio: 1.64, $p = 0.008$)

CSD closed suction drain, *RP* radical prostatectomy, *RRP* retropubic RP, *RARP* robot-assisted RP, *PLND* pelvic lymph node dissection, *LOS* length of stay

significant ileus and >2 day hospitalizations include increased narcotic use for the added discomfort of the CSD and/or that placement of a CSD in the abdominal cavity adjacent to bowel could cause some focal bowel irritation. These hypotheses seem clinically plausible, and could be tested moving forward with prospective assessment of these and other patient-reported outcomes.

Our results support the findings of a recent smaller, but randomized controlled, study that the incidence of adverse events (90-day overall and major (Clavien–Dindo grade >III) complications) in those without CSD was not inferior to the group who received a CSD [20]. The authors concluded that in properly selected patients, CSD placement after RARP can be safely withheld without significant additional morbidity. We hope that the present work will serve to convince more surgeons that routine CSD placement is not necessary.

There are several limitations to our work, most notably the observational study design to analyze these prospectively collected data. The MUSIC database structure permits collection of much data, but some factors (such as reason for CSD placement, extent of PLND, number of lymph nodes, or performance of cystogram) are not collected. In addition, there are likely unmeasured patient-, surgeon-, and practice-associated factors that could influence the results.

Conclusion

We demonstrate that RARP without CSD placement is safe and potentially advantageous in selected patients. We propose that surgeons reconsider regular CSD placement during RARP.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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