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ORIGINAL ARTICLE

Safe transition to opioid-free pathway after robotic-assisted laparoscopic prostatectomy

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Abstract

To determine whether local anesthetic infiltration and non-narcotic pain medications can safely reduce or eliminate opioid use following robotic-assisted laparoscopic prostatectomy while maintaining adequate pain control. After initiation of this quality-improvement project, patients undergoing robotic-assisted laparoscopic prostatectomy had surgeon-administered local anesthesia around all incisions into each successive layer from peritoneum to skin, with the majority infiltrated into the transversus abdominis muscle plane and posterior rectus sheath of the midline extraction incision. Post-operatively patients received scheduled acetaminophen plus ketorolac, renal function permitting. A retrospective review was performed for all cases over 19 months, spanning project implementation. 157 cases (76 in opioid-free pathway, 81 in standard pathway) were included. Five patients (6.6%) in the opioid-free pathway required post-operative opioids while inpatient, versus 61 (75.3%) in the standard pathway, $p < .001$. Mean patient-reported pain score on each post-operative day was lower in the opioid-free pathway compared to the standard pathway [day 0: 2.4 (SD 2.6) vs. 3.9 (SD 2.7), $p < .001$; day 1: 1.4 [SD 1.6] vs. 3.3 (SD 2.2), $p < .001$; day 2 0.9 (SD 1.5) vs. 2.6 (SD 1.9), $p < .001$]. Fewer post-operative complications were seen in the opioid-free pathway versus standard [0 vs. 5 (6.2%), $p = 0.028$], and there was no statistically significant difference in number of emergency room visits or readmissions within 3 weeks of surgery. The use of surgeon-administered local anesthetic plus scheduled non-narcotic analgesics can safely and significantly reduce opioid use after robotic-assisted laparoscopic prostatectomy while improving pain control.

Keywords Prostatectomy · Analgesia · Minimally invasive surgical procedures · Robotic surgical procedures

Introduction

Surgeons have played a critical role in the opioid epidemic. Surgery often represents a patient's first introduction to opioids and an estimated 5–8% of opioid-naïve individuals transition to chronic use after a single prescription [1, 2]. Persistent opioid use is associated with comorbid psychiatric conditions, pre-operative pain disorders, and tobacco, alcohol, and substance abuse [2]. Over-prescription is common, and exacerbates the problem. The number of prescribed pills strongly correlates with the number consumed, and unused opioids are usually stored at home, risking abuse by family or friends [3–6]. A 2018 study found that of patients undergoing surgery who stayed in the hospital for at least 24 h, 35% did not have opioids administered within 24 h prior to discharge, yet 44% of these patients still were discharged with an opioid prescription [4]. Another study found that 77% of prescribed opioids remained unused after robotic-assisted laparoscopic prostatectomy (RALP)[5]. Reasons for over-prescription include inability to e-prescribe, fear of inadequate pain control, and concern for patient dissatisfaction [1].

Several methods to decrease post-operative opioid use have been explored. Non-opioid medications such as non-steroidal anti-inflammatory drugs (NSAIDs) have been shown to reduce pain after laparoscopic surgery, possibly due to disruption of the inflammatory response. While NSAIDs appear to be more efficacious than acetaminophen for post-operative pain, the combination of both appears to

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provide better pain control than either medication alone [7, 8]. One study of RALP cases receiving scheduled acetaminophen and ketorolac post-operatively found that 61% of patients did not require opioids while in the hospital [9]. Another strategy to reduce post-operative opioid administration is the use of local anesthetic. Infiltration around incision sites following minimally invasive surgery has been shown to reduce pain scores and post-operative opioid use, and combining this with administration of a transversus abdominis plane (TAP) block further improves pain scores [10, 11]. TAP blocks are traditionally performed under ultrasound guidance by anesthesiology which adds time and cost. An alternative technique allows for surgeon administration using the laparoscopic camera to visualize that the correct plane is reached [12]. This method was shown to be non-inferior to ultrasound guidance with regard to pain scores and opioid consumption [13]. The objective of this quality-improvement project was to safely and significantly reduce opioid use after RALP while still controlling pain. We hypothesized that this could be achieved with the use of non-narcotic pain medications, specifically scheduled acetaminophen and ketorolac, and surgeon-administered local anesthesia in a modified TAP block.

Materials and methods

A single-institution quality-improvement project was implemented at the Miami Veterans Affairs Medical Center to reduce opioid use after RALP. The Institutional Review Board (IRB) approved the study as a Quality Improvement Project not subject to further IRB review. The authors certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. A retrospective analysis was performed for all RALP performed over a 19-month period, spanning the transition month between standard (S) and opioid-free (OF) pathways. There was temporal separation between the two pathways, with the exception of the transition month in which cases from both pathways overlapped.

In the new OF pathway, the technique described by Chetwood et al. using the laparoscopic camera to ensure the TAP block is correctly administered was modified, with local anesthetic infiltrated in the pre-peritoneal space and each successive layer out to the skin with the majority of volume into the transversus abdominis plane around each incision, plus posterior rectus sheath of the midline supraumbilical extraction incision at the conclusion of the case [12]. Post-operatively, acetaminophen was scheduled (650 mg every 6 h or 1 g every 6–8 h), as was ketorolac if glomerular filtration rate > 60 ml/min (15–30 mg every 6 h). Depending on surgeon preference, patients either used opioids or ibuprofen as initial breakthrough medication, with potential for escalation to opioids from ibuprofen if analgesia was insufficient. Patients were not discharged with an opioid prescription unless they required opioids post-operatively.

This was a departure from the prior standard (S) pathway where local anesthesia, if used, was only given subcutaneously and in a much lower volume. Post-operative pain management varied, with some patients receiving scheduled acetaminophen and/or ketorolac with oral and intravenous opioids for breakthrough pain, whereas others received pain medication only as-needed, starting with oral acetaminophen–oxycodone and progressing to intravenous hydromorphone or morphine if the oral medication was insufficient. Regardless of the pathway, patients were observed at least overnight, and were cleared for discharge once pain was controlled with oral medications, diet was tolerated, and they were ambulatory.

Pre-operative factors assessed included demographics, body mass index (BMI); history of drug, tobacco, or alcohol abuse; history of anxiety; and opioid prescriptions within a year of surgery. Patients were classified as having a chronic opioid prescription before surgery if they filled a prescription for opioids for 3 or more months in the 12 months prior to RALP. Intra-operative factors included duration of surgery, estimated blood loss (EBL), intra-operative opioids used, drain placement, and complications. Post-operative outcomes of interest included pain regimen, patient-reported pain score on post-operative days (POD) 0–2, time to regular diet, time to discharge order entry, complications before discharge, medications prescribed upon discharge, and whether patients presented to an emergency room, were admitted to the hospital, or were prescribed opioids within 3 weeks post-operatively. To determine emergency room presentation or readmission, we conducted a review of the VA's computerized patient record system (CPRS). For patients from Florida, the online drug monitoring program E-FORCSE (Electronic-Florida Online Reporting of Controlled Substance Evaluation program) was queried to check for opioid prescriptions pre- and post-operatively. Prescription records within CPRS were used for patients from Puerto Rico to assess both pre- and post-operative opioid prescriptions.

Comparison between opioid-free and standard pathways were performed using the chi-square test or Fisher's exact test for categorical variables, and the independent-samples t test or the Wilcoxon Mann–Whitney *U* test for continuous variables. Univariable and multivariable logistic regressions were performed to assess predictors of opioid use post-surgery. A p value ≤ 0.05 was considered statistically significant. Statistical analysis was performed in SAS v9.4 (SAS Institute Inc., Cary, NC, USA).

Results

A total of 157 patients underwent RALP over the 19-month study period, with 76 (48.4%) of these patients in the opioid-free (OF) pathway and 81 in the standard (S) pathway. There was no statistically significant difference between pathways with respect to age, race, history of alcohol or substance abuse, prior anxiety diagnosis, or any opioid prescription prior to surgery (Table 1). Patients in the OF pathway had a higher rate of obesity (40.8 vs. 29.6%), and were less likely to have a normal BMI (10.5 vs. 30.9%), compared to patients in S pathway ($p = 0.007$). They were also significantly less likely to have a history of tobacco use (18.4 vs. 35.8%, $p = 0.015$).

Patients in the OF pathway were given significantly less opioids intra-operatively (mean 32.6 vs. 48.6 morphine milligram equivalents [MME], $p < 0.001$) (Table 2), had shorter operative times (mean 3.8 vs. 4.1 h, $p = 0.007$), and lower EBL (mean 88.3 vs. 142.9 mL, $p < 0.001$). Six (7.9%) of the OF patients had a closed suction drain placed, in contrast to all of the patients in the S pathway ($p < 0.001$). One surgeon in the OF pathway had routinely omitted closed suction drain placement for over a decade, and the second surgeon transitioned to this approach during the study period. All 76 patients in the OF pathway received local anesthetic, versus 30 (37%) of patients in the S pathway, and in significantly higher volumes (mean 58.6 vs. 10.7 mL, $p < 0.001$). This represented a higher dose per kg body weight albeit within the safety limit for toxicity, with an average of 1.7 mg/kg compared to 0.3 mg/kg in the S pathway. The majority of patients received bupivacaine 0.25%, except for four who received ropivacaine 0.2 or 0.5% during a hospital shortage of bupivacaine.

Post-operative pain control regimens (Table 3) varied between the pathways, with 73 (96.1%) of OF patients receiving ketorolac, compared to 45 (55.6%) of standard patients ($p < 0.001$). 74 (97.4%) of patients in the OF pathway received scheduled acetaminophen (75% IV, 22.4% oral), compared to 42 (51.9%) of S pathway patients

Table 1 Patient demographics and pre-operative characteristics

	All *N* (%)	Standard *N* (%)	Opioid-free *N* (%)	*P*
All	157 (100.0)	81 (100.0)	76 (100.0)	
Age				
< 60	26 (16.6)	14 (17.3)	12 (15.8)	0.955
60–70	93 (59.2)	48 (59.3)	45 (59.2)	
> 70	38 (24.2)	19 (23.5)	19 (25.0)	
Mean (SD)	65.3 (6.3)	65.2 (6.2)	65.4 (6.4)	0.904
Median (Min, Max)	66 (43, 78)	66 (46, 78)	65.5 (43, 77)	
Race/Ethnicity				
White/Non-Hispanic	24 (15.3)	13 (16.0)	11 (14.5)	0.405
White/Hispanic	92 (58.6)	46 (56.8)	46 (60.5)	
Black	32 (20.4)	15 (18.5)	17 (22.4)	
Unknown	9 (5.7)	7 (8.6)	2 (2.6)	
BMI (kg/m^2)				
18–24.9 (Normal)[#]	33 (21.0)	25 (30.9)	8 (10.5)	**0.007**
25–29.9 (Overweight)	69 (43.9)	32 (39.5)	37 (48.7)	
≥ 30 (Obese)	55 (35.0)	24 (29.6)	31 (40.8)	
Mean (SD)	28.7 (5)	27.9 (4.7)	29.5 (5.1)	0.051
Median (Min, Max)	28 (13.8, 45.2)	27.5 (19.5, 41.6)	28.6 (13.8, 45.2)	
History of tobacco use	43 (27.4)	29 (35.8)	14 (18.4)	**0.015**
History of alcohol abuse	30 (19.1)	14 (17.3)	16 (21.1)	0.548
History of substance abuse	10 (6.4)	3 (3.7)	7 (9.2)	0.158
Anxiety diagnosis	23 (14.6)	14 (17.3)	9 (11.8)	0.335
Opioid prescription within 1 year before surgery	29 (18.5)	15 (18.5)	14 (18.4)	0.987
Chronic opioid prescription before surgery	8 (5.1)	2 (2.5)	6 (7.9)	0.122

The bold value designate a statistically signficant value

P: *p*-value from the chi-square test or the Fisher's exact test for categorical variables and Student's *t* test for continuous variables

[#]Included one patient with BMI 13.8

Table 2 Intra-operative medications used and surgical variables

	Standard *N* (%)	Opioid-free *N* (%)	*P*
Intra-op morphine milligram equivalents (MME)	81 (100.0)	76 (100.0)	
Mean (SD)	48.6 (30)	32.6 (19.6)	**< 0.001**
Median (Min, Max)	40 (10, 170)	29.4 (5, 150)	
Local anesthetic	30 (37.0)	76 (100.0)	**< 0.001**
Type of local			
Bupivacaine 0.25%	30 (100)	72 (94.7)	NA
Ropivacaine 0.2%	0	2 (2.6)	
Ropivacaine 0.5%	0	2 (2.6)	
Amount (mL)			
N (missing)	30 (51)	76 (0)	
Mean (SD)	10.7 (4)	58.6 (11.9)	**< 0.001**
Median (Min, Max)	10 (3, 20)	60 (7, 80)	
Dose (mg/kg)			
N (missing)	30 (51)	76 (0)	
Mean (SD)	0.3 (0.1)	1.7 (0.4)	**< 0.001**
Median (Min, Max)	0.3 (0.1, 0.8)	1.7 (0.2, 2.7)	
Surgery duration (hours)			
Mean (SD)	4.1 (1)	3.8 (0.6)	**0.007**
Median (Min, Max)	4 (1.5, 8.5)	3.8 (2.3, 5.8)	
Estimated blood loss (mL)			
Mean (SD)	142.9 (76.4)	88.3 (70.7)	**< 0.001**
Median (Min, Max)	100 (50, 500)	50 (15, 350)	
Drain left in place	81 (100.0)	6 (7.9)	**< 0.001**

The bold values designate a statistically signficant value

P: *p*-value from the chi-square test or the Fisher's exact test for categorical variables and Student's *t* test for continuous variables

NA Not applicable

($p < 0.001$). The patients in the S pathway who received acetaminophen in combination with an opioid such as oxycodone on an as-needed basis were not considered to have received scheduled acetaminophen. Ten (10.5%) of the OF patients received breakthrough ibuprofen. Use of post-op opioids was significantly lower in the OF than in the S pathway [6 (6.6%) vs. 61 (75.3%) patients, $p < 0.001$] and the median dosage was lower in the OF pathway (median: 7.5 vs. 32 MME, $p = 0.002$). OF patients were started on a regular diet earlier (average 7 h post-op vs. 17 h in S pathway, $p < 0.001$), and had fewer complications prior to discharge (0 vs. 6.2%, $p = 0.028$). Complications observed in five patients from the S pathway included ileus ($n = 2$), anemia requiring transfusion ($n = 2$), anastomotic leak ($n = 2$), pulmonary embolism ($n = 1$), and bacteremia ($n = 1$). Opioid prescriptions were significantly reduced for patients on the OF pathway, with 74 (97.4%) of patients discharged without an opioid prescription, compared to 4 (4.9%) on the S pathway ($p < 0.001$). There was no difference in prescribed opioids within 3 weeks following surgery, with six (7.4%) of S and seven (9.2%) of OF patients receiving an opioid prescription within that timeframe ($p = 0.682$). There was also no statistically significant difference in number of emergency room visits [18 (22.2%) of S vs. 14 (18.4%) of OF, $p = 0.555$] or readmissions [8 (9.9%) of S vs. 5 (6.6%) of OF, $p = 0.454$] within 3 weeks following surgery between the two groups.

Despite decreased opioid utilization, patients in the OF pathway had significantly lower average patient-reported pain score on POD 0–2, ranging from 1.5 to 1.9 points less, and were significantly more likely to have an average pain score ≤ 3 (Table 4). Additionally, significantly more patients in the OF pathway had an average pain score ≤ 1 on each post-operative day [34 (42.1%) vs. 9 (11.1%), $p < 0.001$]. While most patients in OF pathway did not have a drain, pain scores and post-operative opioid use was comparable between OF patients with and without a drain, and lower than S pathway; however, this did not reach statistical significance likely due to small sample size.

Analysis of the role of ketorolac is also shown in Table 4, with breakdown of the S group into those who did and did not receive ketorolac compared to the OF group. On POD 0, there was a significantly reduced pain score in the patients in the OF group compared to the S groups with and without ketorolac (2.2 vs. 4.1 and 3.7, respectively, $p < 0.001$ and $p = 0.008$). On POD 1, an improvement in pain score in the S group receiving ketorolac emerged, with a statistically significant lower pain score in the S group given ketorolac compared to the S group without ketorolac (2.7 vs. 4.0, $p = 0.002$). Regardless of S group, the pain score remained significantly higher than the OF group receiving ketorolac, who had a mean reported pain score of 1.3 ($p < 0.001$ in both comparisons). On POD 2, the trend towards lower pain score in the S group receiving ketorolac (mean 1.8) compared to the group without ketorolac (mean 3.3) remained, though the difference was not statistically significant; both were significantly higher than the OF group with ketorolac (mean 0.7, $p = 0.004$ and $p < 0.001$, respectively). Additionally, patients in the OF group with ketorolac had the lowest opioid use (2.7%, $p < 0.001$), though the S group receiving ketorolac used opioids less often than the S group without ketorolac (62.2% compared to 86.1%).

Discussion

Overuse and over-prescription of opioids is a significant problem even following minimally invasive surgeries such as RALP, with opioid-naïve patients moving to persistent use in 5–8% of cases [2, 4, 6, 14]. In this quality-improvement project, we accomplished our goal of safely controlling

Table 3 Post-operative and discharge medications used with outcomes

	Standard *N* (%)	Opioid-free *N* (%)	*P*
All	81 (100.0)	76 (100.0)	
Ketorolac	45 (55.6)	73 (96.1)	**< .001**
Mean daily dose (SD)	62.6 (43.5)	53.3 (20.4)	0.119
Acetaminophen	42 (51.9)	74 (97.4)	**< 0.001**
IV	20 (24.7)	57 (75.0)	
PO	22 (27.2)	17 (22.4)	
Mean daily dose (SD)	3018 (1127.2)	3083.4 (827.3)	0.721
Ibuprofen	0	8 (10.5)	**0.003**
Mean daily dose (SD)		709 (407.1)	NA
Post-op opioid use (MME)	61 (75.3)	5 (6.6)	**< 0.001**
Mean (SD)	37.8 (33.1)	10.2 (7.5)	
Median (Min, Max)	32 (2, 230)	7.5 (0.8, 20)	0.002§
Oral post-op opioid use (MME)	59 (72.8)	4 (5.3)	**< 0.001**
Mean (SD)	37.9 (28.6)	12.5 (6.1)	
Median (Min, Max)	30 (7.5, 180)	11.3 (7.5, 20)	0.011§
Intravenous post-op opioid use (MME)	35 (43.2)	2 (2.6)	**< 0.001**
Mean (SD)	4.6 (8.1)	2.4 (2.3)	
Median (Min, Max)	2 (2, 50)	2.4 (0.8, 4)	0.491§
Opioids prescribed at discharge (MME)	77 (95.1)	2 (2.6)	**< 0.001**
Mean (SD)	162.5 (50.8)	75 (0)	
Median (Min, Max)	150 (90, 250)	75 (75, 75)	**0.003**§
Time to regular diet (hours)			
N (missing)	78 (3)	76 (0)	
Mean (SD)	17 (3.7)	7 (8.5)	**< 0.001**
Median (Min, Max)	18.2 (0.1, 23.5)	0 (0, 24.7)	
Hours post-op at discharge order entry			
Mean (SD)	41.2 (63.9)	33.8 (20.7)	0.332
Median (Min, Max)	25.9 (12.5, 547.5)	25.4 (14.5, 141)	
Post-op complications before discharge	5 (6.2)	0	**0.028**
Within 3 weeks after surgery			
Opioids prescribed	6 (7.4)	7 (9.2)	0.682
ER visit	18 (22.2)	14 (18.4)	0.555
Readmission	8 (9.9)	5 (6.6)	0.454

The bold values designate a statistically signficant value

post-op post-operative, *MME* morphine milligram equivalents

*Excluded 87 patients discharged before POD 2

P: *p*-value from the chi-square test or the Fisher's exact test for categorical variables and two samples Student's *t* test for continuous variables. §Exceptions: *p*-value from Mann–Whitney-Wilcoxon *U* test for some prescribed MME measurements which are not normally distributed with small sample size in one group

post-operative pain adequately without opioids, thus eliminating the need for an opioid prescription at discharge. This was achieved by surgeon-administered local anesthetic infiltration around each incision with majority administered in the transversus abdominis plane (TAP) and scheduled post-operative acetaminophen and ketorolac. This approach led to a significant reduction in opioid use, with only 6.6% of OF patients receiving opioids, versus 75.3% of patients in the S pathway. Despite the reduction in opioids, patients in the OF pathway had significantly lower pain scores on each post-operative day. The lower complication rates in the OF group is likely related to sample size, and only the two ileus cases observed in the S pathway could potentially be attributed to opioid use. Finally, the lack of significant difference between S and OF groups for opioid prescriptions written within 3 weeks after surgery is encouraging for clinicians who may have reservations about discharging patients after

Table 4 Relationship between post-operative pain scores and opioid use with or without ketorolac

Variable	Standard	Opioid-free		Standard		Opioid-free	
				Ketorolac	No Ketorolac	Ketorolac	
	N (%)	*N* (%)	*P*	N (%)	*N* (%)	*N* (%)	*P*
All	81 (100.0)	76 (100.0)		45 (100.0)	36 (100.0)	73 (100.0)	
Average pain score POD 0							
≤ 3	35 (43.2)	50 (65.8)	**0.005**	17 (37.8)	18 (50.0)	50 (68.5)	**0.004**
> 3	46 (56.8)	26 (34.2)		28 (62.2)	18 (50.0)	23 (31.5)	
Mean (SD)	**3.9 (2.7)**	**2.4 (2.6)**	**< 0.001**	**4.1[a] (2.7)**	**3.7[b] (2.8)**	**2.2[ab] (2.5)**	**< 0.001**
Median (Min, Max)	4 (0, 10)	1.7 (0, 10)		4 (0, 9)	3.2 (0, 10)	1.5 (0, 10)	
Estimated mean (SE)[¤]				**4.2[A] (0.4)**	**3.6 (0.5)**	**2.5[A] (0.4)**	**0.003**
Average pain score POD 1							
≤ 3	42 (51.9)	61 (80.3)	**< 0.001**	28 (62.2)	14 (38.9)	60 (82.2)	**< 0.001**
> 3	39 (48.1)	15 (19.7)		17 (37.8)	22 (61.1)	13 (17.8)	
Mean (SD)	**3.3 (2.2)**	**1.4 (1.6)**	**< 0.001**	**2.[cd] (2)**	**4.0[ce] (2.2)**	**1.3[de] (1.5)**	**< 0.001**
Median (Min, Max)	3 (0, 7.7)	1 (0, 6.5)		2.5 (0, 7)	4.1 (0, 7.7)	0.9 (0, 6.5)	
Estimated mean (SE)[¤]				**2.8[CD] (0.3)**	**4.0[CE] (0.3)**	**1.7[DE] (0.3)**	**< 0.001**
Scheduled acetaminophen subset				29 (64.4)	13 (36.1)	71 (97.3)	
Average pain score POD 0							
Mean (SD)				4.0[g] (2.8)	3.1 (2.5)	2.3[g] (2.6)	**< 0.001**
Estimated mean (SE)				4.0[G] (0.5)	3.0 (0.8)	2.4[G] (0.4)	**< 0.001**
Average pain score POD 1							
Mean (SD)				2.2[hi] (1.8)	4.1[hj] (2.3)	1.4[ij] (1.5)	**< 0.001**
Estimated mean (SE)				2.3[HI] (0.3)	4.1[HJ] (0.5)	1.5[IJ] (0.2)	**< 0.001**
No scheduled acetaminophen				16 (35.6)	23 (63.9)	2 (2.7)	
Average pain score POD 0							
Mean (SD)				4.5 (2.6)	4.0 (3.0)	0.5 (0.7)	NA
Estimated mean (SE)				4.0 (0.8)	4.1 (0.7)	NA	NA
Average pain score POD 1							
Mean (SD)				3.7 (2.1)	4.0 (2.3)	0.6 (0.3)	NA
Estimated mean (SE)				3.7 (0.6)	3.8 (0.6)	NA	NA
Average pain score POD 2*							
≤ 3	21 (56.8)	31 (93.9)	**< 0.001**	13 (76.5)	8 (40.0)	31 (96.9)	**< 0.001**
> 3	16 (43.2)	2 (6.1)		4 (23.5)	12 (60.0)	1 (3.1)	
Mean (SD)	**2.6 (1.9)**	**0.9 (1.5)**	**< 0.001**	**1.8[f] (1.6)**	**3.3[g] (1.9)**	**0.7[fg] (1.2)**	**< 0.001**
Median (Min, Max)	2.8 (0, 6.2)	0 (0, 6)		1.7 (0, 4.6)	3.7 (0, 6.2)	0 (0, 4.5)	
Average pain score overall							
≤ 1	9 (11.1)	32 (42.1)	**< 0.001**				
> 1	72 (88.9)	44 (57.9)					
Opioid use post-op (MME)							
No	22 (27.2)	72 (94.7)	**< 0.001**	17 (37.8)	5 (13.9)	71 (97.3)	**< 0.001**
Yes	59 (72.8)	4 (5.3)		28 (62.2)	31 (86.1)	2 (2.7)	
Mean (SD)	37.9 (28.6)	12.5 (6.1)	–	31.6 (17.6)	43.5 (35.1)	11.3 (5.3)	
Median (Min, Max)	30 (7.5, 180)	11.3 (7.5, 20)	0.011[§]	30 (7.5, 75)	37.5 (7.5, 180)	11.3 (7.5, 15)	0.136[§]

The bold values designate a statistically signficant value

POD Post-operative day, when day 0 refers to same day as surgery. *MME* morphine milligram equivalents. SD: standard deviation, SE: standard error, *OR (95% CI)* odds ratio and corresponding 95% confidence interval

P: *p*-value from the chi-square test or the Fisher's exact test for categorical variables, and from the Student's *t* test or ANOVA for comparison of means. *NA* not applicable; statistical testing of 3 group means not reliable given n = 2 in one group. Statistically significant pairwise means differences:

[a]$p < 0.001$, [b]$p = 0.008$, [A]$p = 0.003$, [c]$p = 0.002$, [d]$p < 0.001$, [e]$p < 0.001$, [C]$p = 0.009$, [D]$p = 0.004$, [E]$p < 0.001$, [f]$p = 0.004$, [g]$p < 0.001$, [F]$p = 0.006$, [g]$p = 0.005$, [G]$p = 0.005$, [h]$p = 0.001$, [i]$p = 0.034$, [j]$p < 0.001$, [H]$p = 0.002$, [I]$p = 0.0496$, [J]$p < 0.001$

[¤]Multivariable linear regression models for average pain score POD 0 and POD 1 (continuous variable) assessing effect of group, with adjustment for acetaminophen use (No, Yes), tobacco, and BMI (obese, non-obese)

*Excluded 87 patients discharged before POD 2

Table 4 (continued)

[§] *P*-value from Mann–Whitney-Wilcoxon *U* test for some prescribed MME measurements that were not normally distributed with small sample size in one group

RALP without an opioid prescription given the inability to e-prescribe [1].

While the patients in this study were not randomized, they were temporally separated so there was overlap between the standard and opioid-free pathway patients only during the transition month. Potential confounding factors, including the use of a drain and use of ketorolac were examined through statistical analysis in an effort to elucidate their role in the results. Drain use was surgeon-dependent, with six patients having a drain in the OF pathway, compared to all patients in the S pathway. Pain scores and post-operative opioid use were comparable between OF patients with and without a drain, and lower than S pathway patients though not statistically significant likely due to small sample size. Ketorolac was used in 96% of cases in the OF group, compared to 56% of those in the S group. As shown in Table 4, lower pain scores were not seen in S patients receiving ketorolac on POD 0, however, a statistically significant decrease in pain compared to S patients not receiving ketorolac was seen on POD 1. On all post-operative days, OF patients receiving ketorolac had significantly lower pain scores than S patients with and without ketorolac. Post-operative opioid use was also varied in S patients whether they were given ketorolac or not, with 62.2 and 86.1% using opioids, respectively, compared to 2.7% of OF patients. These findings suggest that the lower pain scores and opioid usage in the OF pathway were not solely due to ketorolac usage.

This quality-improvement initiative builds upon previous studies in the field, combining multiple techniques to safely and efficiently control pain while reducing opioid use. Wong et al. found that opioid-free analgesia following RALP was possible in their study of 44 patients who received scheduled intravenous acetaminophen and ketorolac post-operatively. While 61.4% of patients avoided opioids during hospitalization, over a third still required opioid medications [9]. The use of TAP block for reduction of in-hospital opioid use is supported by several studies including one by Dal Moro et al., which prospectively randomized 100 patients to receive TAP block or placebo administered under ultrasound guidance prior to surgery start. All patients received scheduled acetaminophen post-operatively, but those in the TAP group required less rescue medication. Neither of these studies examined opioid prescriptions upon discharge [9, 15]. Though Dal Moro et al.'s study does not quantify patient-reported pain, TAP block has been shown to improve post-operative pain scores in other types of robotic surgery, even if surgeon-administered [13, 15, 16].

This study has several strengths, including lack of exclusion criteria, robust study size, and the advantage of the Veteran's Affairs Computerized Medical Records System (CPRS) which allows patient information to be reviewed across all Veteran's Affairs (VA) hospitals. However, if a patient was seen at an emergency room or admitted to a hospital outside the VA system, this was not captured unless documented in their post-operative visit note. Additionally, the use of E-FORCSE allows for opioids prescribed outside VA hospitals to be captured, but the system does not extend to Puerto Rico, where many of our patients reside. While the sample size was robust, it was conducted at a single institution with a limited number of surgeons. This impacts intra-operative variables such as operative time and EBL, and there is variation in surgeon preference for drain use and when regular diet is given post-operatively. One area that was not examined is the non-opioid medications given in the operating room or in pre-op, which can impact post-operative pain and opioid use. Future research in this area may improve post-operative pain control and allow even further reduction in opioids.

Conclusions

This retrospective review illustrates that the combination of layered local anesthesia infiltration, with the majority of volume in the transversus abdominis muscle plane and posterior rectus sheath of the midline extraction incision, in conjunction with a non-opioid-based analgesic regimen can safely and significantly reduce post-operative opioid use in patients undergoing robotic-assisted laparoscopic prostatectomy. These techniques have the potential to be applied to other minimally invasive procedures to improve pain control and reduce reliance on post-operative opioids.

Authors' contributions Authors Leslie A Deane, Chad R Ritch, Joshua Livingstone, Christina Matadial, Mara Carrasquillo, and Laura Horodyski contributed to the study conception and design. Material preparation and data collection were performed by Laura Horodyski, Brittany Ball, Clarence Emile, and Adriana Rhodes. Analysis was performed by Feng Miao and Isildinha M Reis. The first draft of the manuscript was written by Laura Horodyski and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The study data will be made available for review upon request.

Declarations

Conflicts of interest The authors Laura Horodyski, Brittany Ball, Clarence Emile, Adriana Rhodes, Feng Miao, Isildinha M Reis, Mara Z Carrasquillo, Joshua Livingstone, Christina Matadial, Chad R Ritch, and Leslie A Deane declare that they have no conflict of interest relevant to this article.

Ethical approval The Institution Review Board (IRB) approved the study as a Quality Improvement Project not subject to further IRB review. The authors certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was not obtained given the retrospective review design of this study.

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