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Large Reduction in Opioid Prescribing by a Multi-pronged Behavioral Intervention after Major Urologic Surgery

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Abstract

Background: Surgeons play a pivotal role in combating the opioid crisis that currently grips the United States. Changing surgeon behavior is difficult, and the degree to which behavioral science can steer surgeons towards decreased opioid prescribing is unclear.

Methods: We conducted a single institution, single arm, pre- and post-intervention study examining prescribing of opioids by urologists for adult patients undergoing prostatectomies

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or nephrectomies. The primary outcome was quantity of opioids prescribed in oral morphine equivalents (OMEs) after hospital discharge. The primary exposure was a multi-pronged behavioral intervention designed to decrease opioid prescribing. The intervention had three components: 1) formal education; 2) individual audit feedback; and 3) peer comparison performance feedback. There were three phases to the study: a pre-intervention phase, an intervention phase, and a wash-out phase.

Results: 382 patients underwent a prostatectomy and 306 patients underwent a nephrectomy. The median OMEs decreased from 195 to 19 in the prostatectomy patients and from 200 to 0 in the nephrectomy patients (both $p<0.05$). The median OMEs prescribed did not increase during the wash-out phase. Prostatectomy patients discharged with opioids had higher levels of anxiety than patients discharged without opioids ($p<0.05$). Otherwise, prostatectomy and nephrectomy patients discharged with and without opioids did not differ in their perception of postoperative pain management, activity level, psychiatric symptoms, and somatic symptoms (all $p >0.05$).

Conclusions: Implementing a multi-pronged behavioral intervention significantly reduced opioid prescribing for patients undergoing prostatectomies and nephrectomies without compromising patient-reported outcomes.

Condensed abstract:

Surgeons can play a pivotal role in combating the opioid crisis. In this single institution, single arm, pre- and post-intervention study, we observed a significant decrease in the median oral morphine equivalents prescribed after prostatectomies (195 to 19) and after nephrectomies (200 to 0) without compromising patient-reported outcomes after implementing a multi-pronged behavioral intervention.

Keywords

opioids; behavioral intervention; behavioral science; prostatectomy; nephrectomy

INTRODUCTION

Surgeons play a pivotal role in creating and combating the opioid crisis that grips the United States. They are the “gatekeepers” who provide many patients their first exposure to opioids.[1] Over 6% of these patients will become new persistent opioid users after recovering from their surgery.[1]

Changing surgeon behavior is difficult, and the degree to which behavioral science can steer surgeons towards decreased opioid prescribing is unclear. Historically, surgeons felt pressure to assess and treat pain in all patients.[2,3] Until recently, patients answered questions on the Center for Medicare and Medicaid Services’ Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey about how well their pain was managed—a survey that created incentives for hospitals to improve their quality of care.[4] Yet, now there is a heightened awareness about how opioid-naïve patients can become persistent users even after a single opioid prescription.[5] Seemingly daily, articles surface in the lay press about the harms of opioids, making the public keenly aware of this issue. Further, significant changes in perioperative pain management (e.g., Enhanced Recovery after Surgery [ERAS]) protocols) provide new opportunities for non-opioid pain control. Even if surgeons respond to a behavioral intervention aimed to reduce opioid prescribing, whether that prescribing behavior will persist after the intervention ceases is debatable.[6]

To examine these issues further, we conducted a study that involved a multi-pronged behavioral intervention designed to reduce the quantity of opioids prescribed by surgeons to patients undergoing major urologic surgery. Specifically, we assessed whether formal education, individual audit feedback, and peer comparison performance feedback reduced surgeon prescribing of opioids after prostatectomies and nephrectomies—two major urologic oncology procedures that traditionally required opioids for pain control after hospital discharge. We hypothesized that the behavioral intervention would lead to a reduction in opioid prescribing without worsening patients' postoperative pain control. Further, we believed the effect would persist after the intervention ceased.

METHODS

Study Population

We examined the prescribing of opioids by urologists for adults (18 years or older) undergoing prostatectomies or nephrectomies (radical nephrectomies, partial nephrectomies, and nephroureterectomies) to treat cancer, starting in November 2018 and ending in July 2019. We included all urologists in our academic department who performed these surgeries. We chose to examine prostatectomies and nephrectomies for a few reasons. First, they are common urologic surgeries that historically required opioids postoperatively.[7] Second, we previously demonstrated that the quantity of opioids patients consumed after these surgeries was significantly less than the quantity used.[8] Third, the majority of patients undergoing these surgeries participated in a specific ERAS protocol aimed to minimize the use of perioperative opioids, among other things.[9] Prostatectomies included those performed through a traditional open approach (lower midline incision) or a minimally invasive approach (robotically). Nephrectomies included those performed through an open approach (typically a subcostal or flank incision) or a minimally invasively approach (i.e., hand-assisted laparoscopy, pure laparoscopy, or robotically). We excluded patients who had another planned surgery during the same hospitalization because it could impact opioid prescribing.

Study design—This was a single institution, single arm, pre- and post-intervention study examining prescribing of opioids by urologists. The primary outcome was the quantity of opioids prescribed in oral morphine equivalents (OMEs) after hospital discharge. We converted the number of opioid pills prescribed into OMEs using the morphine conversion factor provided by the Centers for Medicare and Medicaid Services, which accounts for variation in opioid concentrations in pills.[10] The primary exposure was a 3-pronged behavioral intervention designed to decrease opioid prescribing. The intervention included, 1) formal education with a grand rounds presentation to the majority of urology residents and surgeons on the risks of becoming a persistent opioid user in the postoperative setting as well as alternative non-opioid pain management regimens; 2) individual audit feedback (BJD) that included reinforcement via text messages and emails based on individual results in the month prior; and 3) peer comparison performance feedback that consisted of monthly, surgeon-identifiable reports distributed to the entire department with each surgeon's quantity of opioids prescribed compared to other surgeons in the study. Examples of individual audit feedback and peer comparison performance feedback are included (Appendix 1).

There were three phases to the study: a pre-intervention phase, an intervention phase, and a wash-out phase. The pre-intervention phase occurred over 4 months prior to the intervention wherein we collected baseline opioid prescribing data. The intervention phase extended over 6 months and reflected the period of the behavioral intervention. The wash-out phase constituted a 3-month period in which we collected data after the intervention ceased. We included a wash-out phase because the effects of some interventions lessen once the intervention is removed.[11] To be included in the study, for a given surgery (prostatectomy or nephrectomy) attending urologists needed to perform at least one surgery in the pre-intervention phase and one surgery in either the intervention or wash-out phase. We collected demographic information on the participating surgeons. The ERAS program was not part of the intervention per se, but was ongoing and remained substantively unchanged throughout the study.

Patient reported outcomes

As a secondary outcome, we assessed patients' perceptions about their postoperative pain management using the International Pain Outcomes questionnaire, which was distributed to patients at their 2-week postoperative visit. This questionnaire comprises key patient-level outcomes of postoperative pain management, including perceived pain control, activity level, psychiatric symptoms (i.e., feelings of anxiety, depression, being frightened, or helplessness), and somatic symptoms (i.e., nausea, drowsiness, itchiness, or dizziness).[12] The questions related to these topics are scored on a 0-10 scale, where 0 indicates no symptoms and 10 indicates severe symptoms. The questionnaire has achieved satisfactory psychometric quality for both reliability and validity.[12] In addition, for the first few months of the study, we kept track of patient phone calls, interventions from primary care physicians, emergency room visits, and readmissions.

Statistical Analyses

We first compared demographics of prostatectomy and nephrectomy patients stratified by the study phase (i.e., pre-intervention, intervention, wash-out) using ANOVA for continuous variables and Fisher's exact test for categorical variables. Race was self-determined by patients and was examined because it can influence pain management.[13] We then reported the demographics of the participating urologic surgeons. Next, for each type of surgery (prostatectomy, nephrectomy), we calculated the median of each surgeon's median OMEs prescribed during each of the three study phases. With the surgeon as the unit of analysis, we compared the median OMEs prescribed during the pre-intervention and intervention phase as well as the pre-intervention and wash-out phase using the Wilcoxon sign-rank test. A Bonferroni correction was applied for multiple comparisons. For each month, we also calculated each surgeon's number of procedures performed and median OMEs prescribed.

For the patient reported outcomes, we first compared patient demographics between those who were prescribed opioids and non-opioids after discharge. We then compared the demographics of survey responders and non-responders. In both instances, we used two-sample t-tests for continuous variables and Fisher's exact tests for categorical variables. Next, we compared the average patient-reported outcomes on the International Pain Outcomes questionnaire using the two-sample t-test.

We performed two sensitivity analyses to assess the robustness of the results. First, we repeated the analyses after excluding the highest volume surgeon for each type of surgery to examine whether this skewed the results. Second, we excluded the co-principal investigators to address researcher bias.

We performed all data management and analyses in STATA v15.1 (Stata Corporation, College Station, TX). All tests were two-sided, and the probability of a type I error was set at 0.05. The University of Pittsburgh institutional review board approved this study.

RESULTS

A total of 382 patients underwent a prostatectomy: 120 in the pre-intervention phase, 178 in the intervention phase, and 84 in the wash-out phase (Table 1). The patient demographics did not differ across the three phases (all p>0.05). Compared with national trends, there were a greater number of prostatectomies performed through an open approach.[14] A total of 306 patients underwent a nephrectomy: 92 in the pre-intervention phase, 142 in the intervention phase, and 72 in the wash-out phase. Patient characteristics did not differ across the three phases, except for hospital length of stay: fewer patients stayed 3 or more days in the wash-out phase (p=0.02). About half the surgeries were performed through a minimally invasive approach. Nearly 60% were partial nephrectomies and 3% were nephroureterectomies.

Thirteen urologists were included in the study, 10 of whom were in both the prostatectomy and nephrectomy cohorts. The average years in practice was 17 (range 4-36 years), and 8 urologists (62%) were fellowship trained.

The median OMEs prescribed among surgeons decreased significantly between the pre-intervention phase and intervention phase as well as between the pre-intervention phase and wash-out phase for both prostatectomy (Figure 1A; both p=0.01) and nephrectomy (Figure 1B; both p=0.01). Specifically, the median OMEs decreased from 195 to 19 in the prostatectomy patients and from 200 to 0 in the nephrectomy patients. There was no difference in the median OMEs prescribed during the intervention and wash-out phases for both prostatectomy and nephrectomy (both p>0.05). After excluding the highest volume surgeon (Appendix 2A-B) and after excluding the co-principal investigators (Appendix 2C-D), the results were similar.

The median OMEs prescribed per surgeon each month of the study is demonstrated for prostatectomy (Figure 2A) and nephrectomy (Figure 2B). By the end of the study, 40% and 60% of the attendings prescribed a median of 0 opioids for prostatectomy and nephrectomy, respectively.

The demographics of the patients responding to the postoperative pain management survey stratified by whether they were prescribed opioids are shown in Table 2. For prostatectomy, the response rate was 18%. Eighty-five percent of patients discharged with opioids had an open approach as opposed to a minimally invasive approach (p<0.001). A greater proportion of patients who were discharged with opioids stayed at least 2 days in the hospital (p=0.001). For nephrectomy, the response rate was 26%. Seventy-one percent of patients discharged with opioids had an open approach as opposed to a minimally invasive approach (p=0.17). The demographics of the survey responders did not differ significantly from the survey non-responders (Appendix 3).

The patient reported outcomes are demonstrated for those who underwent a prostatectomy (Figure 3A-D) and nephrectomy (Figure 3E-F). Prostatectomy patients discharged with opioids had higher levels of anxiety than patients discharged without opioids (p<0.05). Otherwise, prostatectomy and nephrectomy patients discharged with and without opioids did not differ in their perception of postoperative pain management, activity level, other psychiatric symptoms (i.e., depression, being frightened, or helplessness), and somatic symptoms (all p >0.05). Over the first few months of the study, we did not observe an increase in patient phone calls, interventions from primary care physicians, emergency room visits, or readmissions.

The number of prostatectomies and nephrectomies each surgeon performed each month is demonstrated in Appendix 4.

DISCUSSION

This study is the first of its kind to demonstrate a dramatic decrease in opioid prescribing for major surgery after a behavioral intervention. The decrease in opioid prescribing was sustained throughout a wash-out phase after the behavioral intervention ceased. Other than increased anxiety in patients prescribed opioids, there were no differences in perceived pain management, activity level, psychiatric symptoms, or somatic symptoms between patients discharged with and without opioids.

We observed a significant decrease in opioid prescribing department-wide for both prostatectomies and nephrectomies. By the end of the study period, the median number of OMEs prescribed decreased from 195 to 19 for prostatectomies and from 200 to 0 for nephrectomies. We are not advocating for no opioids in all cases. Some patients may require opioids, such as those with prior opioid use.[15] However, the majority of patients will not need opioids after discharge.

There are a couple reasons why most patients had adequate pain control without opioids. First, our institution implements a robust perioperative pain management program that incorporates an ERAS protocol, which emphasizes multimodal analgesia. This protocol effectively controls pain and promotes early recovery in many surgical patients, including those undergoing urologic procedures.[9,16,17] Our institution's ERAS protocol includes encouraging regular activity and good nutrition preoperatively, clear liquids up to 3 hours prior to surgery, and gabapentin and acetaminophen in the preoperative holding area. Patients are offered perioperative single-shot quadratus lumborum pain blocks, which consist of 20ml of 0.5% ropivacaine, 30mcg of dexmedetomidine, and 4mg of dexamethasone on each side of the abdomen.[18] Intraoperatively, management includes ketamine for pain control and close monitoring of fluids to ensure euvolemia. Postoperatively, patients receive ketamine, gabapentin, acetaminophen, and ketorolac (in the prostatectomy patients). Opioids are available for rescue. Upon discharge, patients are prescribed acetaminophen, ibuprofen, and opioids if needed.

Second, given the magnitude of the opioid crisis, many patients want to manage their pain without opioids if possible. In the preoperative setting, physicians advise patients to expect some pain or discomfort, but ensure them that this will not negatively impact their healing after surgery.

It was reassuring that patients discharged without opioids reported similar pain control as those discharged with opioids. For both prostatectomies and nephrectomies, patients perceived similar pain management, activity level, psychiatric symptoms (other than increased anxiety in prostatectomy patients discharged with opioids), and somatic symptoms, supporting the notion that the majority of patients can have adequate pain control with a non-opioid pain regimen upon discharge.

The sustained effect of the behavioral intervention stems from its design, which tailored to the targeted individuals (surgeons) and the work environment in which it was implemented (academic urology department). In developing the choice architecture, we considered the Mindspace framework for behavioral change, which provides nine robust elements that affect behavior through automatic neurobiological systems and psychological processes.[19-21] Of these nine elements, three were particularly relevant to physicians within the department, namely "messenger", "norms", and "ego". Messenger suggests that people are heavily influenced by the individual who communicates information to them, norms relies on the fact that individuals are strongly influenced by what others do, and ego suggests that people act in ways that make them feel better about themselves.[21] With these elements in mind, the intervention included, 1) individual audit feedback from one of the principal investigators who was a professor in the department with a large clinical and research presence; and 2) monthly peer comparison performance feedback via a department-wide email distributing a bar chart with each participating surgeon by name along with the median number of opioid pills prescribed, allowing physicians to directly compare themselves to their colleagues.

A fourth element, "defaults", was most relevant to the work environment, which includes urology residents. Defaults is based on the idea that individuals "go with the flow" of preset options.[21] In our department, residents typically prescribe the opioids for discharged patients. In straightforward cases, the quantity of opioids prescribed is standardized for each surgeon. Thus, once a surgeon decides to reduce the quantity of opioids prescribed, this becomes the default, or habit, for residents unless directed otherwise. With information shared this way, it increases the sustainability of the desired effect even after the intervention ceases.[6]

Our findings have several policy implications. First, the sustainable decrease in opioid prescribing observed in the wash-out phase shows that an intervention can remain effective even after it ceases. This is an important finding given that many departments have a finite amount of resources, making them unable to invest in an ongoing intervention. Second, our study corroborates the belief that patients can undergo major surgery with minimal to no opioid requirements. Investing in the infrastructure to deliver non-opioid analgesia in the perioperative setting, including the use of peripheral nerve blocks and implementing an ERAS protocol, can help reduce opioid prescribing, and thus, decrease the rate of new persistent opioid users. Third, the reduction in opioid prescribing for both open and minimally invasive approaches provide an opportunity to implement interventions for other urologic surgeries (e.g., cystectomies) as well as non-urologic surgeries (e.g., colectomies) to impart an even more profound reduction in opioid prescribing. The reduction observed even with large incisions seen in our open nephrectomy patients provides a solid rationale for other surgeons to extrapolate our findings to their practice.

Our findings should be interpreted in the context of several limitations. First, several external factors (e.g., concurrent opioid reduction strategies by medical organizations and by state and local agencies) could have contributed to the observed reduction in opioid prescribing. Nonetheless, the dramatic decrease in prescribing between the pre-intervention and intervention phase suggests that the multi-pronged behavioral intervention influenced this decrease. Second, the primary outcome is the quantity of opioids prescribed, not taken. From prior work, we know that patients do not use all the opioids prescribed.[8] If anything, this further supports the notion that many patients need few or no opioids after these surgeries. Third, we did not account for patients who were prior opioid users, making them more susceptible to requiring opioids. We acknowledge that opioids will be needed in certain instances, but for most patients, they are unnecessary. Fourth, an increase in non-opioid pain control (e.g., acetaminophen, ibuprofen) could lead to unintended side effects such as liver toxicity, renal failure, or gastric ulcers.[22] However, we did not observe an increase in patients presenting with these complications after the intervention was implemented nor did we observe an increase in emergency room visits or readmissions. Fifth, the co-investigators participated in the study, which could introduce researcher bias. These investigators were included to capture the “real-world” experience of our department. Nonetheless, we performed a sensitivity analysis after excluding the co-principal investigators and found that the decrease in opioid prescribing followed a similar trend. Sixth, our survey response rate was low. We feel this was more attributable to disruption of the typical workflow in busy clinics rather than patient unwillingness to fill out the survey. Nonetheless, it is reassuring that no differences were seen between survey responders and non-responders.

Despite these limitations, our findings have some important implications. Implementing a multi-pronged behavioral intervention significantly reduced opioid prescribing for patients undergoing prostatectomies and nephrectomies. This lays the foundation for department-wide decreases in opioid prescribing among other urologic procedures and for institution-wide decreases among other surgical procedures. In addition, it is an example of a behavioral intervention that sustained its desired effect after it ceased.

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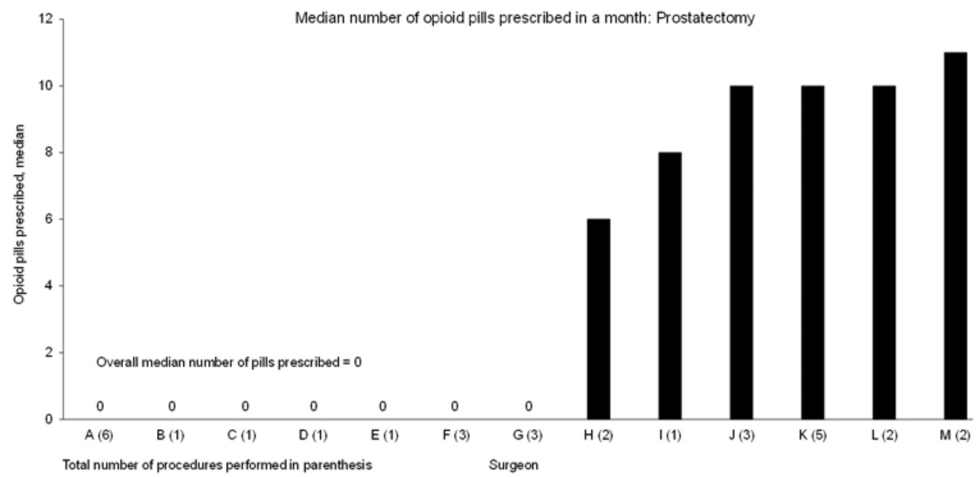
Appendix

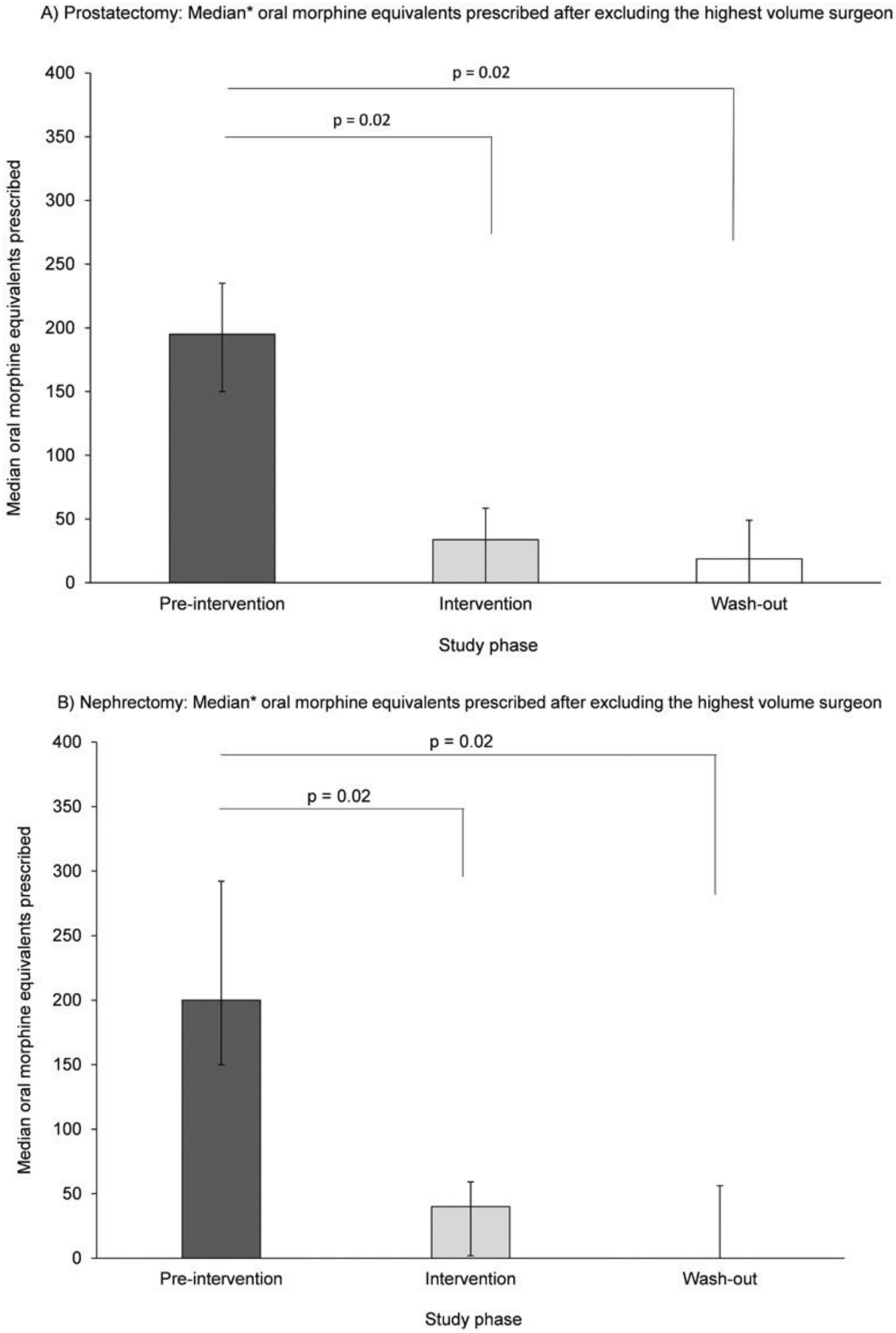


Appendix 1. Examples of individual positive audit feedback (A), individual negative audit feedback (B), and peer comparison performance feedback (C).

A) Text message or e-mail: “I noticed most of your prostatectomies and nephrectomies did not get any opioids last month. Great job, we are really proud of the work you are doing!”

B) Text message or e-mail: “I noticed many of your prostatectomies were discharged with a lot of opioids. Why? Were they complaining of a lot of pain? We would like you to cut back on your prescriptions. They are much higher than our group’s average.”

C) Monthly peer comparison feedback figure regarding opioid prescribing after prostatectomy. Of note, in reality the letters across the x-axis were identifiable surgeons.


A) Prostatectomy: Median* oral morphine equivalents prescribed after excluding the highest volume surgeon
p = 0.02
p = 0.02
Median oral morphine equivalents prescribed
400
350
300
250
200
150
100
50
0
Pre-intervention
Intervention
Wash-out
Study phase
B) Nephrectomy: Median* oral morphine equivalents prescribed after excluding the highest volume surgeon
p = 0.02
p = 0.02
Median oral morphine equivalents prescribed
400
350
300
250
200
150
100
50
0
Pre-intervention
Intervention
Wash-out
Study phase

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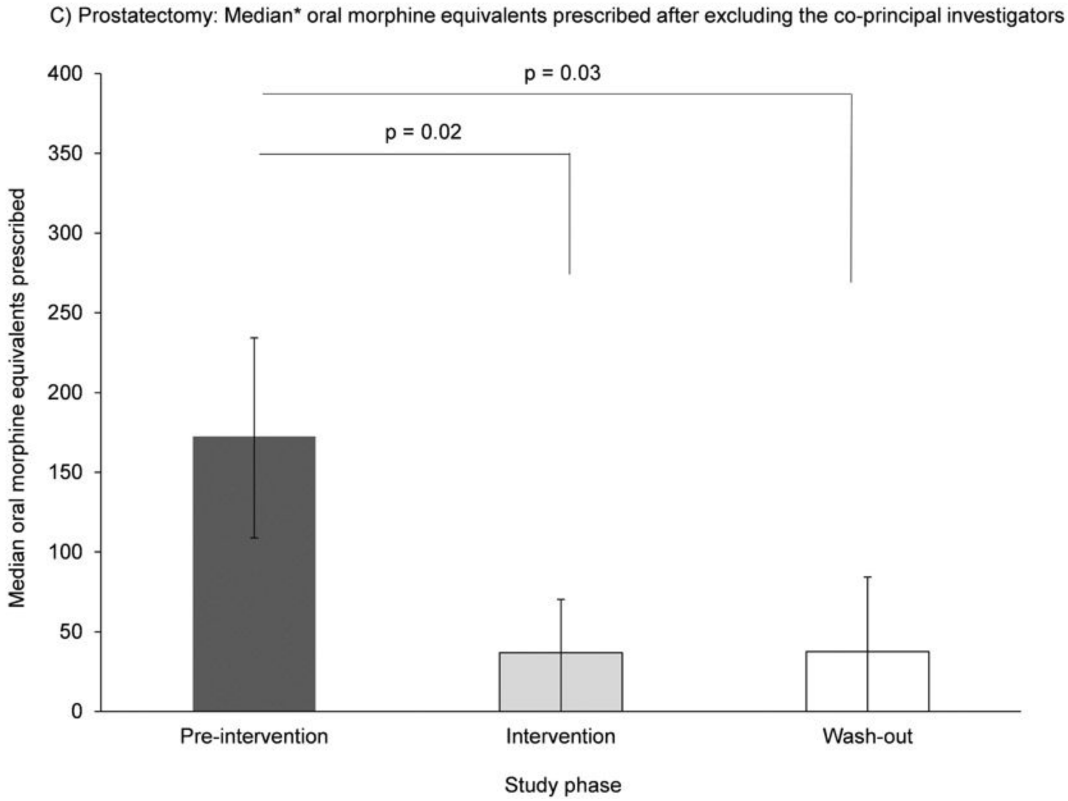

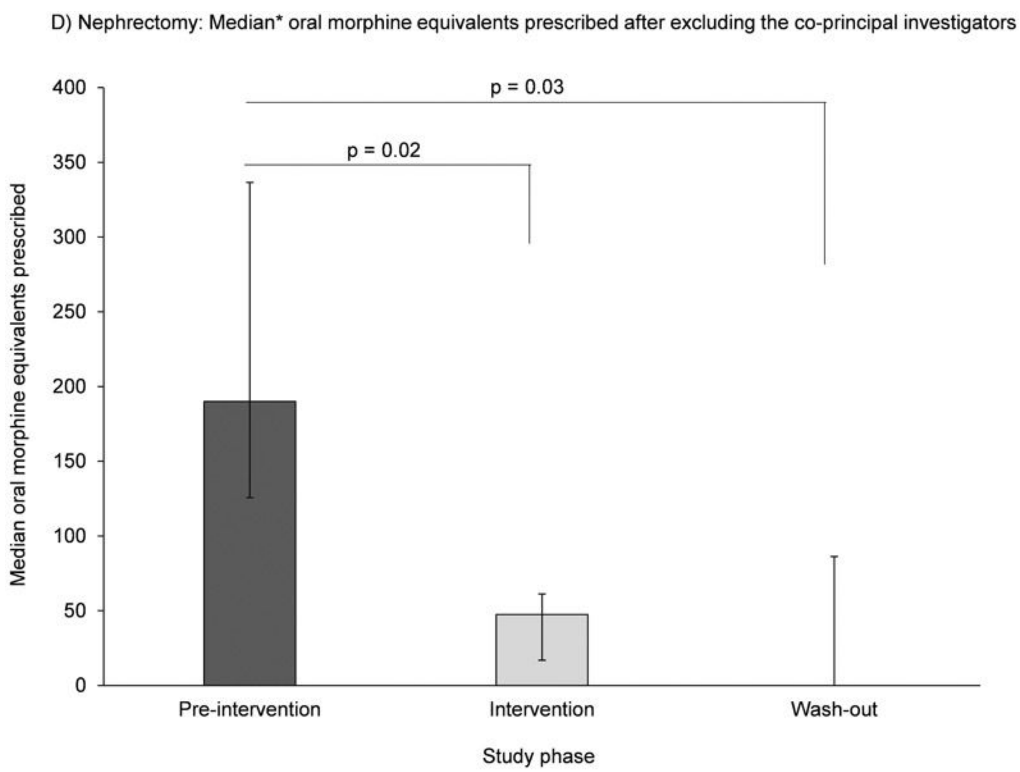

Appendix 2. Median* oral morphine equivalents (OMEs) prescribed for patients after excluding the highest volume surgeon for prostatectomy (A) and nephrectomy (B) and after excluding the co-principal investigators for prostatectomy (C) and nephrectomy (D)

*Median represents the median of each surgeon's median OMEs prescribed.

After excluding the highest volume surgeon for prostatectomy (A) and nephrectomy (B) and after excluding the co-principal investigators for prostatectomy (C) and nephrectomy (D), the median OMEs prescribed among surgeons remained significantly decreased between the pre-intervention phase and intervention phase as well as between the pre-intervention phase and wash-out phase (all p<0.05; Wilcoxon sign-rank test with Bonferroni correction). There is no significant difference in the median OMEs prescribed during the intervention and wash-out phases. Error bars represent the 95% confidence intervals.

Appendix 3:

Comparison of the responders and non-responders of the International Pain Outcomes questionnaire[*a]

Characteristics	Prostatectomy			Nephrectomy		
	Responder (n=42)	Non-responder (n=340)	P value[**]	Responder (n=37)	Non-responder (n=269)	P value
Age, mean (SD)	64 (6)	64 (6)	0.76	63 (15)	62 (13)	0.49
Sex (%)			n/a			0.16
Male	42 (100)	324 (100)		26 (70)	154 (57)	
Female	n/a	n/a		11 (30)	115 (43)	
Race (%)			0.72			0.91
White	40 (95)	308 (91)		32 (86)	236 (88)	
Non-White	2 (5)	28 (8)		4 (11)	26 (10)	
Unknown	0 (0)	4 (1)		1 (3)	7 (2)	
Marital status (%)			0.95			0.34
Married	34 (81)	261 (77)		22 (59)	165 (61)	
Not married	7 (17)	65 (19)		13 (35)	99 (37)	
Unknown	1 (2)	14 (4)		2 (6)	5 (2)	
Surgical approach (%)			0.99			0.30
Open	18 (43)	139 (41)		23 (62)	142 (53)	
Minimally invasive	24 (57)	201 (59)		14 (38)	127 (47)	
Partial nephrectomy (%)	n/a	n/a	n/a	25 (68)	151 (56)	0.22
Hospital length of stay, days, (%)			0.78			0.78
1	30 (71)	232 (68)		11(30)	70 (26)	
2	11 (26)	88 (26)		14 (38)	97 (33)	
3 or more	1 (3)	20 (6)		12 (32)	102 (41)	
BMI, mean (SD)	28 (4)	29 (5)	0.53	30 (7)	30 (7)	0.95

Abbreviations: BMI, body mass index (kg/m^2); n/a, not applicable; SD, standard deviation

Percentages might not sum to 100 because of rounding

[*] All surveys distributed during the intervention and wash-out phases.

[**] P values generated from two sample t-test for continuous variables and Fisher's exact test for categorical variables.

Appendix 4.

Number of prostatectomies (A) and nephrectomies (B) performed by each surgeon during the 3 study phases

A)

Study phase	Surgeon*									
	A	B	D	F	G	H	I	J	K	L
	Number of prostatectomies performed									
Pre-Intervention										
Month 1	3	1	0	1	1	4	3	8	2	1
Month 2	5	3	0	2	2	4	6	8	0	1
Month 3	6	4	1	1	1	8	7	8	2	1
Month 4	3	2	0	1	1	5	2	7	4	1
Total	17	10	1	5	5	21	18	31	8	4
Intervention										
Month 1	2	4	4	6	0	2	4	8	1	3
Month 2	2	2	0	4	0	1	3	12	1	1
Month 3	3	1	4	2	1	1	3	10	0	3
Month 4	1	4	2	2	2	3	0	11	2	2
Month 5	2	3	1	3	1	1	5	6	3	1
Month 6	3	3	1	2	2	2	5	13	2	2
Total	13	17	12	19	6	10	20	60	9	12
Wash-out										
Month 1	2	2	2	1	1	5	3	9	4	0
Month 2	1	4	0	4	1	2	2	10	2	0
Month 3	2	3	4	2	2	2	3	7	4	0
Total	5	9	6	7	4	9	8	26	10	0

B)

Study phase	Surgeon*									
	A	C	D	E	F	G	H	I	J	M
	Number of nephrectomies performed									
Pre-Intervention										
Month 1	8	2	1	1	1	1	3	0	5	0
Month 2	12	2	1	1	2	0	3	1	2	0
Month 3	8	1	1	0	3	1	0	0	4	1
Month 4	6	2	0	1	7	3	2	2	4	0
Total	34	7	3	3	13	5	8	3	15	1
Intervention										
Month 1	10	0	2	0	5	2	3	1	3	1
Month 2	8	0	3	0	1	2	2	1	2	1
Month 3	6	0	2	4	5	1	2	0	2	2

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A)										
Study phase	**Surgeon***									
	A	**B**	**D**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
	Number of prostatectomies performed									
Month 4	8	0	1	4	4	0	1	1	2	1
Month 5	13	0	3	0	1	0	2	2	1	2
Month 6	11	2	2	3	2	0	2	1	1	1
Total	56	2	13	11	18	5	12	6	11	8
Wash-out										
Month 1	12	1	4	4	4	1	1	1	3	0
Month 2	5	1	4	2	6	0	0	0	2	0
Month 3	11	0	2	0	3	2	0	1	2	0
Total	28	2	10	6	13	3	1	2	7	0

*Each surgeon in the study had a unique letter assigned.

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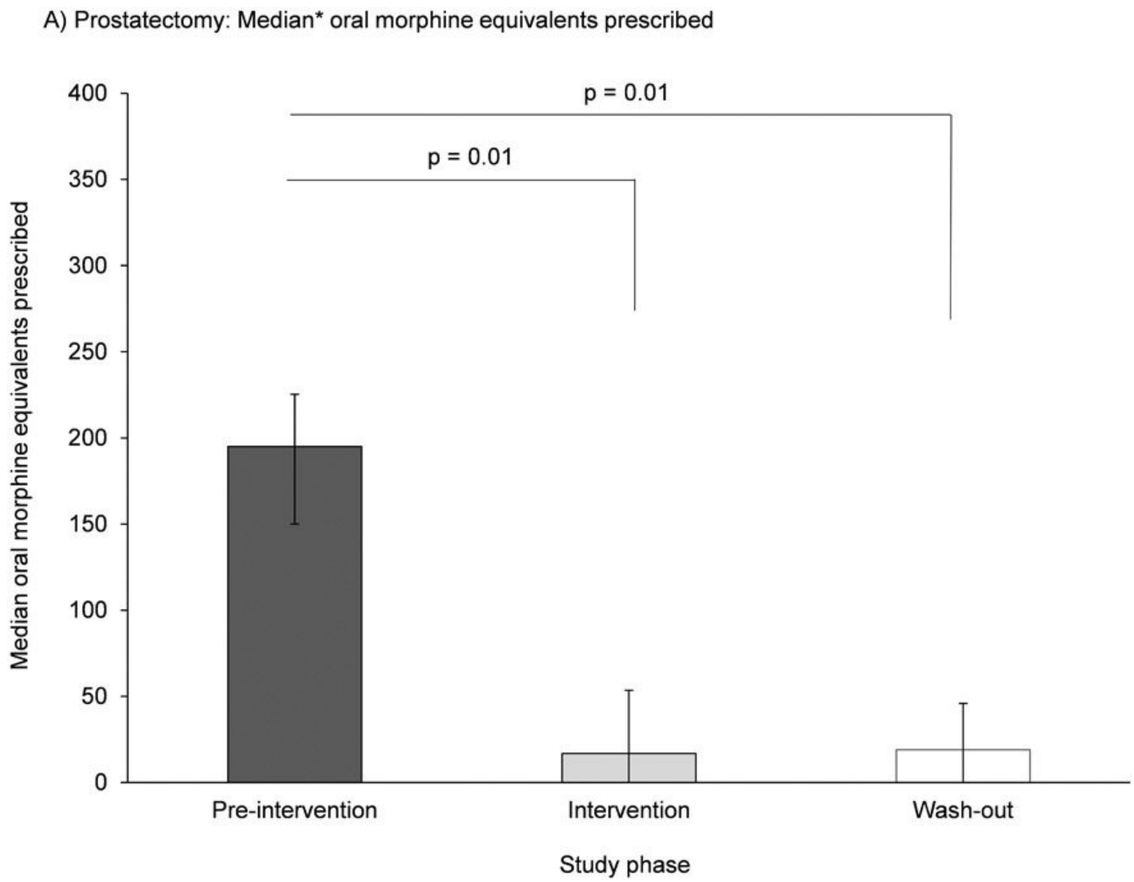

A) Prostatectomy: Median* oral morphine equivalents prescribed
p = 0.01
p = 0.01
Median oral morphine equivalents prescribed
400
350
300
250
200
150
100
50
0
Pre-intervention
Intervention
Wash-out
Study phase

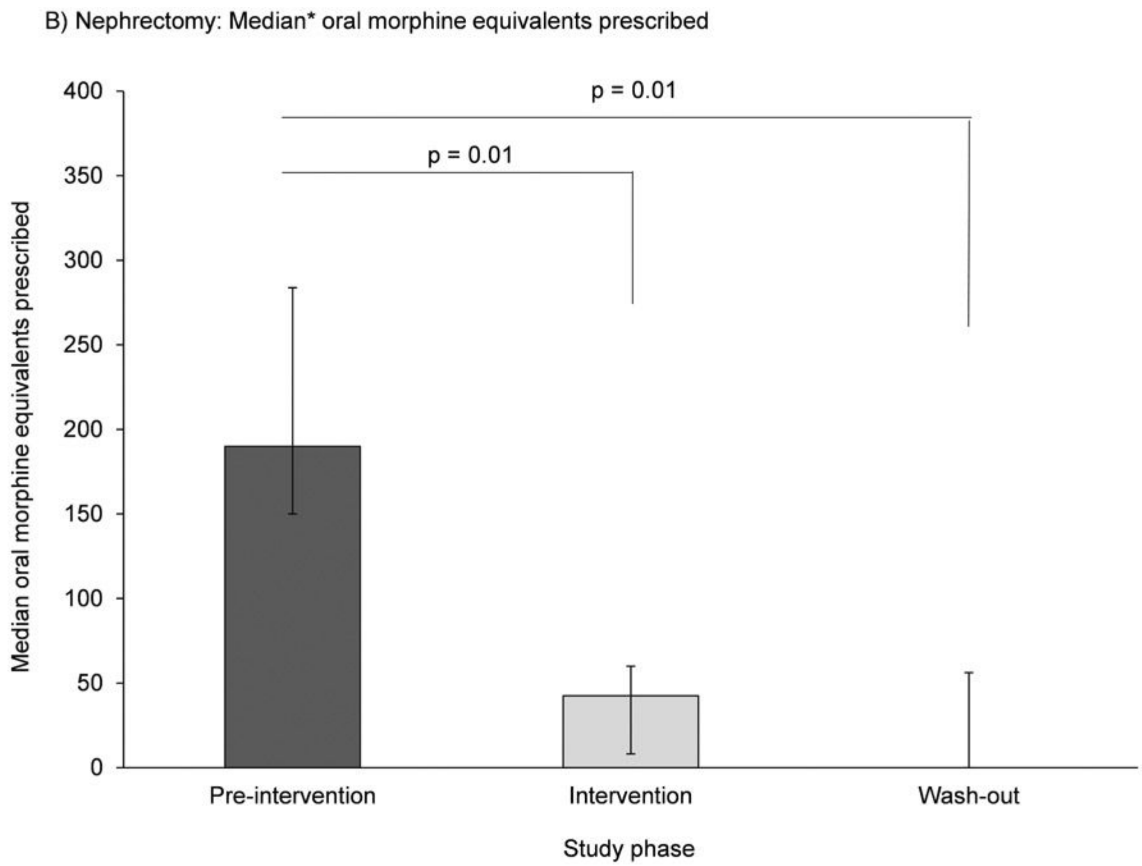


Figure 1. Median* oral morphine equivalents (OMEs) prescribed for patients undergoing prostatectomy (A) and nephrectomy (B)

*Median represents the median of each surgeon's median OMEs prescribed.

The median OMEs prescribed among surgeons decreased significantly between the pre-intervention phase and intervention phase as well as between the intervention phase and wash-out phase for both prostatectomy (Figure 1A; both p=0.01; Wilcoxon sign-rank test with Bonferroni correction) and nephrectomy (Figure 1B; both p=0.01; Wilcoxon sign-rank test with Bonferroni correction). Specifically, the median OMEs decreased from 195 to 19 in the prostatectomy patients and from 200 to 0 in the nephrectomy patients. There is no significant difference in the median OMEs prescribed during the intervention and wash-out phases. Error bars represent the 95% confidence intervals.

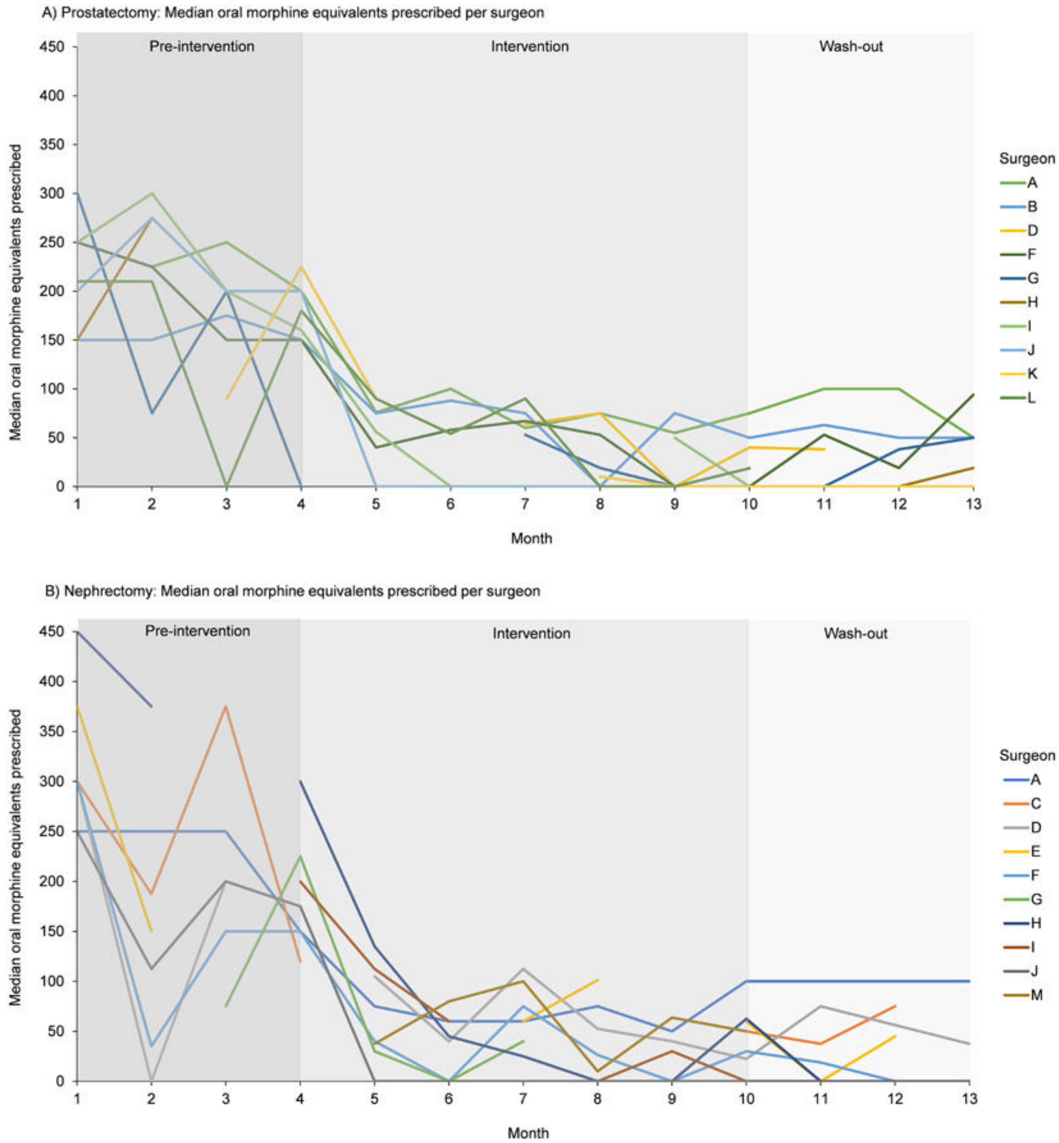
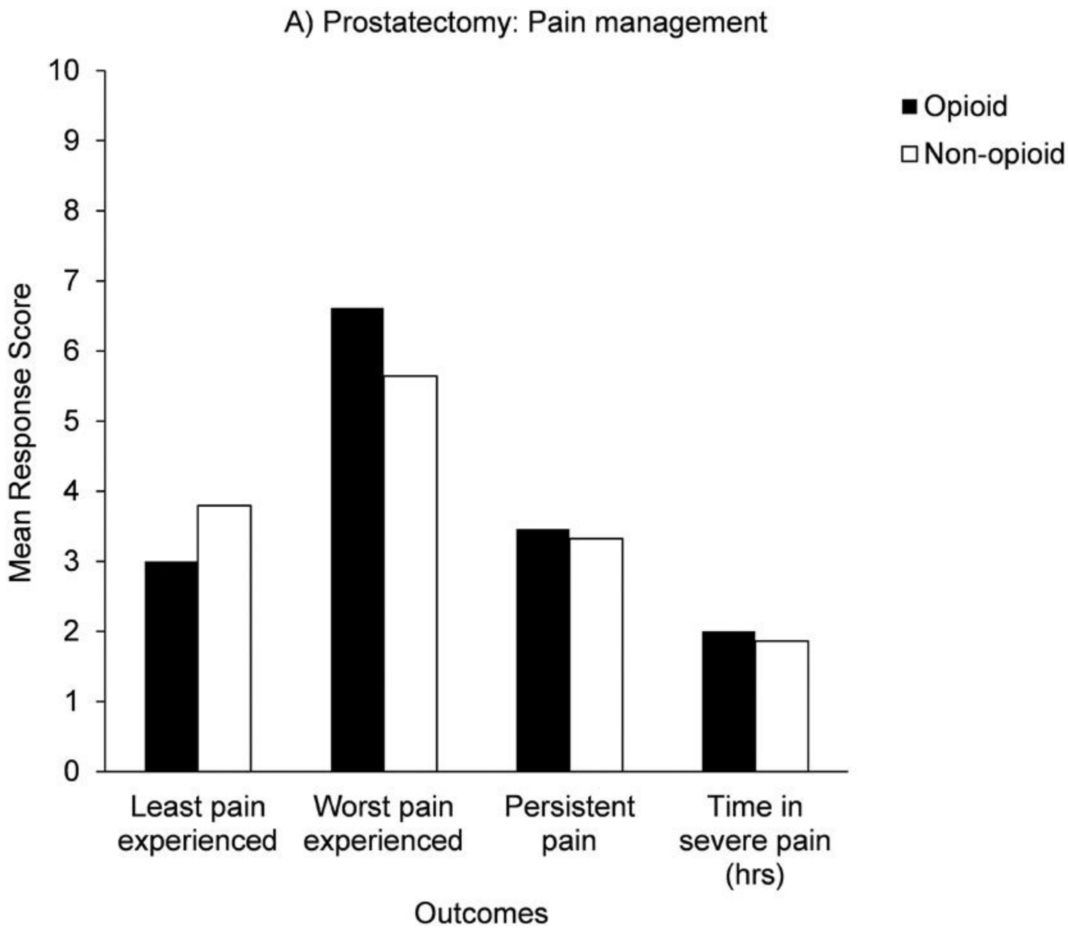
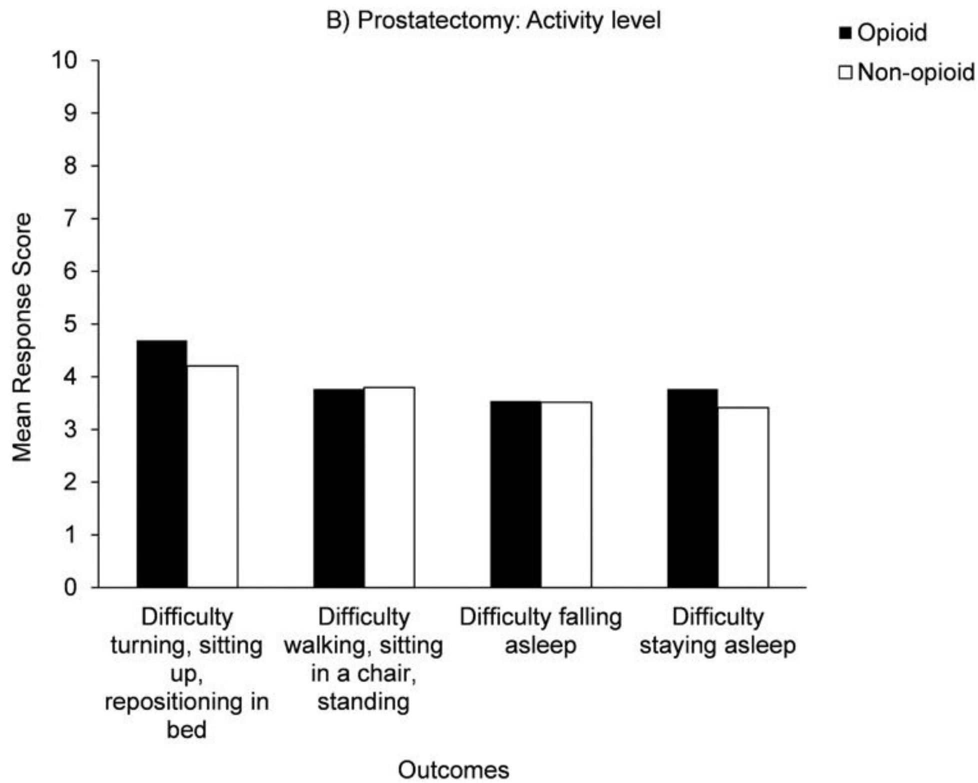


Figure 2. Median oral morphine equivalents prescribed per surgeon for patients undergoing prostatectomy (A) and nephrectomy (B)

The median oral morphine equivalents prescribed per surgeon are decreasing for both prostatectomy (A) and nephrectomy (B) patients. By the end of the study, 40% and 60% of the attending surgeons prescribed a median of 0 oral morphine equivalents for prostatectomy and nephrectomy, respectively. Of note, if a given surgeon did not perform a procedure in a given month, then the data point for that month will be missing, making the line discontinuous.


A) Prostatectomy: Pain management
Mean Response Score
0
1
2
3
4
5
6
7
8
9
10
Opioid
Non-opioid
Least pain experienced
Worst pain experienced
Persistent pain
Time in severe pain (hrs)
Outcomes


B) Prostatectomy: Activity level
Opioid
Non-opioid
Mean Response Score
10
9
8
7
6
5
4
3
2
1
0
Difficulty turning, sitting up, repositioning in bed
Difficulty walking, sitting in a chair, standing
Difficulty falling asleep
Difficulty staying asleep
Outcomes

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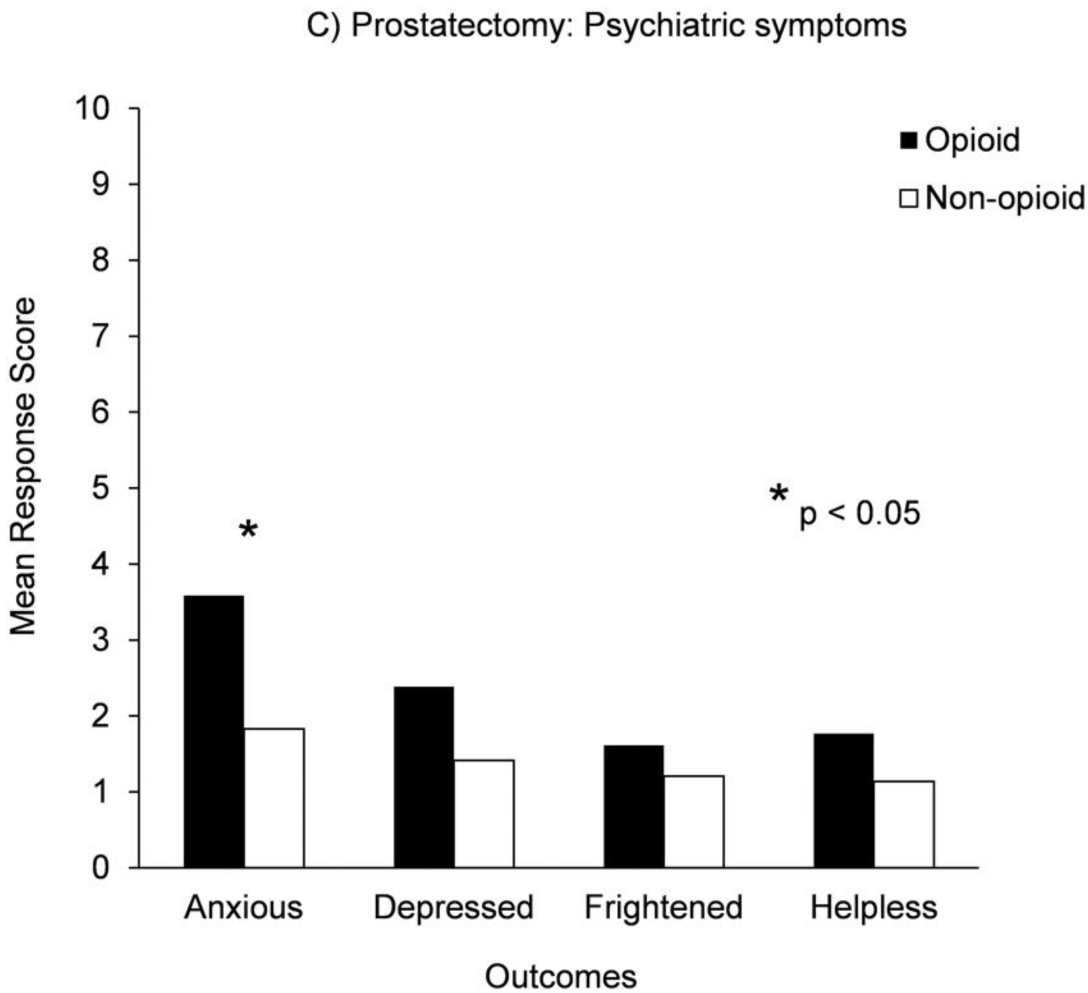
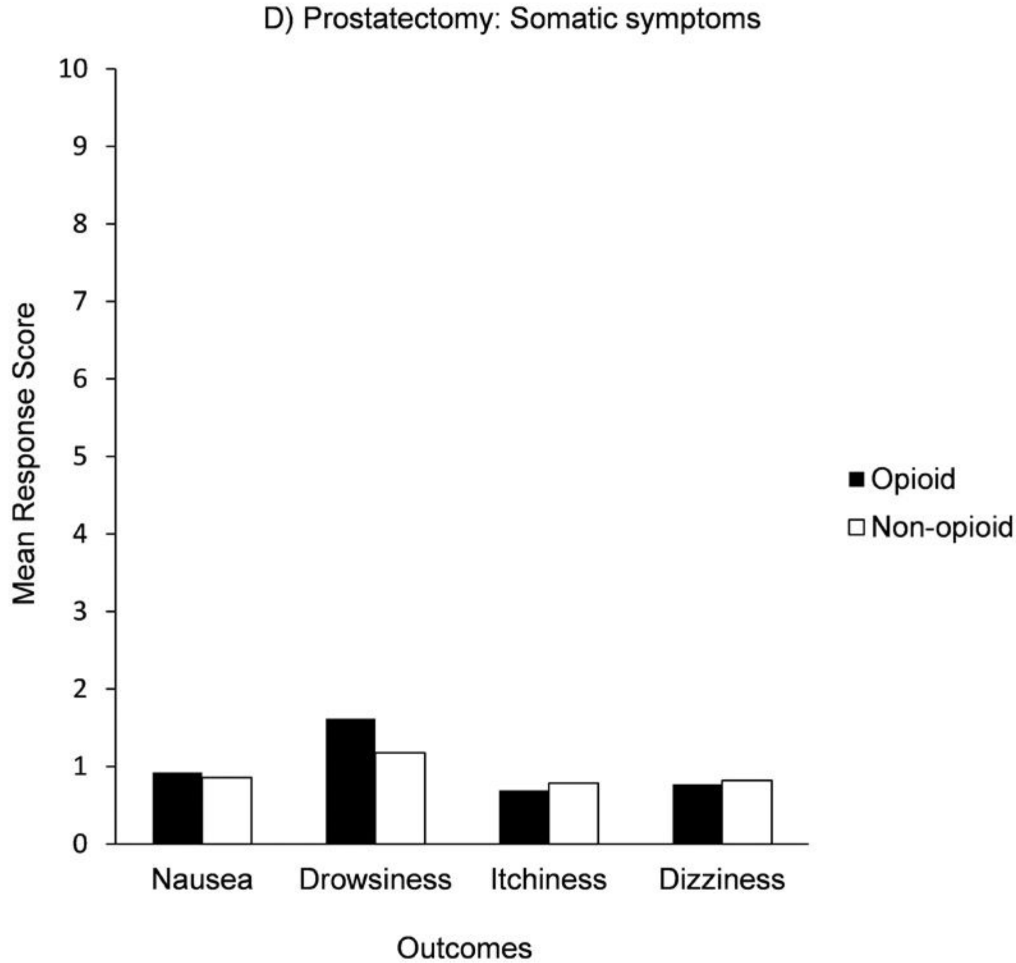
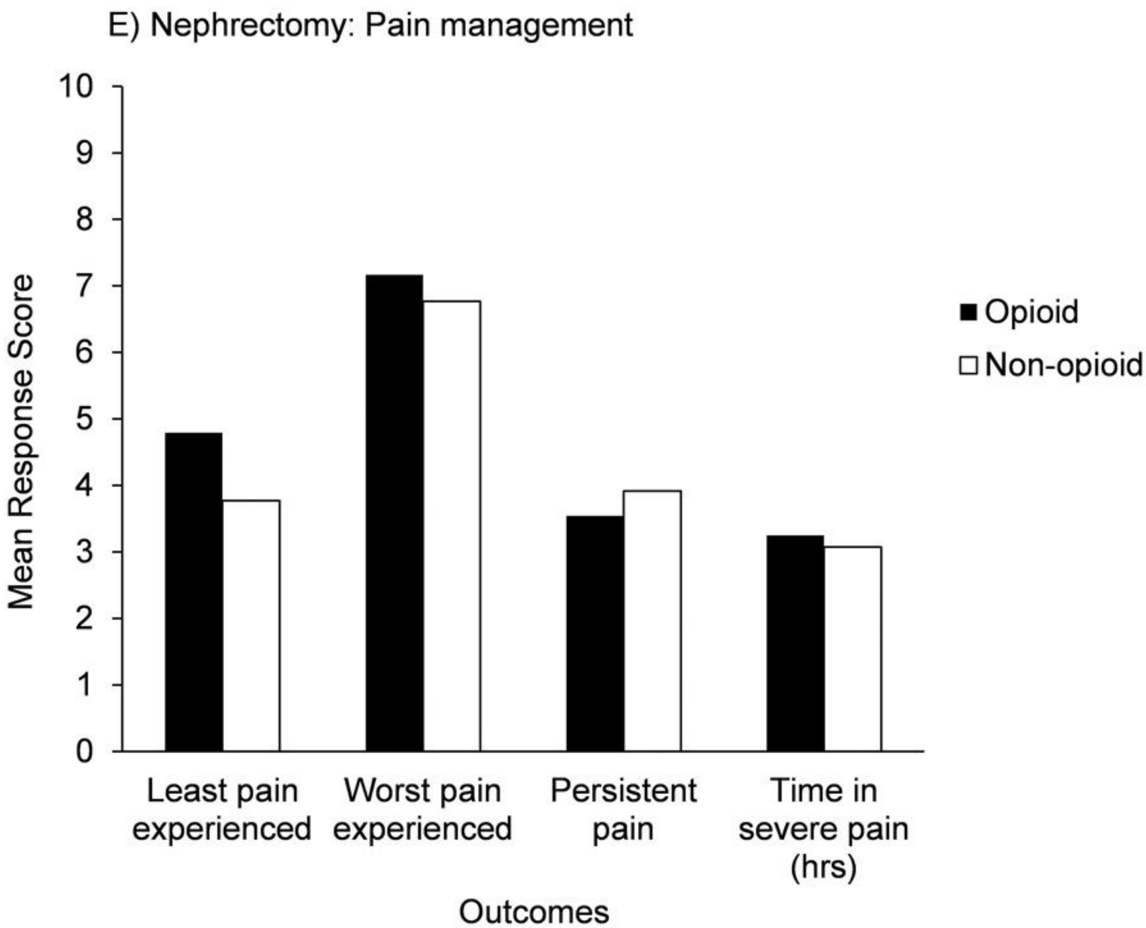
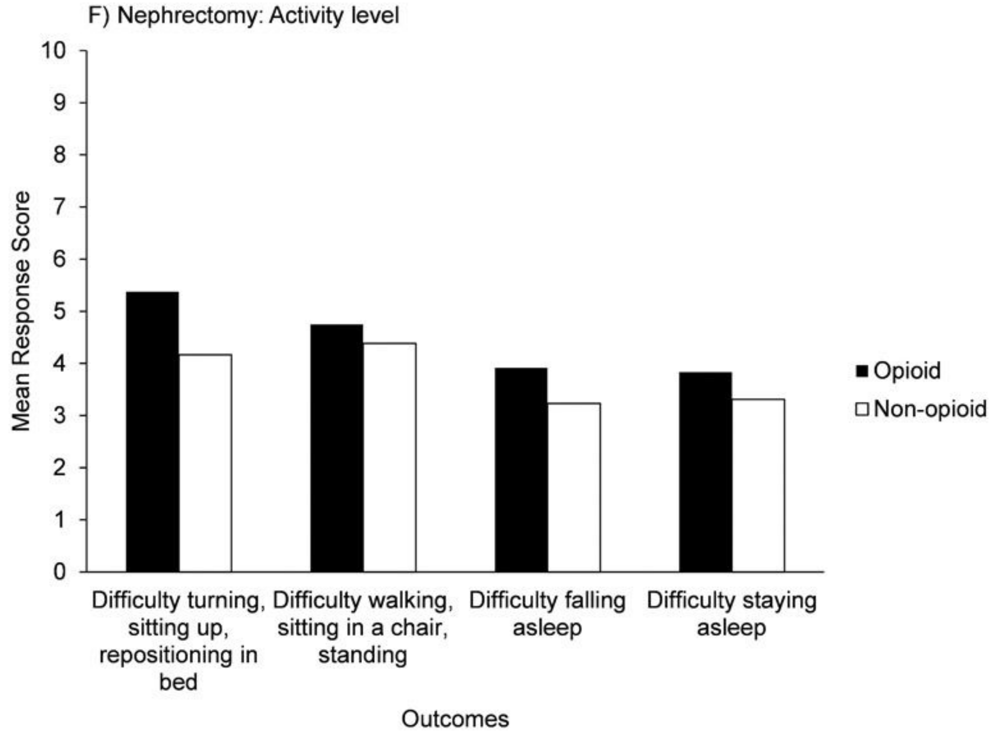
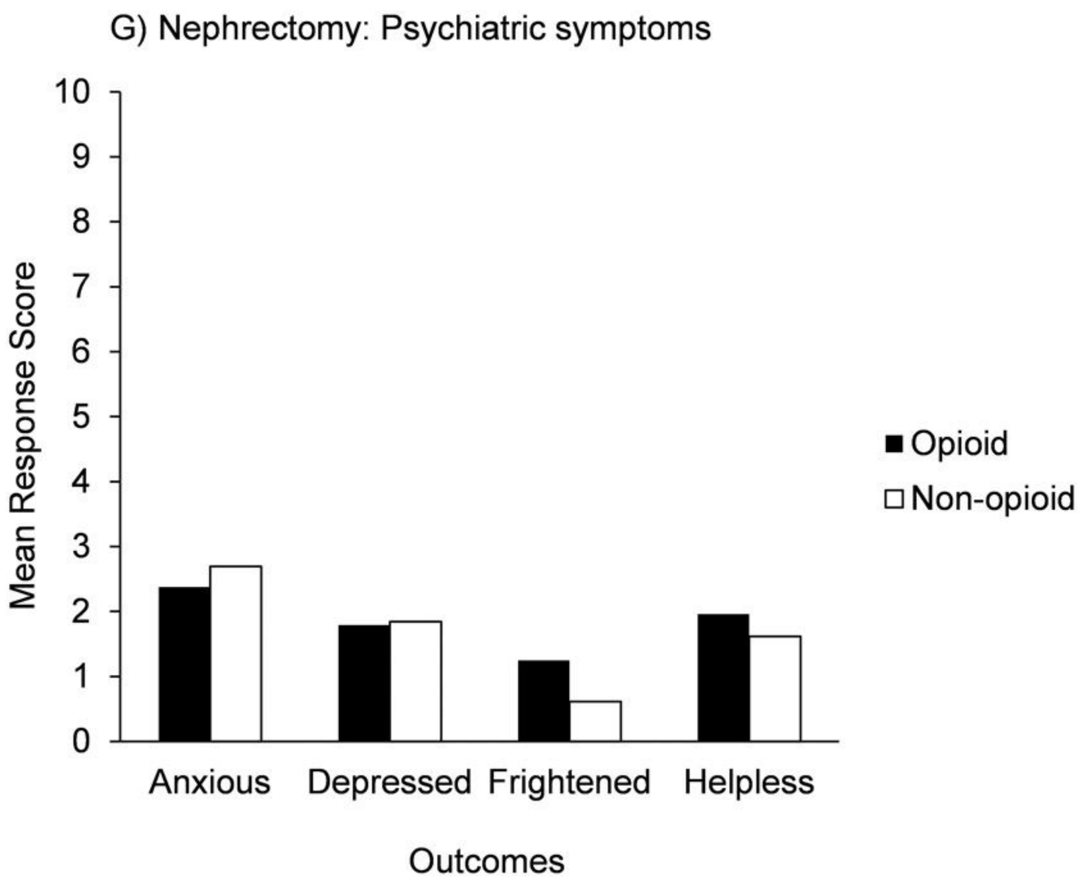



D) Prostatectomy: Somatic symptoms
Mean Response Score
10
9
8
7
6
5
4
3
2
1
0
Nausea
Drowsiness
Itchiness
Dizziness
Outcomes
Opioid
Non-opioid


E) Nephrectomy: Pain management
Mean Response Score
10
9
8
7
6
5
4
3
2
1
0
Opioid
Non-opioid
Least pain experienced
Worst pain experienced
Persistent pain
Time in severe pain (hrs)
Outcomes



F) Nephrectomy: Activity level
10
9
8
7
6
5
4
3
2
1
0
Mean Response Score
Opioid
Non-opioid
Difficulty turning, sitting up, repositioning in bed
Difficulty walking, sitting in a chair, standing
Difficulty falling asleep
Difficulty staying asleep
Outcomes



G) Nephrectomy: Psychiatric symptoms
10
9
8
7
6
5
4
3
2
1
0
Mean Response Score
Opioid
Non-opioid
Anxious
Depressed
Frightened
Helpless
Outcomes

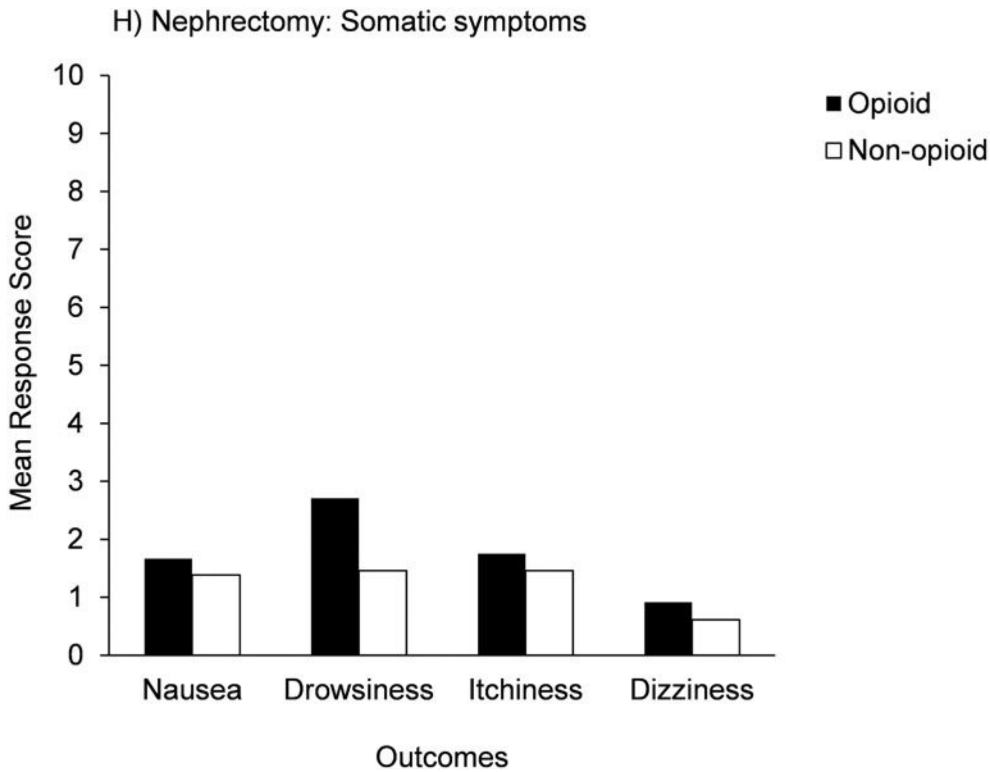


Figure 3. Patient reported outcomes using the International Pain Outcomes questionnaire for prostatectomy (A-D) and nephrectomy (E-H)

Prostatectomy patients discharged with opioids had higher levels of anxiety than patients discharged without opioids ($p<0.05$; two-sample t-test). Otherwise, prostatectomy and nephrectomy patients discharged with and without opioids did not differ in their perception of postoperative pain management, activity level, other psychiatric symptoms, and somatic symptoms (all $p >0.05$; two-sample t-test). The questions are scored on a 0-10 scale, where 0 indicates no symptoms and 10 indicates severe symptoms.

Table 1:

Demographic information for prostatectomy and nephrectomy patients

Characteristics	Prostatectomy				Nephrectomy			
	Pre-intervention (n=120)	Intervention (n=178)	Wash-out (n=84)	P value*	Pre-intervention (n=92)	Intervention (n=142)	Wash-out (n=72)	P value
Age, mean (SD)	63 (7)	64 (6)	65 (6)	0.06	61 (11)	61 (14)	64 (13)	0.41
Sex (%)				n/a				0.69
Male	120 (100)	178 (100)	84 (100)		57 (62)	80 (56)	43 (60)	
Female	n/a	n/a	n/a		35 (38)	62 (44)	29 (40)	
Race (%)				0.21				0.27
White	113 (94)	149 (90)	74 (88)		77 (84)	128 (90)	63 (88)	
Non-White	5 (4)	15 (9)	10 (12)		11 (12)	13 (9)	6 (8)	
Unknown	2 (2)	2 (1)	0 (0)		4 (4)	1 (1)	3 (4)	
Marital status (%)				0.28				0.81
Married	93 (78)	132 (79)	60 (71)		59 (64)	84 (59)	44 (61)	
Not married	20 (17)	28 (17)	22 (26)		32 (35)	53 (37)	27 (38)	
Unknown	7 (5)	6 (4)	2 (3)		1 (1)	5 (4)	1 (1)	
Surgical approach (%)				0.65				0.45
Open	53 (44)	60 (37)	32 (38)		46 (50)	82 (58)	37 (51)	
Minimally invasive	67 (56)	106 (63)	52 (62)		45 (50)	60 (42)	35 (49)	
Partial nephrectomy (%)	n/a	n/a	n/a	n/a	52 (57)	80 (56)	44 (61)	0.80
Hospital length of stay, days, (%)				0.17				0.02
1**	90 (75)	117 (66)	55 (65)		19 (21)	41 (29)	21 (29)	
2	24 (20)	48 (27)	27 (32)		31 (34)	45 (32)	35 (49)	
3 or more	6 (5)	13 (7)	2 (2)		42 (45)	56 (39)	16 (22)	
BMI, mean (SD)	29 (5)	29 (5)	28 (4)	0.17	31 (8)	30 (7)	30 (7)	0.93

Abbreviations: BMI, body mass index (kg/m^2); n/a, not applicable; SD, standard deviation

Percentages might not sum to 100 because of rounding

* P values generated from ANOVA for continuous variables and Fisher's exact test for categorical variables.

** One prostatectomy patient in the intervention phase was discharged the day of surgery.

Table 2:

Demographics of patients who completed the International Pain Outcomes questionnaire*

Characteristics	Prostatectomy			Nephrectomy		
	Opioid (n=13)	**Non-opioid (n=29)**	**P value****	**Opioid (n=24)**	**Non-opioid (n=13)**	**P value**
Age, mean (SD)	64 (5)	64 (6)	0.72	62 (15)	65 (16)	0.62
Sex (%)			n/a			0.14
Male	13 (100)	29 (100)		19 (79)	7 (54)	
Female	n/a	n/a		5 (21)	6 (46)	
Race (%)			0.99			0.53
White	13 (100)	27 (93)		21 (88)	11 (84)	
Non-White	0 (0)	2 (7)		3 (12)	1 (8)	
Unknown	0 (0)	0 (0)		0 (0)	1 (8)	
Marital status (%)			0.99			0.06
Married	11 (85)	23 (79)		17 (71)	5 (38)	
Not married	2 (15)	5 (17)		7 (29)	6 (46)	
Unknown	0 (0)	1 (4)		0 (0)	2 (16)	
Surgical approach (%)			<0.001			0.17
Open	11 (85)	6 (21)		17 (71)	6 (46)	
Minimally invasive	2 (15)	23 (79)		7 (29)	7 (54)	
Partial nephrectomy (%)	n/a	n/a	n/a	18 (75)	7 (54)	0.27
Hospital length of stay, days, (%)			0.001			0.07
1	5 (38)	25 (86)		4 (17)	7 (54)	
2	8 (62)	3 (10)		11 (46)	3 (23)	
3 or more	0 (0)	1 (4)		9 (37)	3 (23)	
BMI, mean (SD)	28 (3)	29 (4)	0.52	29 (6)	33 (9)	0.14

Abbreviations: BMI, body mass index (kg/m^2); n/a, not applicable; SD, standard deviation

Percentages might not sum to 100 because of rounding

*All surveys distributed during the intervention and wash-out phases.

** P values generated from two sample t-test for continuous variables and Fisher's exact test for categorical variables.