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Identifying Best Practices for Pain Management in Plastic Surgery: A Quality Improvement Project

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Abstract

Introduction: Postoperative opioid prescriptions often exceed patient consumption, creating opportunities to reduce excess prescribing while addressing individual pain management needs. This quality improvement project examined postoperative pain, medication consumption, and associated patient characteristics following abdominoplasty, with or without breast surgery. **Methods:** Electronic medical records and patient-reported data from the CPMRx mobile application were reviewed for 97 patients treated at a plastic surgery center between June 2023 and January 2024. Bivariate analyses examined associations between patient characteristics and total oxycodone consumption and pain-category membership on the day of surgery (Day 0) and postoperative Day 4. Exploratory interaction tests examined whether selected associations with pain-category membership differed between days. **Results:** Among 95 patients with recorded oxycodone consumption, mean use was 13.8 tablets ($SD = 9.7$); 81.1% consumed 22 or fewer tablets, compared with the standard prescription of 30. Greater consumption was associated with anxiety diagnosis ($p = 0.025$), norepinephrine-dopamine reuptake inhibitor use ($p = 0.035$), and groups defined by the selected medication-class count ($p = 0.014$). No patient characteristics were significantly associated with pain-category membership on Day 0. Among 71 Day 4 reporters, category membership was associated with age, body mass index, anxiety, and nicotine use. Exploratory interactions were significant for age and anxiety in the four-category analysis; only anxiety remained significant when pain was dichotomized. Among Day 4 reporters with anxiety, 76.2% reported pain scores ≥ 4, compared with 44.0% without anxiety. **Conclusions:** Observed consumption supports consideration of reducing the standard prescription from 30 to 22 oxycodone tablets. Mental

health history and postoperative reassessment may help identify differing patient needs and inform more individualized prescribing and follow-up.

Keywords

Opioids, Postoperative Pain, Quality Improvement, Abdominoplasty, Opioid Prescribing

1. Introduction

Opioid misuse is an epidemic and a public health crisis. Opioid misuse, use disorders, and overdoses are costly in terms of morbidity, mortality, and humanitarian and economic burden. The economic cost of opioid overdose, misuse, and dependence in the U.S. has been estimated at $78.5 billion annually [1]; including reduced quality of life from opioid use disorder and the value of life lost due to fatal opioid overdose increases that estimate to more than $1 trillion [2]. One known risk factor for prescription opioid misuse and dependence is the prescription of opioids to manage post-surgical pain [3]. Prolonged opioid use is a common post-surgical complication and various surgeries have been associated with increased risk of chronic opioid use [4]. Thus, dosing post-operative pain medication to maximize analgesia and minimize risk is critical.

Post-operative prescribing practices vary widely and can result in more prescribed opioids (i.e., more pills) than required for effective analgesic management. This practice may inadvertently promote continued opioid use when its indication is no longer warranted and increase risk for misuse, addiction, and overdose. Decreasing the total number of opioid pills prescribed after surgeries could substantially reduce risk for opioid misuse. Studies on post-operative opioid consumption suggest that 50% - 60% of opioids prescribed for acute pain relief by surgeons go unused in a variety of specialties [5] [6]. Educational efforts on prescribing practices have been successful in reducing opioid prescribing by 50% - 60% without a negative impact on effective pain management [5] [6]. For the patient being prescribed opioids, there is a need to ensure appropriate use to prevent habit-forming behaviors during postoperative recovery, as it has been estimated that among U.S. adults who reported prescription opioid use in the past year, 12.5% reported misuse [7]. For members of the patient's family and others in the community, it is important that excess prescription opioids not be available for misuse; indeed, more than half of people who misused prescription pain relievers reported obtaining them from a friend or relative, either for free, by purchasing them, or by taking them without asking [8].

Extant research conducted specifically within plastic surgery patients has shown that opioid overprescribing is common, with more than half of prescribed opioids going unused in one study [9]. Concerningly, this study also found that 83% of patients did not store opioids in a locked location and 64% of patients had not

disposed of unused opioids one month following their procedure [9]. These results indicate a need to improve postoperative prescribing and patient education for those undergoing plastic surgery.

Patient characteristics, including anxiety, may help explain differences in postoperative pain and opioid use. In a prospective cohort of 1771 surgical patients, clinically significant anxiety was associated with greater postoperative pain and higher odds of opioid use [10], while a recent systematic review and meta-analysis also identified anxiety as a risk factor for moderate-to-severe pain within the first 24 hours after surgery [11]. These findings highlight the importance of considering patients' mental health history when evaluating postoperative pain management needs. Examining routinely documented patient characteristics, including mental health diagnoses and current medication use, may help identify patients who require additional monitoring or support during recovery.

Preoperative mental health medication use has also been associated with postoperative opioid use. Studies have linked benzodiazepine use with subsequent opioid prescribing and use of certain antidepressants with greater opioid consumption during hospitalization, although associations have not been consistent across surgical populations and outcomes [12]-[14].

Use of Software to Improve Patient Outcomes

Continuous Precision Medicine (CPM, Research Triangle Park, NC) has developed a suite of software (CPMRx) that uses evidence-informed tools to help clinicians understand postoperative pain trends and actual medication usage. The suite of software includes a mobile application for patients, which includes a behavioral health intervention, and a clinical decision support tool for healthcare providers, which provides feedback about pain and medication use trends. A public health research pipeline approach for designing, evaluating, and implementing behavioral health interventions has been used to evaluate this software. The CPMRx mobile app has been shown to be feasible and acceptable for supporting postoperative pain management across several patient populations and surgery types, including young adults undergoing third molar extraction (Dental Clinic, Womack Army Medical Center, Ft. Bragg, NC) [15], adults undergoing tonsillectomy (ENT, WakeMed Hospital, Raleigh, NC), women undergoing cesarean section (OB/GYN, Temple University Health, Philadelphia, PA) [16] [17], and older Veterans undergoing total knee arthroplasty (Charles George VA Medical Center, Asheville, NC) [18]. Effectiveness of the mobile app has also been evaluated; in a randomized controlled trial conducted at Temple University ($N = 100$), the CPM Rx app was shown to reduce the odds of prescription opioid misuse during the postoperative period by 92% [17].

The final development and evaluation of the clinician-facing clinical decision support tool was funded by an SBIR Phase II grant through the National Institute on Drug Abuse. The CPM Clinical Decision Support Tool (CDST) allows physicians to deliver personalized medication schedules, and record patient dosing and

pain data, enabling the measurement of outcomes and improvement of treatment plans. The implementation of the mobile app and CDST provides actionable insights that can be used to establish more precise prescribing guidelines. At Womack Army Medical Center (Fayetteville, NC), for example, clinicians were able to reduce over-prescription of an opioid by 10,000 pills annually for a single surgery type [19].

The overall aim of our quality improvement project was to characterize postoperative pain and actual pain medication use among patients undergoing abdominoplasty, with or without breast surgery, and to examine patient characteristics associated with these outcomes. We also examined whether associations between patient characteristics and pain differed between the day of surgery and postoperative Day 4. The review of extant data would then inform any necessary adjustments to current prescribing practices, with the overarching goal of prescribing the correct amount of medications to most safely and effectively manage patients' postoperative pain. Additionally, we wanted our patients to benefit from the use of the mobile app and its embedded behavioral health intervention to improve the safety of their recovery.

2. Methods

2.1. Project Design

This quality improvement project was conducted at a plastic surgery and medical spa center in an urban area in the Southeastern United States. The plastic surgery center had recently implemented the CPM software system that allowed patients to voluntarily report any pain medication usage and their pain rating throughout their postoperative period. These data were monitored by the Nurse Case Manager as part of standard of care.

The quality improvement project received a Non-Human Subject Research Determination by Advarra's Institutional Review Board in 2023 (Pro00074798). All methods were carried out in accordance with relevant guidelines and regulations.

2.2. Participants

Participants were patients undergoing abdominoplasty ("tummy tuck") or abdominoplasty plus breast surgery (lift, reduction, implant, or implant exchange) between June 19, 2023, and January 11, 2024. Enrollment occurred when personnel associated with the quality improvement project were available to assist patients with the CPMRx mobile application. Of 112 patients approached, 97 entered the analytic sample. Patients needed to have a mobile phone capable of downloading the app with them to participate; the reasons for nonparticipation among the remaining 15 were not enumerated. Among the 97 included patients, 95 had recorded oxycodone totals and 95 reported pain on the day of surgery.

2.3. Measures

Outcome Measures. The primary outcomes for this project were the total number

of prescribed oxycodone tablets used as well as self-reported pain scores (on a scale of 0 - 10). The total numbers of gabapentin, acetaminophen, and ibuprofen tablets used were also obtained from the app. Daily pain scores were calculated as the average of all pain ratings reported by each patient on a given postoperative day. Oxycodone totals reflect available reports through each patient's last app entry; no fixed completion criterion was applied, and reporting gaps were not imputed. The analytic dataset did not distinguish consumption from an initial prescription from consumption after a refill.

Independent Variables. Reviews of electronic medical records were conducted to obtain potential predictors of postoperative pain and opioid consumption, including sociodemographic characteristics, mental and physical health history, and clinical characteristics related to the surgical procedure.

Sociodemographic characteristics included age (in years).

Health history included body mass index (BMI), nicotine use within the previous 12 months, an opioid risk score (ORS) obtained from the prescription drug monitoring program (PDMP) and recorded in the EMR, and diagnosis (ICD-9 or ICD-10 codes, or report at intake) of anxiety, depression, attention-deficit/hyperactivity disorder (ADHD), insomnia, or chronic pain. Current use of tetrahydrocannabinol (THC), cannabidiol (CBD), sedative-hypnotics (specifically non-benzodiazepine hypnotics), benzodiazepines, buspirone (BuSpar), opioid antagonists, anti-epileptic drugs (AEDs), serotonin antagonist and reuptake inhibitors (SARIs), norepinephrine-dopamine reuptake inhibitors (NDRIs), serotonin and norepinephrine reuptake inhibitors (SNRIs), selective serotonin reuptake inhibitors (SSRIs), and ADHD medications were also documented. Recorded ORS values ranged from 0 to 3 and were analyzed categorically. An exploratory count of selected medication classes was calculated by summing the number of medication classes used among AEDs, SARIs, benzodiazepines, and NDRIs. This count summarized concurrent use of the four selected classes and was not intended as a comprehensive measure of psychotropic use or a validated clinical risk score. Preoperative opioid use contributed to the PDMP-derived ORS, but was not available as a separate variable in the analytic dataset. A score of zero was not interpreted as evidence that a patient was opioid-naïve.

Clinical characteristics included the procedure type, operative time (in minutes, from Operation Notes), recovery time (in minutes, from the postanesthesia care unit [PACU] record), and whether or not the patient was considered a travel patient (out of state).

2.4. Procedures

All participants downloaded the CPMRx mobile app prior to discharge and were instructed to record pain ratings and medication use while taking pain medication. Patients could report pain independently of medication use and could continue using the app without a fixed end date. At discharge, the standard prescription included 30 oxycodone tablets (5 mg each), 21 gabapentin tablets (300 mg

each), and 30 ibuprofen tablets (200 mg each). Oxycodone was to be taken as one 5-mg tablet every 6 - 8 hours as needed for breakthrough pain. Gabapentin was scheduled as one 300-mg tablet three times daily for the first week; occasional refills were provided for use as needed up to three times daily. Patients were instructed to obtain acetaminophen over the counter and take approximately 1000 mg every 6 - 8 hours as needed (three 325-mg tablets or two 500-mg tablets per dose), without exceeding 4000 mg in 24 hours. Beginning 48 hours after surgery, ibuprofen could be taken as three 200-mg tablets (600 mg) every 6 - 8 hours as needed, alternating with acetaminophen. Following discharge, patients self-managed their pain using these medications.

2.5. Statistical Analysis

Original analyses were conducted using SAS software, Version 9.4 (SAS Institute Inc., Cary, NC), with additional analyses conducted using Python. Descriptive statistics were computed to summarize patient characteristics and postoperative medication use. Means and standard deviations were calculated for continuous variables, and frequencies and percentages were calculated for categorical variables. Analyses used available data for each variable, with corresponding sample sizes reported. To describe postoperative pain patterns, the number of patients reporting pain within each category was summarized by postoperative day, with the day of surgery designated as Day 0. The figure displays daily counts of patients reporting average pain scores of 4 or higher; total reporter counts and counts within all four pain categories were summarized for Days 0 and 4.

One-way analyses of variance were conducted to examine bivariate associations between categorical patient characteristics and total postoperative oxycodone consumption. Pearson correlations were calculated to examine associations of age, BMI, operative time, and recovery time with total postoperative oxycodone consumption. Spearman rank correlations were also examined as sensitivity analyses. Statistical significance was evaluated at $p < 0.05$. Reported p-values were not adjusted for multiple comparisons.

Bivariate associations between patient characteristics and pain-category membership were examined separately on postoperative Days 0 and 4. Daily average pain scores were categorized as below 4, 4 to less than 6, 6 to less than 8, or 8 - 10. Primary analyses included only patients reporting pain on the respective day. Continuous patient characteristics were compared across pain categories using permutation Kruskal-Wallis tests. Associations between categorical patient characteristics and pain categories were evaluated using contingency-table tests with Monte Carlo estimation of p values conditional on the observed marginal totals. Permutation and Monte Carlo tests used 199,999 draws. The selected medication-class count was treated as a categorical variable with levels of zero, one, and two.

A secondary exploratory analysis combined patients without a pain report on the respective day with those reporting average pain below 4. This grouping reflected the possibility that patients discontinued reporting as pain and medication

needs decreased; it did not establish that nonreporters had low pain or had stopped taking medication.

Exploratory interaction tests examined whether associations of age, BMI, anxiety diagnosis, and nicotine use with pain-category membership differed between postoperative Days 0 and 4. Each predictor was examined separately using a multinomial logistic model that included postoperative day and the predictor. Pain categories were treated as nominal, with scores below 4 as the reference category. Age and BMI were modeled continuously. Predictor-by-day interactions were evaluated jointly across the three nonreference pain categories using score tests with patient-clustered robust covariance estimates to account for repeated observations within patients. Each interaction test had three degrees of freedom. Models were not adjusted for other patient characteristics.

Interaction tests were conducted first among patients reporting pain on the respective day and repeated in the secondary analysis combining nonreporters with those reporting pain below 4. These tests were exploratory and were conducted following review of the day-specific bivariate findings. As a sensitivity analysis, we repeated the age-by-day and anxiety-by-day tests among reporters after dichotomizing daily mean pain as below 4 versus 4 or higher. Separate binary logistic models included day and the predictor; the interaction was evaluated using a one-degree-of-freedom score test with patient-clustered robust covariance.

3. Results

A total of 97 patients were included in the analyses for this quality improvement project. The final sample of participants ranged in age from 26 to 67 years old with an average age of 40.7 years old (SD = 8.00). The average patient BMI was 26.30 (SD = 4.05, min = 17.00, max = 36.00). Patient characteristics and postoperative medication consumption are summarized in Table 1.

Table 1. Patient characteristics and postoperative medication consumption (N = 97).

Characteristic	*M* (*SD*)	*n* (%)
Patient characteristics		
Age (years)	40.68 (8.00)	
Body mass index (kg/m^2)	26.30 (4.05)	
Nicotine use in previous 12 months		8 (8.2)
Mental health history		
Anxiety		25 (25.8)
Depression		17 (17.5)
Attention-deficit/hyperactivity disorder		16 (16.5)
Insomnia		2 (2.1)
Opioid risk score (*recorded value*)		
0		58 (59.8)

Continued

1		14 (14.4)
2		7 (7.2)
3		18 (18.6)
Current medication and substance use		
Tetrahydrocannabinol		4 (4.1)
Nonbenzodiazepine sedative-hypnotics		1 (1.0)
Benzodiazepines		4 (4.1)
Buspirone		1 (1.0)
Antiepileptic drugs		1 (1.0)
Serotonin antagonist and reuptake inhibitors		3 (3.1)
Norepinephrine-dopamine reuptake inhibitors		10 (10.3)
Serotonin-norepinephrine reuptake inhibitors		5 (5.2)
Selective serotonin reuptake inhibitors		15 (15.5)
ADHD medications		16 (16.5)
Selected medication class count		
0		83 (85.6)
1		10 (10.3)
2		4 (4.1)
Surgical and clinical characteristics		
Abdominoplasty only		17 (17.5)
Abdominoplasty plus breast procedure		80 (82.5)
Travel patient (out of state)		13 (13.4)
Operative time (minutes)	173.12 (58.82)	
Recovery time (minutes)	73.86 (13.16)	
Postoperative medication consumption (tablets)		
Oxycodone	13.81 (9.72)	
Gabapentin	13.06 (9.48)	
Acetaminophen	24.58 (22.71)	
Ibuprofen	23.15 (26.50)	

Note. Values are means (standard deviations) or frequencies (percentages). Percentages use available data; all categorical variables were complete ($N = 97$). For binary characteristics, the frequency indicates presence or use. Medication classes are not mutually exclusive. The selected medication class count sums use of antiepileptic drugs, serotonin antagonist and reuptake inhibitors, benzodiazepines, and norepinephrine-dopamine reuptake inhibitors. No patients had documented chronic pain, cannabidiol use, or opioid antagonist use. Available medication totals were $n = 95$ for oxycodone, $n = 97$ for gabapentin, $n = 96$ for acetaminophen, and $n = 87$ for ibuprofen. Confirmed nonuse was retained as zero consumption. ADHD = attention-deficit/hyperactivity disorder.

Patients used an average of 13.8 oxycodone tablets ($SD = 9.7$). Among the 95 patients with recorded oxycodone consumption, 81.1% used 22 or fewer tablets and 76.8% used 21 or fewer, compared with the standard prescription of 30 tablets.

On the day of surgery (Day 0), 95 patients reported pain: 23 had average daily scores below 4, 30 had scores from 4 to less than 6, 25 had scores from 6 to less than 8, and 17 had scores of 8 - 10. By Day 4, 71 patients reported pain, with 33, 25, 12, and 1 patient in these respective categories. Figure 1 shows the number of patients reporting average daily pain scores of 4 or higher across postoperative Days 0 - 10. Pain levels among patients who did not report on a given day were unknown.

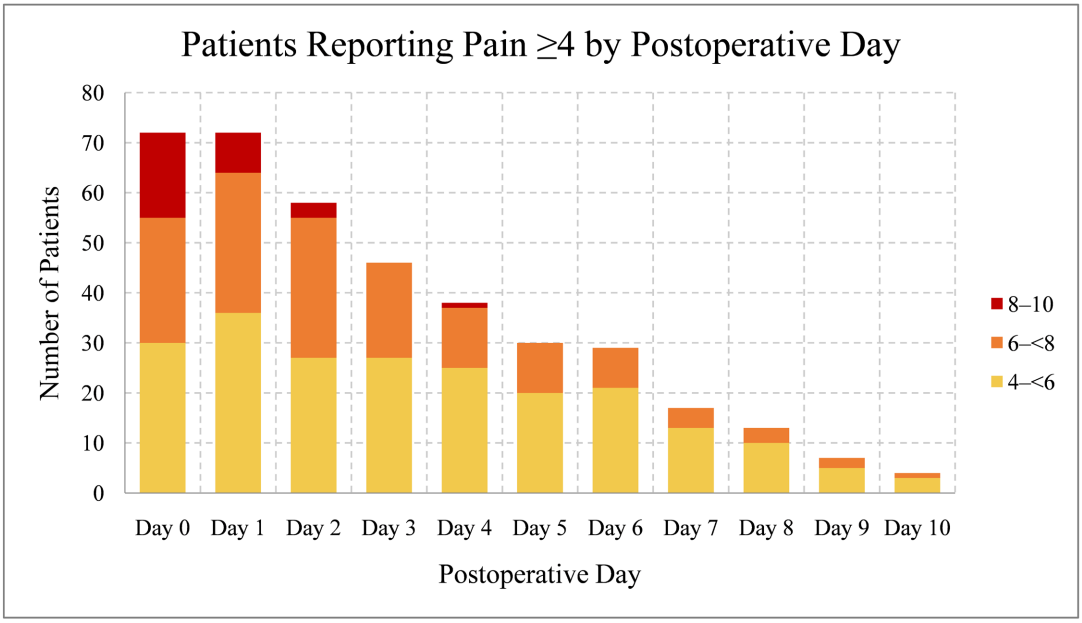

Figure 1. Number of patients reporting average daily pain scores of 4 or higher by postoperative day. *Note.* Categories represent average daily pain scores of 4 - <6, 6 - <8, and 8 - 10. Day 0 is the day of surgery. Patients reporting scores below 4 and those without a report on a given day are excluded.

Bivariate analyses revealed differences in oxycodone consumption across several patient subgroups. Patients reporting THC use consumed fewer oxycodone tablets on average than those not reporting THC use (M = 9.5 vs. 14.0), although this difference was not statistically significant (p = 0.367). Patients taking NDRIs reported significantly greater oxycodone consumption than those not taking NDRIs (n = 10, M = 19.9 vs. 13.1), $F(1, 93) = 4.56$, p = 0.035. Although mean consumption was also higher among patients taking AEDs, SARIs, or benzodiazepines, these individual comparisons were not statistically significant. Oxycodone consumption differed significantly across groups defined by the number of these selected medication classes used, $F(2, 92) = 4.46$, p = 0.014. Patients taking none consumed an average of 12.9 oxycodone tablets, compared with 16.0 among those taking one class and 26.8 among those taking two classes (see Figure 2). Patients diagnosed with anxiety also reported significantly greater oxycodone consumption than those without an anxiety diagnosis (M = 17.52 vs. 12.49), $F(1, 93) = 5.17$, p = 0.025. No statistically significant differences were observed by ADHD medication use or diagnosis of depression, insomnia, or ADHD.

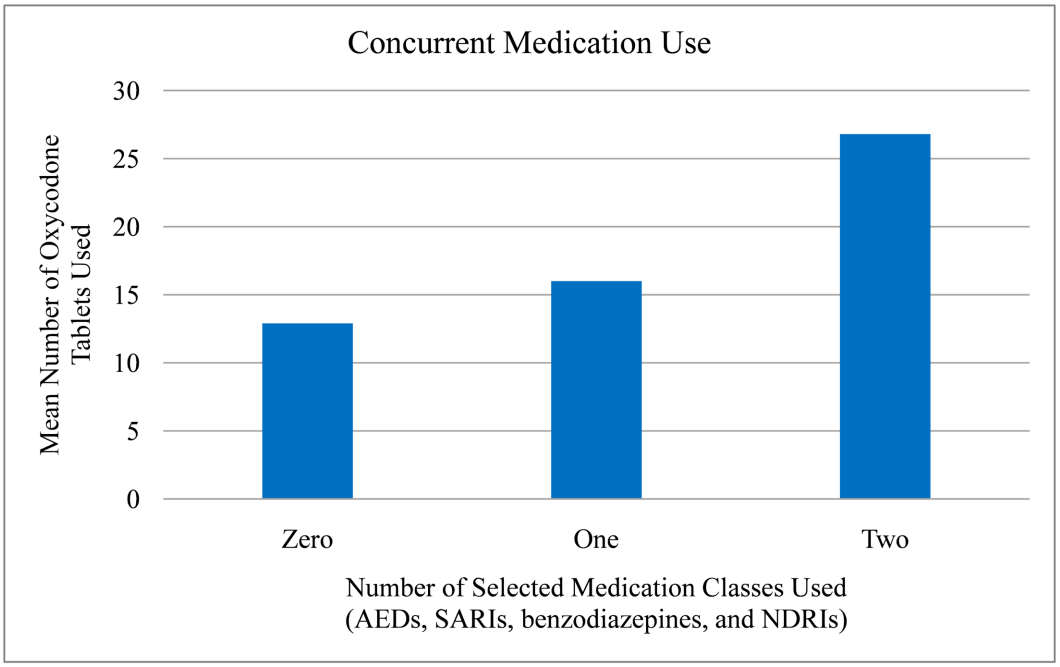

Figure 2. Mean number of oxycodone tablets used postoperatively by number of selected mental health medication classes being used (AEDs, SARIs, benzodiazepines, and NDRIs). *Note.* Group sample sizes were n = 81 for zero medication classes, n = 10 for one class, and n = 4 for two classes.

No statistically significant differences in oxycodone consumption were observed by SNRI use, SSRI use, nonbenzodiazepine sedative-hypnotic use, opioid risk score, procedure type, nicotine use, or travel patient status (all p's > 0.05). Oxycodone consumption was not significantly correlated with age (r = −0.125, p = 0.229), BMI (r = 0.191, p = 0.063), operative time (r = 0.122, p = 0.240), or recovery time (r = 0.079, p = 0.446). Spearman sensitivity analyses were also nonsignificant for all four continuous predictors.

Bivariate analyses of pain-category membership revealed no statistically significant associations with patient characteristics on the day of surgery (Day 0; n = 95). By Day 4, among the 71 patients reporting pain, category membership was significantly associated with age (p = 0.003), BMI (p = 0.040), anxiety diagnosis (p = 0.014), and nicotine use within the previous 12 months (p = 0.012). Mean age decreased across the four pain categories, from 42.5 years among patients reporting scores below 4 to 39.8, 34.8, and 32.0 years among those reporting scores of 4 - <6, 6 - <8, and 8 - 10, respectively. BMI differences did not follow a consistent increasing or decreasing pattern across pain categories.

Among Day 4 reporters with anxiety, 76.2% (16/21) reported average pain scores of 4 or higher, compared with 44.0% (22/50) of those without anxiety. The association with nicotine use reflected sparse category counts: only four patients reporting nicotine use provided Day 4 pain ratings, with three reporting scores below 4 and one reporting a score of 8 - 10. No statistically significant associations were observed for the remaining estimable patient characteristics, including individual mental health medication classes and the selected medication-class count.

In the secondary exploratory analysis combining nonreporters with patients reporting pain below 4 ($N = 97$ at each day), no statistically significant associations were observed on Day 0. The same four characteristics remained associated with category membership on Day 4: age ($p = 0.001$), BMI ($p = 0.045$), anxiety diagnosis ($p = 0.003$), and nicotine use ($p = 0.008$). The remaining estimable associations were nonsignificant.

Exploratory interaction tests indicated that associations of age and anxiety diagnosis with pain-category membership differed between postoperative Days 0 and 4. Among reporters, the age-by-day interaction was significant, $\chi^2(3) = 8.40$, $p = 0.039$, as was the anxiety-by-day interaction, $\chi^2(3) = 9.26$, $p = 0.026$. Interactions involving BMI, $\chi^2(3) = 2.76$, $p = 0.429$, and nicotine use, $\chi^2(3) = 3.48$, $p = 0.324$, were not statistically significant.

The secondary analysis combining nonreporters with patients reporting pain below 4 yielded similar findings. Interactions remained significant for age, $\chi^2(3) = 8.37$, $p = 0.039$, and anxiety diagnosis, $\chi^2(3) = 10.60$, $p = 0.014$, but were nonsignificant for BMI, $\chi^2(3) = 2.89$, $p = 0.409$, and nicotine use, $\chi^2(3) = 4.40$, $p = 0.222$. In the binary sensitivity analysis (166 observations from 95 patients), evidence of an anxiety-by-day interaction remained ($\chi^2(1) = 5.86$, $p = 0.016$), whereas the age-by-day interaction was not statistically significant ($\chi^2(1) = 2.39$, $p = 0.122$).

4. Discussion

Overall, results from this quality improvement project suggest an opportunity to reduce standard opioid prescribing following abdominoplasty, with or without breast surgery, while accounting for differences in individual patients' pain management needs. More than 80% of patients reported consuming 22 or fewer oxycodone tablets, compared with the standard prescription of 30 tablets. Anxiety diagnosis, NDRI use and the selected medication-class count were associated with greater oxycodone consumption, while the anxiety association differed by day in both pain categorizations. The age interaction was sensitive to how pain was categorized.

Our findings are consistent with prior research indicating that opioid prescriptions following plastic surgery often exceed actual patient consumption [9]. Reducing the standard prescription from 30 to 22 oxycodone tablets would represent an approximately 27% reduction while encompassing the consumption reported by more than 80% of patients in this sample. These results support consideration of a smaller standard prescription, with additional medication needs addressed individually. This approach could reduce the number of unused opioids available for diversion while allowing prescribing decisions to account for variation in patients' postoperative needs. The potential impact of this change extends beyond individual prescriptions. According to the clinical team, the study site performed 243 abdominoplasty procedures in 2024, including 136 abdominoplasty-only procedures and 107 combined with breast surgery. If an eight-tablet reduction were applied to both procedure groups at that annual volume, 1944 fewer oxycodone

tablets would be prescribed each year, reducing the potential supply of unused medication available for diversion. Further stratification of prescription quantities based on patient characteristics and observed consumption patterns could offer additional opportunities to reduce excess prescribing while addressing individual pain management needs.

Although overall consumption suggests an opportunity to reduce standard prescribing, differences across patient subgroups highlight the importance of individualized postoperative care. Patients diagnosed with anxiety consumed more oxycodone and, among those reporting pain on Day 4, were more likely to report scores of 4 or higher than patients without an anxiety diagnosis. These complementary findings are consistent with Nguyen and colleagues' observation that clinically significant anxiety was associated with greater postoperative pain and higher odds of opioid use [10]. Together, these results suggest that an anxiety history may help clinicians identify patients who would benefit from additional preparation before surgery and closer follow-up during recovery.

Medication history may also provide useful information when planning postoperative care. Oxycodone consumption was higher among patients taking NDRIs and differed across groups defined by the number of selected mental health medication classes used. Prior studies have similarly linked preoperative benzodiazepine use with subsequent opioid prescribing and certain antidepressants with greater opioid consumption during hospitalization [13] [14]. Our findings extend this literature to patients undergoing abdominoplasty, with or without breast surgery, and support considering current medication use alongside mental health diagnoses when assessing postoperative needs. The underlying conditions being treated and potential medication interactions offer possible explanations for these associations that warrant further investigation.

The timing of these associations also has implications for postoperative monitoring. No patient characteristics were significantly associated with pain-category membership on the day of surgery, whereas younger age and anxiety were associated with higher pain categories among patients reporting on Day 4. Exploratory interaction tests supported differences in these associations between days in the four-category analysis. The anxiety interaction remained significant when pain was dichotomized at 4; the age interaction did not, so the evidence for an age-related difference was sensitive to the choice of pain categories. This pattern complements our prior work at Womack Army Medical Center, where differences in pain by smoking status were apparent from postoperative Day 4 onward, and Day 4 pain was a significant predictor of total opioid consumption [19]. Although the patient populations and associated characteristics differed, both projects suggest that assessment several days after surgery may provide useful information about individual pain management needs beyond the immediate postoperative period. Follow-up around Day 4 may therefore offer an opportunity to reassess pain control and identify patients who need additional support. Although BMI and nicotine use were also associated with Day 4 pain-category membership, BMI showed

no consistent gradient across categories, and the nicotine finding involved very few patients. These results offer less clear guidance for postoperative care.

Taken together, these findings illustrate how patient-reported pain and medication use can inform both prescribing practices and individual follow-up. At the practice level, actual consumption data provide a basis for reconsidering standard prescription quantities. At the patient level, information about mental health history and pain several days after surgery may help clinicians anticipate and respond to differing recovery needs. The combination of the CPMRx mobile application and clinician-facing CDST provides a means of reviewing these patterns as recovery progresses. Integrating this information into postoperative care could support smaller initial prescriptions alongside timely reassessment for patients whose pain or medication needs remain elevated.

Several limitations should be considered when interpreting these findings. This quality improvement project was conducted at a single plastic surgery center with a relatively small sample, which may limit generalizability to other settings and patient populations. Several medication groups were particularly small, including only four patients taking two of the selected medication classes. Only one patient reported average pain in the highest category on Day 4, further limiting the stability of category-specific findings and interaction tests. These findings therefore warrant replication in larger samples. The associations reported were not adjusted for other patient characteristics, and medication use may reflect underlying conditions or treatment needs that were not fully captured in the EMR. Multiple comparisons were conducted without adjustment, increasing the possibility of chance findings; the subgroup associations and exploratory interaction results should be interpreted accordingly. Prior opioid use was incorporated into the PDMP-derived ORS but could not be separately analyzed or used to identify opioid-naïve patients.

Pain and medication consumption were self-reported, and participation in app reporting varied over time. Patients were instructed to continue reporting while taking pain medications, so later reports may disproportionately represent patients with ongoing pain or medication needs. The reporter-only analyses describe patients who provided data on each day and cannot establish the pain status of the full sample. Although the secondary analysis combining nonreporters with patients reporting pain below 4 yielded similar findings, this grouping does not confirm that nonreporters had low pain or had stopped taking medication. Prospective follow-up at scheduled intervals, regardless of medication use, would help clarify these patterns.

Finally, consumption under the existing regimen does not establish that a smaller initial prescription would provide adequate pain control for the same proportion of patients. A subsequent quality improvement cycle could evaluate this change while monitoring pain control, refill requests, and patient satisfaction, with a process for addressing additional medication needs.

This project identified an opportunity to reduce standard opioid prescribing while recognizing variation in patients' postoperative needs. Actual medication

consumption, routinely documented patient characteristics, and pain reported several days after surgery provide complementary information that can inform prescribing and follow-up. Incorporating these data into ongoing quality improvement may help clinicians reduce excess prescribing while remaining responsive to patients who need additional support during recovery.

Author Contributions

Jeremy Pyle, Steven K. Walther, and Jessica Kelley Morgan conceived the project. Jessica Kelley Morgan led the analyses, interpreted the findings, and drafted the manuscript. Kelly Jaglowski and Alexandra Zannino supported implementation at the clinical site and contributed to data collection and interpretation. Annmarie O'Donnell and Andrew Harvey supported implementation of the CPMRx system and preparation of the analytic data. Steven K. Walther provided project oversight, and Jeremy Pyle provided clinical oversight and contributed to interpretation of the findings. All authors reviewed and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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