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Original Research

PACU Outcomes Across Anesthesiology Resident Training Levels: A Retrospective Cohort Study

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Introduction

Graduate medical education increasingly emphasizes competency-based assessment with increasing pressure driven by national shifts toward competency-based medical education and programmatic assessment to identify objective measures of trainee performance.[1,2] In anesthesiology residency training, performance metrics derived from electronic anesthesia records, such as intraoperative hemodynamic control and postoperative nausea and vomiting (PONV) prophylaxis, are shown to correlate with resident training level, suggesting that routinely collected perioperative data may serve a useful role in tracking the trajectory of resident competence.[3] Similarly, postanesthesia care unit (PACU) outcomes such as analgesic use, rescue antiemetic administration, and recovery time are appealing as potential assessment metrics because they are routinely captured, consistently documented, and intuitively linked to anesthetic quality although postoperative PONV rates themselves are not typically used as stand-alone quality indicators.

Whether PACU outcomes truly correlate with resident clinical experience, however, remains uncertain. Pain and PONV are among the most common and distressing postoperative complications, and they are influenced by a wide range of factors, including patient comorbidities, surgical procedure, and anesthetic duration, all of which may be independent of resident decision making.[4,5] Without accounting for this context, early learners may appear to have worse outcomes, not because of differences in clinical competence, but because they are more often assigned to cases with a higher inherent risk for pain and PONV. Additionally, institutional protocols and attending supervision practices may limit the extent to which resident performance can be directly assessed by these outcomes.

We, therefore, sought to determine whether PACU outcomes differ across anesthesiology resident training levels and to what extent such differences may be explained by patient and case characteristics.

Methods

This was a retrospective cohort, single-center, observational study conducted at Memorial Hermann Hospital–Texas Medical Center. The study was approved by the UTHealth institutional review board and Memorial Hermann research committee (HSC-MS-25-0501) with a waiver of informed consent granted due to the retrospective nature of the study. The study applied the "Strengthening the Reporting of Observational Studies in Epidemiology" statement to observational studies.[6] Subjects and their associated data were identified using an electronic institutional database.

Eligible cases included anesthetics performed on adult patients aged ≥18 years between October 1, 2024, and May 16, 2025, with a University of Texas at Houston anesthesiology resident, that is, first-, second-, or third-year clinical anesthesia resident (CA-1, -2, or -3) listed as staff in the electronic medical record. The sample size was determined by the number of eligible cases during the study period. The primary outcome was PACU morphine milligram equivalents (MME); secondary outcomes were average PACU rescue antiemetic doses and recovery time. The primary and secondary outcomes were defined and established a priori at initiation of the study design. These outcomes are not part of a formal year-specific curriculum at our institution. At our institution, PACU discharge is determined by clinical criteria, including assessment of pain control, vital signs, level of consciousness, and PONV with physician evaluation required prior to discharge, but a formal score such as the Aldrete scale is not documented. Additional inclusion criteria required PACU recovery and extubation if intubation occurred. As a result, cases routinely admitted postoperatively to the intensive care unit, including cardiothoracic procedures requiring prolonged postoperative ventilation, were excluded by design. For complex subspecialty services such as cardiothoracic surgery, only cases extubated at the conclusion of surgery and

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recovered in the PACU were eligible for inclusion.

Exclusion criteria included cesarean deliveries, missing key outcome data, anesthesia duration >1080 minutes, and recovery times <30 minutes (institutional minimum). One thousand eighty minutes was selected as the upper limit because anesthesia durations beyond 18 hours at our institution are exceedingly rare and typically reflect documentation error rather than true continuous anesthetics. This threshold allowed for the retention of nearly all cases, including very long cases, and excluding durations likely to be inaccurate. Fifty-two extreme outlier cases were also excluded for PACU time or MME >4 standard deviations above the mean. Resident level was assigned based on the provider who initiated the anesthetic; handoffs did not lead to exclusion. A full breakdown of exclusions is shown in the study flow diagram (Figure 1). Given the large sample size (n = 7699), the study was adequately powered to detect small but clinically meaningful differences between groups.

Resident training level (CA-1, -2, or -3) was the primary exposure variable of interest. Covariates included patient age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status classification, race, anesthesia type, primary surgical service (procedure category), preoperative pain score, history of PONV or smoking, and anesthesia duration. These variables were selected based on their clinical relevance. We excluded intraoperative metrics such as intraoperative opioid dosing because they likely act as mediator variables because they are part of the causal pathway linking upstream predictors (eg, resident training level) to PACU endpoints. Although anesthesia type is technically an intraoperative variable, it is typically determined during the preoperative planning phase. Procedure duration was included as an approximate indicator of case complexity although this relationship may vary across procedures and institutions.

Anesthesia type was categorized as "general" if any component of the anesthetic included general anesthesia (eg, general plus spinal). PACU recovery time was calculated as total PACU time minus PACU hold time (the period after discharge criteria were met).

Statistical Analyses

Descriptive statistics were computed for all patient and procedural variables. Continuous variables were reported as means and standard deviations, whereas categorical variables were summarized with counts and percentages. Group differences in categorical variables were assessed using chi-square tests. Effect size was quantified with Cramér's V, for which a value of ~0.1 was considered small, ~0.3 medium, and ~0.5 large.[7] Continuous variables were compared using 1-way analysis of variance (ANOVA). Eta squared (η^2) was calculated as a measure of effect size for which a value ~0.01 was considered small, ~0.06 medium, and ~0.14 large, following conventional guidelines.[7] A significance threshold of $p < .05$ was used for all analyses. Because the sample size was large, we assumed that the data were suitable for ANOVA and regression analyses even if not perfectly normally distributed. Although we did not perform formal distribution checks within each resident class, the large number of cases at each level and the use of adjusted regression models minimize the impact of within-level variability on comparisons.

Post hoc comparisons between resident training levels (CA-1, -2, -3) were conducted using Tukey's honestly significant difference (HSD) test to identify pairwise differences and then multiple linear regression models to address confounders. Three separate multiple linear regression models were constructed to evaluate predictors of the primary and secondary outcomes. A sensitivity analysis of the ANOVA between resident level for the 3 outcomes was performed for only cases in which a resident-to-resident handoff did not occur, followed by multiple linear regressions for each of the 3 outcomes using the handoff-excluded data set.

Receipt of any PACU opioid, a known risk factor for postoperative nausea and vomiting (eg, Apfel score),[8] was included as a predictor in the antiemetic model. Regression coefficients with 95% confidence intervals were reported to describe the direction and magnitude of associations. For continuous predictors, coefficients reflect the expected change in the outcome per 1-unit increase; for categorical variables, they represent the mean difference from the reference group. Missing data were addressed by list-wise deletion; only complete cases were included in regression analyses. Variance inflation factors were calculated to assess multicollinearity with values >10 indicating high collinearity.[9] Analyses were conducted using Python version 3.13.3 (Python Software Foundation, https://www.python.org).

Results

Study Cohort

Patient Demographics

The cohort (n = 7699) had a mean age of 52 years and mean BMI of 29 kg/m^2 (Table 1). Most patients were ASA class II–III, and the largest racial groups represented were White and African American. Preprocedural pain scores were infrequently documented with only 20% of data available. Histories of smoking and PONV were uncommon.

Case Characteristics

The mean anesthesia duration was just over 3 hours. Most cases were managed under general anesthesia though documentation of anesthetic type was incomplete in a subset. Records with incomplete anesthetic type documentation were included in descriptive and unadjusted analyses but excluded from the multivariable analyses due to a missing covariate. Approximately 10% of procedures were laparoscopic or robotic. The most common surgical categories were orthopedic, neurosurgical, and general surgery with smaller contributions from subspecialties such as gynecology, otolaryngology, and plastic surgery. The complete study cohort including all surgery types can be found in Supplemental Table 1.

Outcomes

The average morphine equivalent dose administered in PACU was 14.97 ± 18.79

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mg, with 60% (n = 4595) of patients requiring any postoperative opioid. The average rescue antiemetic dose administered in PACU was 0.26 ± 0.52 of a dose. The average recovery time before meeting PACU discharge criteria was 67.1 ± 38.9 minutes.

Univariable Analysis

Patient Demographics by Resident Level

CA-1 patients were slightly younger than those managed by CA-2 and -3 residents. BMI, sex, and racial distribution were similar across groups though *other/unknown* race was recorded more often in CA-1 cases. Lower ASA classes were more common among CA-1 patients, whereas higher ASA classes were more frequent in CA-2 and -3 cases. Smoking history and prior PONV were also somewhat more common among CA-1 patients.

Case Characteristics by Resident Level

CA-1 residents performed the majority of cases in the cohort (n = 4316, 56%) compared with CA-2 (n = 1894, 25%) and CA-3 (n = 1489, 19%) residents. They were more likely to manage general anesthetics and cases from specialties such as ear–nose–throat, gynecology, plastics, urology, oral/maxillofacial surgery, and orthopedics. In contrast, CA-2 and -3 residents were more often assigned to complex subspecialty cases including cardiothoracic surgery, neurosurgery, spinal surgery, and electrophysiology. Anesthesia time was slightly longer for CA-2 cases. Laparoscopic and robotic procedures were somewhat more common among CA-1 cases. The complete list of variables stratified by resident level can be found in Supplemental Table 2.

Outcomes by Resident Level

CA-1 patients received higher PACU MME (15.9 ± 18.9 mg) compared with CA-2 (13.8 ± 18.2 mg) and CA-3 (13.6 ± 19.0 mg; $p < .001$; Table 2). The requirement for any PACU opioid was also greater among CA-1 cases (63.4%) than CA-2 (55.6%) or CA-3 (54.0%; $p < .001$). Similarly, CA-1 patients received more rescue antiemetic doses (0.28 ± 0.54) compared with CA-2 (0.24 ± 0.51) and CA-3 (0.22 ± 0.50; $p < .001$), equivalent to roughly 1 additional antiemetic per 17 patients compared with CA-3. PACU recovery time was slightly longer for CA-1 cases (68.4 ± 38.6 minutes) versus CA-2 (65.4 ± 39.5 minutes) and CA-3 (65.5 ± 38.7 minutes; $p = .004$).

Post Hoc Comparisons Between Resident Levels

Tukey's HSD Test

Post hoc Tukey's HSD comparisons (Figure 2) showed that CA-1 patients received more PACU MME than CA-2 (mean difference 1.81 mg, 95% CI 1.00–2.62, $p < .001$) and CA-3 (2.62 mg, 95% CI 1.76–3.48, $p < .001$) with no difference between CA-2 and -3 ($p = .11$). CA-1 patients also required more rescue antiemetic doses than CA-2 (0.038, 95% CI 0.010–0.066, $p = .008$) and CA-3 (0.058, 95% CI 0.028–0.089, $p < .001$) with no CA-2 versus -3 difference ($p = .24$). PACU recovery time was longer for CA-1 than -2 (2.71 minutes, 95% CI 1.21–4.20, $p < .001$) and CA-3 (2.86 minutes, 95% CI 1.17–4.54, $p < .001$) with no difference between CA-2 and -3 ($p = .88$).

Multiple Linear Regression

PACU MME (Figure 3, Supplemental Table 3). In the adjusted model, higher opioid use was predicted by orthopedic, spinal, and trauma surgeries; longer anesthesia duration; higher preprocedural pain scores; White race; and younger age. Male sex was associated with lower opioid use. Importantly, resident training level was not an independent predictor once these factors were considered. Although BMI, ASA class, and age showed collinearity, they were retained for clinical relevance.

Rescue antiemetics (Figure 4, Supplemental Table 4). Rescue antiemetic use was more likely in laparoscopic or robotic procedures, in patients receiving postoperative opioids, in those with higher BMI, and among White patients. Lower use was associated with male sex, higher ASA class, and older age. Resident training level was not independently associated with antiemetic administration. Although history of PONV showed high collinearity, it was retained in the model given its clinical importance for prophylaxis decisions.

PACU recovery time (Figure 5, Supplemental Table 5). Longer recovery times were associated with orthopedic, spinal, trauma, and oral/maxillofacial surgeries as well as longer anesthesia duration, higher preprocedural pain scores, and a history of PONV. Male patients had slightly shorter PACU stays. Resident training level was not independently associated with recovery time. Although history of PONV showed high collinearity, it was retained given its clinical relevance.

Sensitivity Analysis

Resident-to-resident handoffs occurred in about 9% of cases. Excluding these cases did not change the findings: CA-1 patients continued to show higher opioid and antiemetic use and slightly longer PACU stays in unadjusted analyses, but resident training level remained nonsignificant in adjusted models.

Discussion

Summary of Key Findings

This large retrospective cohort study evaluates PACU outcomes by anesthesiology resident training level. Unadjusted analyses showed that patients managed by CA-1 residents received significantly more opioids and rescue antiemetics in the PACU and had longer recovery times compared with CA-2 and -3 cases. However, these differences disappeared after adjusting for patient and procedural characteristics. This suggests that the apparent disparities in outcomes between resident experience levels are better explained by differences in case mix and patient factors rather than by resident training level itself. Notably, senior residents, most of whom have typically completed a dedicated PACU rotation, did not demonstrate superior PACU outcomes compared with CA-1 residents after adjustment, indicating that these metrics do not appear sensitive to PACU-specific experiential learning.

Comparison with Other Work

Our results mirrored established patterns of postoperative pain and PONV predictors and extend this body of work by introducing resident training level into the analysis.[5,10–12] Importantly, resident level

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did not alter these associations and did not emerge as an independent predictor, suggesting that these recovery metrics may be poor proxies for evaluating resident performance in isolation.

Prior work examines whether routinely collected perioperative data can be leveraged for trainee evaluation. One framework has emphasized the importance of selecting clinical outcomes that meaningfully reflect resident participation while minimizing the influence of patient and system-level confounders.[13] More recently, electronic anesthesia record–based dashboards have been developed to provide resident-level feedback and support reflective learning.[14] Our findings align with these concerns: although PACU outcomes are appealing because they are objective and readily available, they are strongly influenced by patient and procedural context rather than resident level. This highlights the need for caution when incorporating recovery metrics into trainee assessment and supports the argument for context-sensitive strategies for competency assessment. Risk-adjusted PACU metrics may have a role in milestone-aligned structured feedback systems but only if interpreted in context.

From an educational standpoint, residents may benefit from teaching that focuses on adapting anesthetic plans to patient- and procedure-specific factors rather than standardized, 1-size-fits-all approaches. Risk must be assessed on a case-by-case basis, and assignment to a junior resident may not necessarily indicate that a case is low risk for adverse outcomes. Providing residents with within-class comparisons might be conceptually appealing, but even within a single training level, residents care for heterogeneous patient populations with varying comorbidities and procedural complexity, which limits the usefulness of within-class comparisons as direct indicators of individual performance.

Limitations

Although the study period was limited to less than a year, it was intentionally restricted to October through May to align with standard staffing patterns and avoid the transitional summer months when interns are first introduced to the operating room and CA-1 residents are often supervised in a 1:1 attending-to-resident model. Additionally, the cohort included more than 7000 cases, providing sufficient power for multivariable modeling while minimizing variability due to institutional changes, resident turnover, or evolving practice patterns that might affect longer study periods. The single-center design and the retrospective nature of data collection may limit generalizability and introduce measurement bias. Additionally, the unequal distribution of cases across resident training levels reflects typical rotation and staffing patterns but may limit the precision of between-level comparisons.

Some variables, such as preprocedural pain scores, were incompletely documented. Because available documentation did not reliably distinguish complete total intravenous anesthesia from mixed or low minimum alveolar concentration (MAC) volatile techniques and MAC values were inconsistently captured, anesthetic technique could not be categorized with sufficient accuracy for separate analysis. Although PACU discharge evaluations include assessment of consciousness, ventilation, circulation, and pain control, these elements are not documented using a formal score (ie, Aldrete score), and rare events such as unplanned reintubation were not analyzed due to their low incidence. Detailed timing of intraoperative opioid administration, including long-acting agents given near the end of the case, was not captured in a structured field in the electronic record and, therefore, could not be reliably extracted for analysis. Although analyzed separately, PACU opioid use, antiemetic administration, and recovery time are interrelated clinical outcomes, and this may contribute to some overlap in their associations.

A major limitation is that resident autonomy in intraoperative management is inherently constrained by attending supervision, institutional protocols, and surgical team dynamics. Objective, validated measures of resident autonomy were not available for this analysis, limiting our ability to account for within-level variation in independence. This study did not include measures of individual resident performance or competency, limiting our ability to correlate PACU outcomes with direct assessments of resident skill. Although the study adjusted for procedure type and anesthesia duration, unmeasured differences in patient and case complexity may still contribute to the modest unadjusted outcome differences observed across training levels. The study also did not include cases managed solely by faculty or advanced practice providers, and this may limit applicability to nontraining environments. Whereas resident-to-resident handoffs were addressed in the sensitivity analyses, resident-to-midlevel (and vice versa) were likely included in the data set and not explicitly identified or analyzed as a distinct category, potentially introducing unmeasured variability into the results.

Future Direction

Subsequent investigations might explore whether PACU recovery metrics can be incorporated into case mix–adjusted educational dashboards that allow individual residents to reflect on their perioperative planning and recovery outcomes in the context of patient and procedural factors. Qualitative studies exploring how residents and faculty interpret such outcome data could also clarify whether these metrics are perceived as fair, actionable, and educationally valuable. Future studies with larger, longitudinal data sets may enable attending- or case-matched comparisons or the use of propensity score matching, and this could further reduce confounding and provide deeper insight into resident performance. Additionally, longitudinal analyses across residency years may help clarify learning trajectories.

Conclusions

Resident training level was not independently associated with PACU recovery outcomes after adjustment for patient and procedural factors. These results suggest that unadjusted PACU metrics are poor indicators of resident clinical experience or training level and should be interpreted cautiously within appropriate clinical context.

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Abstract

Background: Opioid use, antiemetic administration, and length of postanesthesia care unit (PACU) stay are commonly documented postoperative recovery measures. The extent to which they differ across anesthesiology resident training levels independent of patient and procedural factors remains uncertain. Characterizing these patterns may help distinguish differences attributable to patient or procedural factors from those related to resident experience.

Objective: To explore whether PACU recovery outcomes differ across anesthesiology resident training levels.

Methods: This single-center retrospective cohort study analyzed 7699 adult nonobstetric anesthetics performed between October 2024 and May 2025, stratified by resident level (first-, second-, or third-year clinical anesthesia resident). The primary outcome was PACU morphine milligram equivalents. Secondary outcomes were rescue antiemetic use and recovery time. Univariable tests, Tukey-adjusted comparisons, and multivariable linear regressions adjusted for demographics, case characteristics, and anesthetic type.

Results: Patient and case characteristics varied across resident levels. After multivariable adjustment, resident training level was not independently associated with PACU opioid use, rescue antiemetic administration, or recovery time. Unadjusted variation in these recovery measures was explained by patient and procedural factors.

Conclusions: Resident training level was not an independent predictor of PACU opioid use, rescue antiemetic administration, or recovery time. Observed differences were explained by patient and procedural factors, and this highlights the complex interplay of patient comorbidities, surgical characteristics, anesthetic plans, and institutional protocols on postanesthesia recovery metrics and emphasizes the importance of case-mix adjustment when interpreting PACU outcomes in educational contexts.

Keywords: Anesthesiology resident education, postanesthesia care unit (PACU), perioperative quality metrics, graduate medical education

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Figures

Figure 1. *Study flow diagram illustrating case selection for inclusion in the study. Eligible cases included all nonobstetric anesthetics staffed by a Univerity of Texas–Houston anesthesiology resident between October 1, 2024, and May 16, 2025, at Memorial Hermann Hospital. Cases were excluded for age <18 years, cesarean delivery, missing PACU outcome data (MME, rescue antiemetics, or recovery time), recovery time <30 minutes (institutional minimum), intubation without extubation, extreme BMI (>500), anesthesia time >18 hours, or PACU values exceeding 4 standard deviations above the mean. The final analytic cohort included 7699 cases. Abbreviations: PACU, postanesthesia care unit; MME, morphine milligram equivalents; BMI, body mass index.*

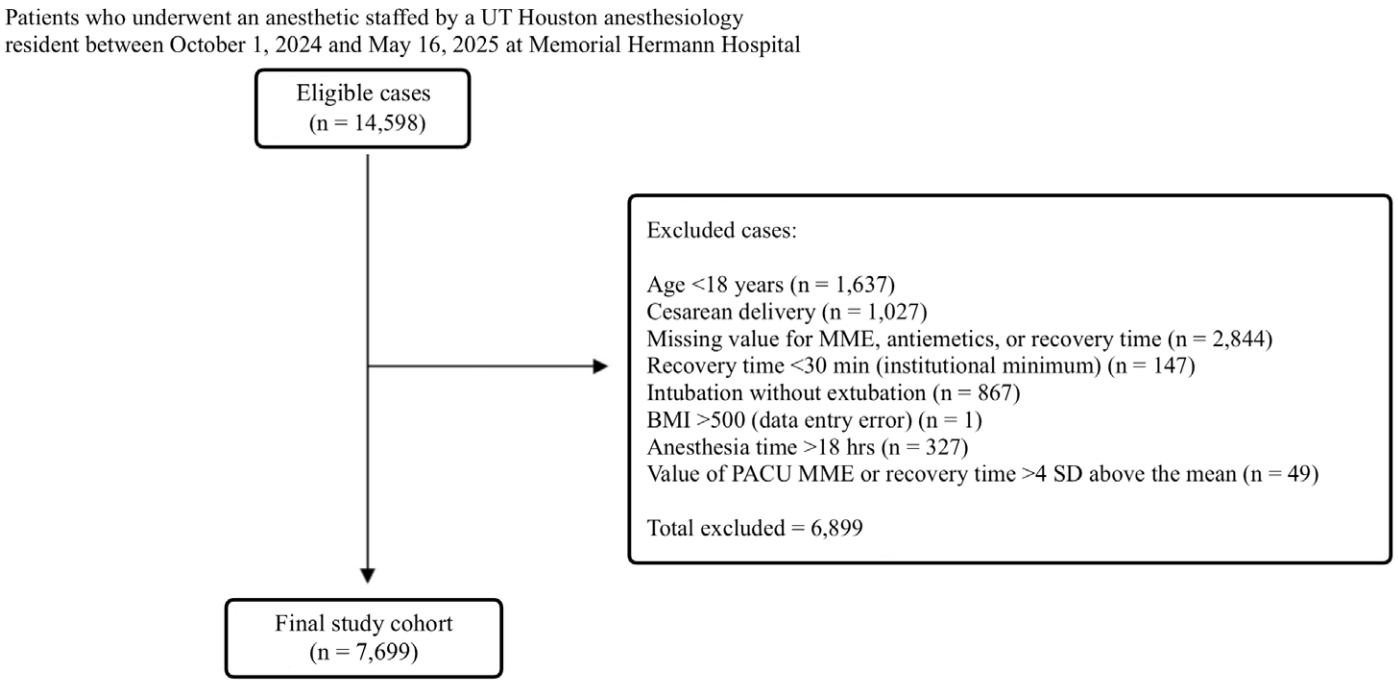

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Figure 2. *Tukey-style plots of MME requirement, rescue antiemetic requirement, and PACU recovery time. Each panel displays pairwise comparisons between anesthesiology resident training levels (CA-1, -2, -3) for a given PACU outcome using Tukey's honest significant difference test following 1-way analysis of variance. Black dots represent mean differences with horizontal bars indicating 95% confidence intervals. The vertical dashed line represents a difference of 0 (no effect). Asterisks denote statistical significance. Abbreviations: MME = morphine milligram equivalents; PACU = postanesthesia care unit. Significance thresholds: p < .05 = *, p < .01 = **, p < .001 = ****

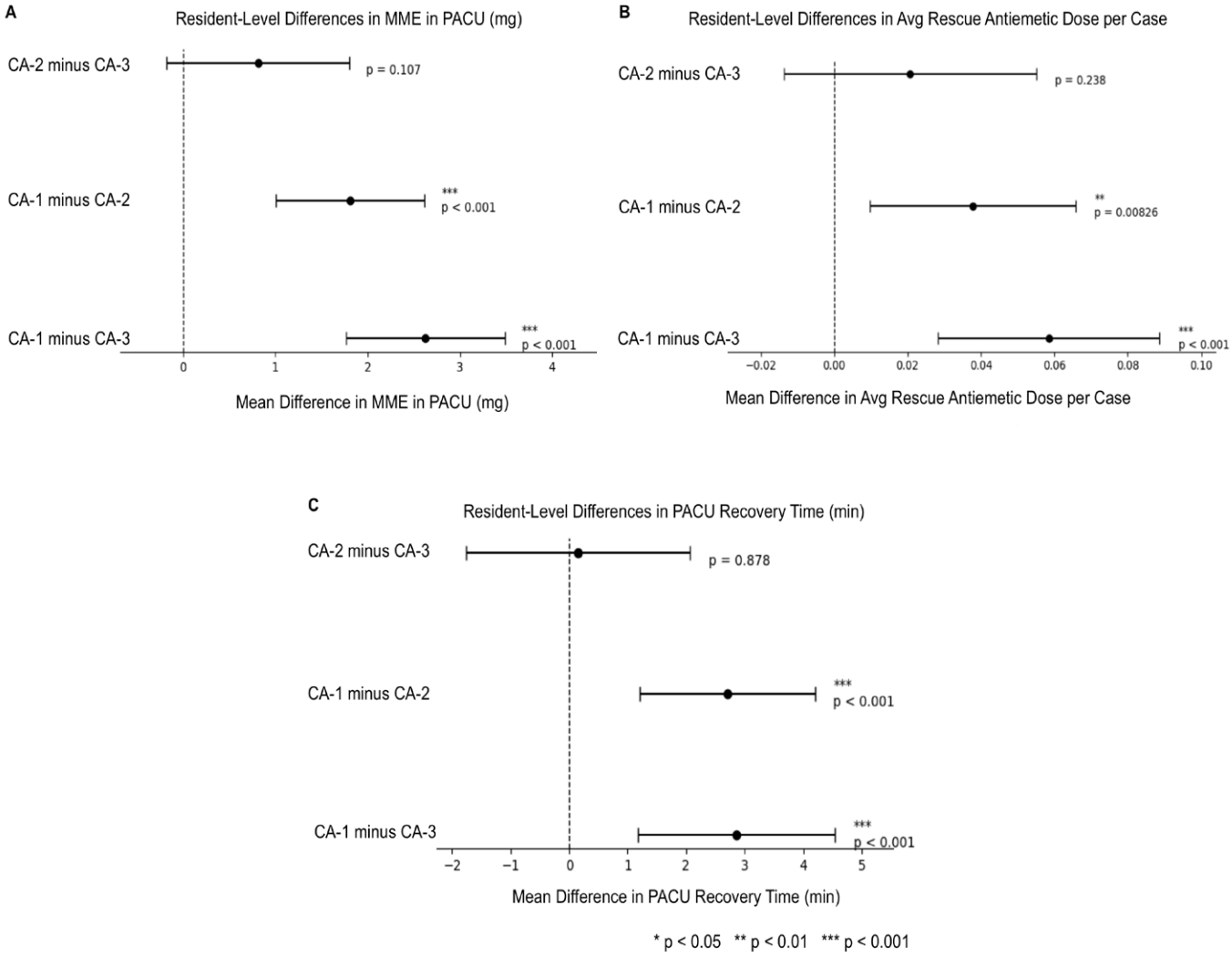

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Figure 3. *Multiple regression coefficient plot for MME (resident level + significant variables only). This figure displays coefficient estimates and 95% confidence intervals from a multiple linear regression model predicting PACU MME administration. Each point represents the adjusted effect size for a given predictor with horizontal lines indicating the 95% confidence interval. A vertical dashed line at 0 reflects the null hypothesis of no association. Asterisks denote statistical significance ($p < .05$). Abbreviations: PACU = postanesthesia care unit; MME = morphine milligram equivalents. Reference groups: CA-1 (for resident level), general anesthesia (for anesthesia type), female (for gender), non-white (for race).*

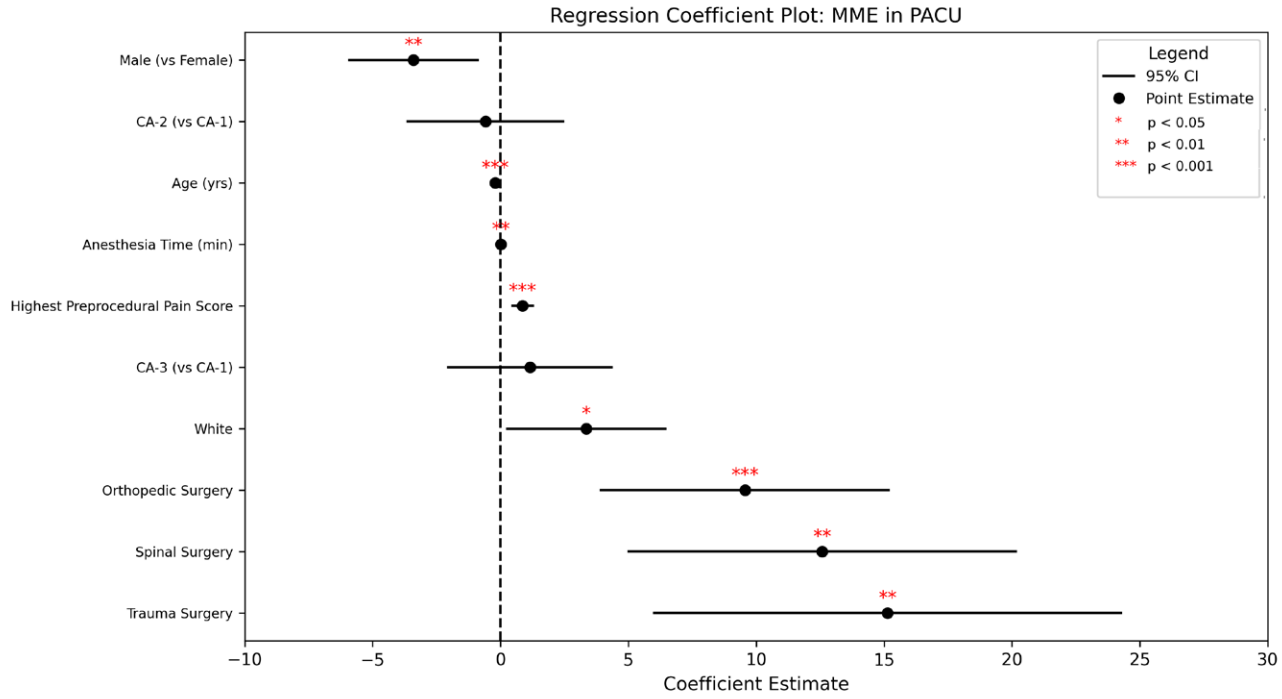

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Figure 4. *Multiple regression coefficient plot for rescue antiemetic doses (resident level + significant variables only). This figure presents coefficient estimates and 95% confidence intervals from a multiple linear regression model evaluating predictors of average rescue antiemetic doses administered in the PACU. Each point represents the adjusted effect size for a given predictor with horizontal bars denoting 95% confidence intervals. A vertical dashed line at 0 indicates no association. Asterisks identify predictors with statistically significant associations (p < .05). Abbreviations: PACU = postanesthesia care unit; BMI = body mass index; ASA = American Society of Anesthesiologists. Reference groups: CA-1 (for resident level), general anesthesia (for anesthesia type), female (for gender), non-white race.*

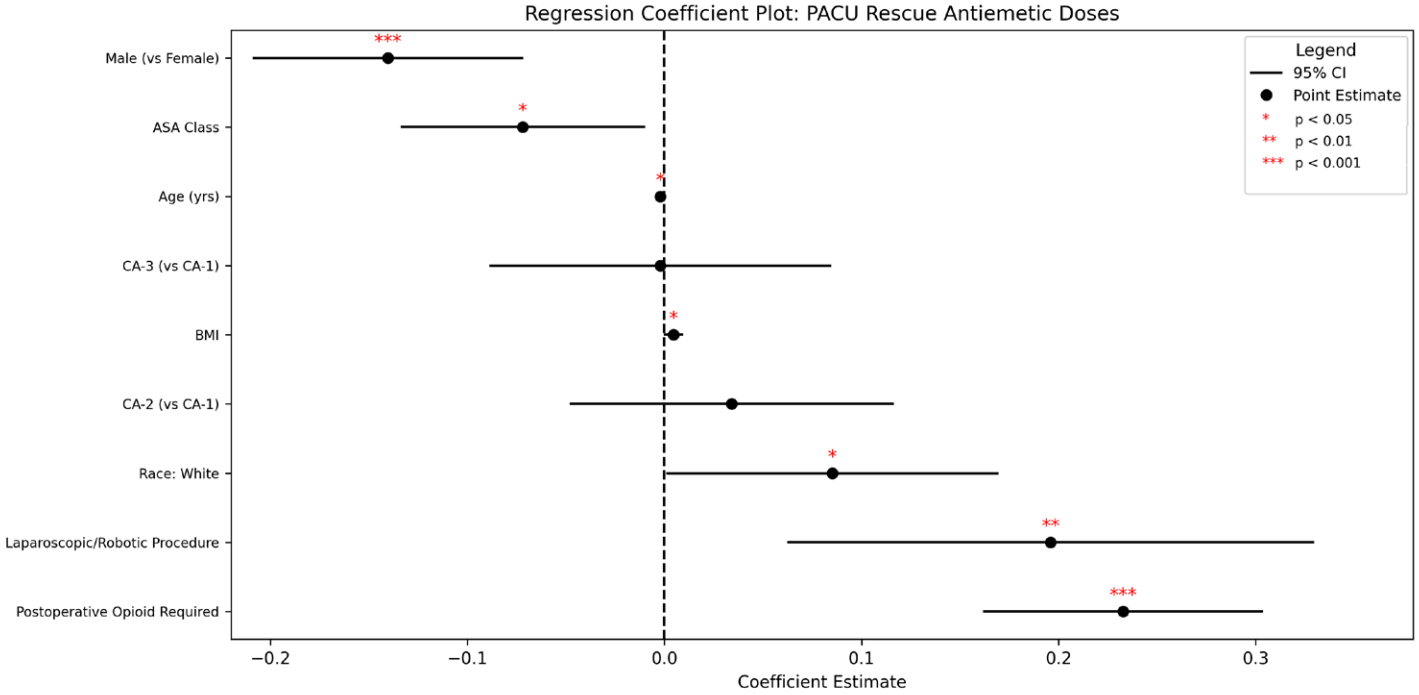

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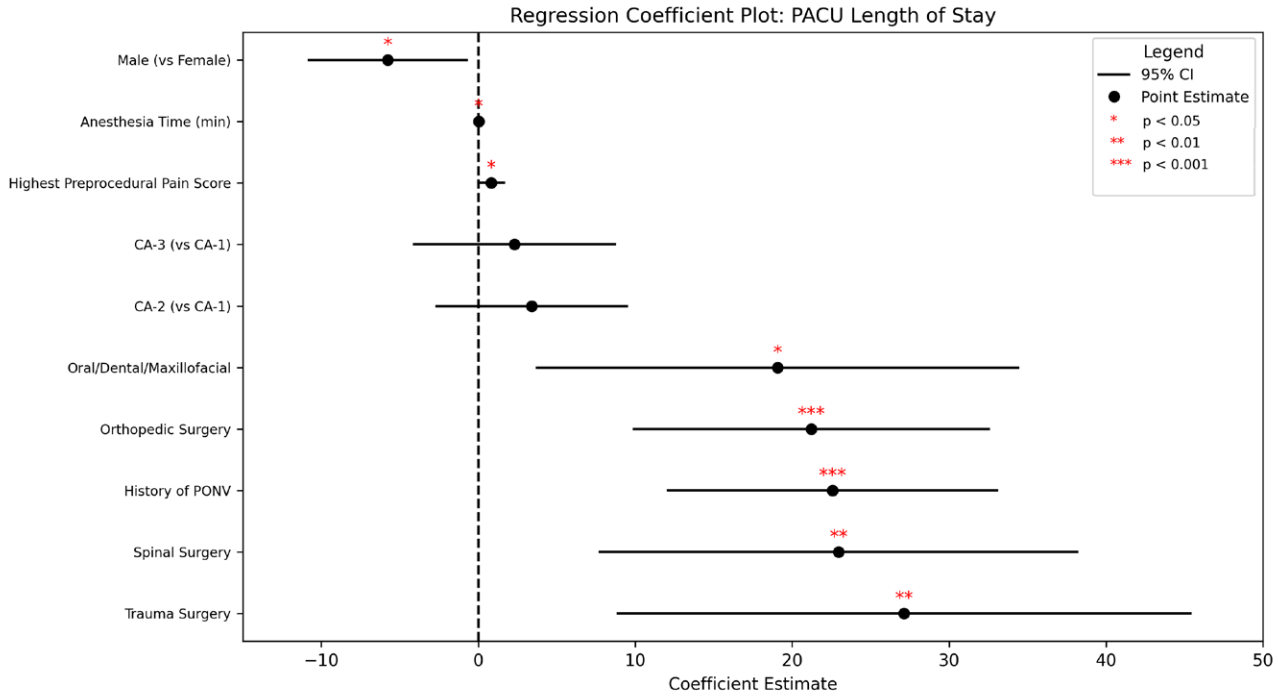
Figure 5. *Multiple regression coefficient plot for recovery time (resident level + significant variables only). This figure displays coefficient estimates and 95% confidence intervals from a multiple linear regression model predicting PACU recovery time (length of stay in minutes). Each point represents the adjusted effect size (regression coefficient) for a given predictor while horizontal lines indicate 95% confidence intervals. A vertical dashed line at 0 indicates no association. Asterisks indicate statistically significant predictors ($p < .05$). Rightward arrows indicate truncated confidence intervals extending beyond the x-axis limits. Abbreviations: PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting. Reference groups: CA-1 (for resident level), general anesthesia (for anesthesia type), female (for gender), non-white race.*



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Tables

***Table 1**. Summary of Key Patient, Procedural, and Outcome Characteristics*

Variable	Count	Mean ± SD	Missing, n (%)
Age (years)	7699	52 ± 19	0
BMI (kg/m²)	7477	28.7 ± 7.7	222 (2.3)
Anesthesia time (minutes)	7699	193 ± 127	0
Highest preprocedural pain score (0-10)	1513	2 ± 3	6186 (80)
Variable	Count	Percentage	Missing
Anesthesia type			
General	6251	81.2	0
Monitored anesthesia care	136	1.8	0
Spinal	13	0.2	0
Missing	1296	16.8	0
Gender			
Female	3836	49.8	0
Male	3860	50.1	0
ASA class			
1	193	2.5	0
2	2188	28.4	0
3	4645	60.3	0
4	655	8.5	0
5	18	0.2	0
Laparoscopic/robotic	774	10.1	0
Smoker	653	8.5	0
History of PONV	311	4.0	0
Required any postoperative opioid	4595	59.7	0
Race			
White	3404	44.2	0
African American	1767	23.0	0
Hispanic	659	8.6	0
Asian	323	4.2	0
Other/unknown	1546	20.1	0

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Tables *continued*

***Table 1** continued*

Surgical service (5 most common + adjusted predictors)			
Orthopedic surgery	1633	21.2	0
Neurosurgery	995	12.9	0
General surgery	746	9.7	0
Gynecology	672	8.7	0
Otolaryngology	609	7.9	0
Oral/dental/maxillofacial	325	4.2	0
Trauma surgery	316	4.1	0
Spinal surgery	294	3.8	0
Unknown	672	8.7	0
Outcome	Count	Mean ± SD	Missing
MME in PACU, mg	7699	14.97 ± 18.79	0
Rescue antiemetic doses, average per case	7699	0.26 ± 0.52	0
PACU recovery time, minutes	7699	67.08 ± 38.90	0

Abbreviations: ASA = American Society of Anesthesiologists; BMI = body mass index; MME = morphine milligram equivalents; PACU = post-anesthesia care unit; PONV = postoperative nausea and vomiting; SD = standard deviation.

Summary statistics are reported as mean ± standard deviation for continuous variables and as counts with percentages for categorical variables. Missing data are shown as counts and percentages where applicable. "Other/unknown" race included patients who self-identified as American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, those who self-identified as "other race" or whose race was unknown. Preprocedural pain scores were only available for a subset of patients (n = 1513, 20%), typically those admitted preoperatively. Surgical service categories shown include the 5 most common services in the cohort and those that were statistically significant predictors in adjusted analyses. The full table including all surgical services is available in Supplemental Table 1.

***Table 2.** Unadjusted Postoperative Outcomes Stratified by Resident Training Level*

Category	Mean ± SD			ANOVA *F*-statistic	Eta squared (η^2)	*p*-value	Significance
	CA-1	CA-2	CA-3				
MME in PACU, mg	15.9 ± 18.9	13.8 ± 18.2	13.6 ± 19.0	$F(2, 7696) = 13.38$	0.004	<.001	[c]
Rescue antiemetic doses, average per case	0.28 ± 0.54	0.24 ± 0.51	0.22 ± 0.50	$F(2,7696) = 8.25$	0.002	<.001	[c]
PACU recovery time, minutes	68.4 ± 38.6	65.4 ± 39.5	65.5 ± 38.7	$F(2,7696) = 5.54$	0.001	.004	[b]

Abbreviations: MME = morphine milligram equivalents; PACU = postanesthesia care unit.

Outcomes were described with mean values ± standard deviations and compared using 1-way analysis of variance with effect sizes reported as η^2 (eta squared). For all outcomes, degrees of freedom = 2. Effect size interpretations follow conventional thresholds: for η^2, small = 0.01, medium = 0.06, and large = 0.14.

[a]$p < .05$, [b]$p < .01$, [c]$p < .001$.

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Supplemental Online Material

Supplemental Digital Content: Supplemental Tables 1-5

Supplemental Table 1. Study cohort (combined descriptive statistics for all variables and outcomes)

Variable	Count	Mean ± SD	Missing (n, %)
Age (years)	7699	51.94 ± 18.99	0
BMI (kg/m²)	7477	28.70 ± 7.66	222 (2.3%)
Anesthesia time (minutes)	7699	193.12 ± 127.27	0
Highest preprocedural pain score (0-10)	1513	2.04 ± 3.08	6186 (80%)
Variable	**Count**	**Percent**	**Missing**
Anesthesia type			
General	6251	81.2%	0
Monitored Anesthesia Care	136	1.8%	0
Spinal	13	0.2%	0
Regional	3	0.0%	0
Missing	1296	16.8%	0
Gender			
Female	3836	49.8%	0
Male	3860	50.1%	0
Unknown	3	0.0%	0
ASA class			
1	193	2.5%	0
2	2188	28.4%	0
3	4645	60.3%	0

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4	655	8.5%	0
5	18	0.2%	0
Laparoscopic/Robotic	774	10.1%	0
Smoker	653	8.5%	0
History of PONV	311	4.0%	0
Required any postoperative opioid	4595	59.7%	0
Race			
White	3404	44.2%	0
African American	1767	23.0%	0
Hispanic	659	8.6%	0
Asian	323	4.2%	0
Other	1546	20.1%	0
Surgical Service			
Orthopedic Surgery	1633	21.2%	0
Neurosurgery	995	12.9%	0
General Surgery	746	9.7%	0
Gynecology	672	8.7%	0
Otolaryngology	609	7.9%	0
Plastic Surgery	496	6.4%	0
Cardiothoracic Surgery	328	4.3%	0
Oral/Dental/Maxillofacial	325	4.2%	0
Trauma Surgery	316	4.1%	0
Spinal Surgery	294	3.8%	0

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Urology	257	3.3%	0
Ophthalmology	178	2.3%	0
Pediatric Otolaryngology	54	0.7%	0
Electrophysiology	40	0.5%	0
Obstetrics	28	0.4%	0
Pediatric General Surgery	21	0.3%	0
Other (Services with <10 cases)	24	0.3%	0
Unknown	672	8.7%	0
Outcome	**Count**	**Mean ± SD**	**Missing**
MME in PACU (mg)	7699	14.97 ± 18.79	0
Rescue antiemetic doses (avg per case)	7699	0.26 ± 0.52	0
PACU recovery time (minutes)	7699	67.08 ± 38.90	0

Summary statistics are reported as mean ± standard deviation for continuous variables and as counts with percentages for categorical variables. Missing data are shown as counts and percentages where applicable. Surgical services with fewer than 10 cases (n = 24, 0.3%) were grouped into an “Other” category and included Pediatric Neurosurgery, Pediatric Urology, Pediatric Orthopedic Surgery, Transplant Surgery, Cardiovascular, and Pain Management. “Unknown” categories reflect documentation gaps in the electronic medical record. “Other” race included patients who self-identified as American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, those who self-identified as “Other race”, or whose race was unknown. Preprocedural pain scores were only available for a subset of patients (n = 1513, 20%), typically those admitted preoperatively.

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Supplemental Table 2. Univariable analysis- descriptive statistics for all variables stratified by resident training level.

Category	Mean ± SD			ANOVA F-statistic	η^2	p-value	Sig
	CA-1	CA-2	CA-3				
Age (years)	51.11 ± 18.77	53.27 ± 19.32	52.66 ± 19.08	F(2, 7696) = 9.8	0.003	< 0.001	***
BMI (kg/m²)	28.86 ± 7.65	28.38 ± 7.60	28.63 ± 7.73	F(2, 7474) = 2.61	0.001	0.08	
Anesthesia Time (minutes)	194.12 ± 117.82	196.37 ± 139.09	186.08 ± 137.38	F(2, 7696) = 3.03	0.001	0.048	*
Highest preprocedural pain score (0-10)	2.09 ± 3.04	2.09 ± 3.19	1.88 ± 3.05	F(2, 1510) = 0.61	0.001	0.54	
Variable	**Count (Percentage)**			**Chi-Square (χ^2) Value (df = 2)**	**Cramér's V**	**p-value**	**Sig**
	CA-1	**CA-2**	**CA-3**				
Total case count	4316 (56.1%)	1894 (24.6%)	1489 (19.3%)	1821.3	0.344	< 0.001	***
Anesthesia type							
General	3747 (86.8%)	1431 (75.6%)	1073 (72.1%)	210.12	0.117	< 0.001	***
MAC	56 (1.3%)	35 (1.8%)	45 (3.0%)	19.07	0.035	< 0.001	***
Regional	1 (0.0%)	2 (0.1%)	0 (0.0%)	3.02	0.014	0.22	
Spinal	6 (0.1%)	3 (0.2%)	4 (0.3%)	1.12	0.009	0.57	
Missing	506 (11.7%)	423 (22.3%)	367 (24.6%)	186.36	0.11	< 0.001	***
Gender							

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Female	2168 (50.2%)	920 (48.6%)	748 (50.2%)	1.57	0.01	0.46	
Male	2146 (49.7%)	974 (51.4%)	740 (49.7%)	1.67	0.01	0.43	
Unknown	2 (0.0%)	0 (0.0%)	1 (0.1%)	1.1	0.008	0.58	
ASA class							
1	131 (3.0%)	41 (2.2%)	21 (1.4%)	13.16	0.029	0.001	**
2	1353 (31.3%)	444 (23.4%)	391 (26.3%)	44.68	0.054	< 0.001	***
3	2539 (58.8%)	1204 (63.6%)	902 (60.6%)	12.41	0.028	0.002	**
4	281 (6.5%)	200 (10.6%)	174 (11.7%)	51.68	0.058	< 0.001	***
5	12 (0.3%)	5 (0.3%)	1 (0.1%)	2.21	0.012	0.33	
Laparoscopic/Robotic	478 (11.1%)	170 (9.0%)	126 (8.5%)	11.58	0.027	0.003	**
Smoker	410 (9.5%)	134 (7.1%)	109 (7.3%)	13.18	0.029	0.001	**
History of PONV	199 (4.6%)	57 (3.0%)	55 (3.7%)	9.28	0.025	0.01	**
Required any postoperative opioid	2737 (63.4%)	1054 (55.6%)	804 (54.0%)	57.8	0.061	< 0.001	***
Race							
White	1909 (44.2%)	853 (45.0%)	642 (43.1%)	1.25	0.009	0.54	
African American	955 (22.1%)	437 (23.1%)	375 (25.2%)	5.87	0.02	0.053	
Hispanic	352 (8.2%)	159 (8.4%)	148 (9.9%)	4.59	0.017	0.1	
Asian	190 (4.4%)	76 (4.0%)	57 (3.8%)	1.12	0.009	0.57	
Other or Unknown	910 (21.1%)	369 (19.5%)	267 (17.9%)	7.42	0.022	0.03	*
Surgical Service							
Orthopedic Surgery	963 (22.3%)	386 (20.4%)	284 (19.1%)	7.99	0.023	0.02	*

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Neurosurgery	445 (10.3%)	343 (18.1%)	207 (13.9%)	72.72	0.069	< 0.001	***
General Surgery	442 (10.2%)	168 (8.9%)	136 (9.1%)	3.48	0.015	0.18	
Gynecology	429 (9.9%)	131 (6.9%)	112 (7.5%)	18.48	0.035	< 0.001	***
Otolaryngology	502 (11.6%)	62 (3.3%)	45 (3.0%)	186.77	0.11	< 0.001	***
Plastic Surgery	342 (7.9%)	64 (3.4%)	90 (6.0%)	45.6	0.054	< 0.001	***
Cardiothoracic Surgery	82 (1.9%)	144 (7.6%)	102 (6.9%)	135.33	0.094	< 0.001	***
Oral/Dental/Maxillofacial	234 (5.4%)	45 (2.4%)	46 (3.1%)	36.05	0.048	< 0.001	***
Trauma Surgery	197 (4.6%)	65 (3.4%)	54 (3.6%)	5.36	0.019	0.07	
Spinal Surgery	140 (3.2%)	95 (5.0%)	59 (4.0%)	11.36	0.027	0.003	**
Urology	189 (4.4%)	34 (1.8%)	34 (2.3%)	33.6	0.047	< 0.001	***
Ophthalmology	109 (2.5%)	37 (2.0%)	32 (2.1%)	2.12	0.012	0.35	
Pediatric Otolaryngology	38 (0.9%)	11 (0.6%)	5 (0.3%)	5.24	0.018	0.07	
Electrophysiology	8 (0.2%)	15 (0.8%)	17 (1.1%)	23.2	0.039	< 0.001	***
Obstetrics	6 (0.1%)	14 (0.7%)	8 (0.5%)	14.62	0.031	< 0.001	***
Pediatric General Surgery	5 (0.1%)	7 (0.4%)	9 (0.6%)	10.58	0.026	0.005	**
Other (Services with <10 cases)	0 (0.0%)	2 (0.1%)	0 (0.0%)	6.13	0.02	0.047	*
Unknown	171 (4.0%)	261 (13.8%)	240 (16.1%)	285.83	0.136	< 0.001	***

Continuous variables were compared using one-way ANOVA, with effect sizes reported as η^2 (eta squared), while categorical variables were analyzed using Chi-square tests, with Cramér's V used to report effect size. All tests used degrees of freedom = 2 unless otherwise noted. Effect size interpretations follow conventional thresholds: for η^2, small = 0.01, medium = 0.06, and large = 0.14; for Cramér's V, small = 0.1, medium = 0.3, and large = 0.5. Abbreviations: MME = morphine milligram equivalents; PACU = Post-Anesthesia Care Unit; PONV = postoperative nausea and vomiting; ASA = American

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28 Society of Anesthesiologists. Statistical significance is denoted as follows: $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***).

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31 **Supplemental Table 3.** Multiple Linear Regression Analysis for PACU MME

Variable	Coefficient	Std Err	t	P>|t|	[0.025	0.975]	Signif.
Intercept	19.64	5.05	3.89	<0.001	9.73	29.54	***
CA-2 (vs CA-1)	-0.59	1.55	-0.38	0.70	-3.63	2.44	
CA-3 (vs CA-1)	1.15	1.63	0.71	0.48	-2.05	4.34	
Spinal (vs General)	-19.4	19.09	-1.02	0.31	-56.87	18.06	
Regional (vs General)	-19.46	19.11	-1.02	0.31	-56.97	18.04	
MAC (vs General)	0	0	0.03	0.98	0	0	
Asian	-2.21	3.18	-0.69	0.49	-8.45	4.04	
Hispanic	-1.88	2.47	-0.76	0.45	-6.74	2.97	
Unknown	-0.46	1.85	-0.25	0.80	-4.08	3.17	
White	3.35	1.58	2.13	0.03	0.26	6.45	*
Electrophysiology	-0.28	9.87	-0.03	0.98	-19.64	19.08	
General Surgery	4.35	3.14	1.38	0.17	-1.82	10.52	
Gynecology	3.27	3.54	0.92	0.36	-3.67	10.22	
Neurosurgery	4.89	3.07	1.59	0.11	-1.14	10.93	
Ophthalmology	-2.71	6.49	-0.42	0.68	-15.45	10.03	
Oral/Dental/Maxillofacial	-0.44	3.9	-0.11	0.91	-8.09	7.21	
Orthopedic Surgery	9.56	2.87	3.33	<0.001	3.93	15.19	***

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Otolaryngology	2.99	3.36	0.89	0.37	-3.6	9.57	
Pediatric Otolaryngology	6.5	11.34	0.57	0.57	-15.75	28.75	
Plastic Surgery	4.93	3.33	1.48	0.14	-1.61	11.47	
Spinal Surgery	12.58	3.86	3.26	0.001	5.01	20.16	***
Transplant Surgery	1.65	19.14	0.09	0.93	-35.91	39.21	
Trauma Surgery	15.14	4.65	3.26	0.001	6.02	24.26	**
Urology	-1.02	3.94	-0.26	0.80	-8.75	6.7	
Male (vs Female)	-3.4	1.27	-2.67	0.008	-5.9	-0.9	**
Anesthesia Time (min)	0.02	0	3.2	0.001	0.01	0.02	**
BMI	0.03	0.08	0.35	0.73	-0.13	0.19	
Highest Preprocedural Pain Score	0.87	0.21	4.2	<0.001	0.46	1.27	***
ASA Class	-0.88	1.16	-0.76	0.45	-3.16	1.39	
Age (yrs)	-0.2	0.04	-5.24	<0.001	-0.28	-0.13	***

This table presents the results of a multiple linear regression model evaluating predictors of PACU morphine milligram equivalent (MME) administration. Coefficients represent the estimated change in MME associated with each predictor, adjusted for all other variables in the model. Standard errors, *t*-statistics, and two-tailed *p*-values are reported. Statistically significant predictors are marked with an asterisk (*). Reference groups include: CA-1 (for resident level), General anesthesia (for anesthesia type), Female (for gender), and Non-White race categories (for racial comparisons). Continuous variables (e.g., age, BMI, ASA class, anesthesia time) were modeled as linear predictors.

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Abbreviations: MME = morphine milligram equivalents; PACU = Post-Anesthesia Care Unit; ASA = American Society of Anesthesiologists; BMI = body mass index.

Significance thresholds: $p < 0.05$ = *, $p < 0.01$ = **, $p < 0.001$ = ***

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Supplemental Table 4. Multiple Linear Regression Analysis for Rescue Antiemetic Doses

Variable	Coeff.	Std Err	t	P>|t|	[0.025	0.975]	Sig
Intercept	0.076	0.073	1.05	0.30	-0.067	0.219	
CA-2 (vs CA-1)	0.034	0.042	0.82	0.41	-0.048	0.116	
CA-3 (vs CA-1)	-0.002	0.044	-0.05	0.96	-0.088	0.084	
Spinal	-0.258	0.515	-0.5	0.62	-1.27	0.753	
Regional	-0.306	0.516	-0.59	0.55	-1.317	0.706	
MAC	0	0	-0.08	0.93	0	0	
Never smoker	0.085	0.055	1.54	0.12	-0.023	0.192	
Race: Asian	0.129	0.086	1.5	0.13	-0.039	0.297	
Race: Hispanic	-0.009	0.067	-0.14	0.89	-0.14	0.122	
Race: Unknown	0.04	0.05	0.8	0.42	-0.058	0.139	
Race: White	0.085	0.043	2	0.046	0.002	0.169	*
Electrophysiology	-0.181	0.266	-0.68	0.50	-0.703	0.34	
General Surgery	0.058	0.088	0.67	0.51	-0.114	0.23	
Gynecology	0.027	0.101	0.27	0.79	-0.171	0.225	
Neurosurgery	0.077	0.083	0.92	0.36	-0.087	0.24	
Ophthalmology	0.08	0.175	0.46	0.65	-0.263	0.424	

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Oral/Dental/Maxillofacial	0.1	0.105	0.95	0.34	-0.106	0.306	
Orthopedic Surgery	0.003	0.078	0.04	0.97	-0.15	0.156	
Otolaryngology	0.05	0.091	0.55	0.59	-0.128	0.228	
Pediatric Otolaryngology	0.109	0.305	0.36	0.72	-0.49	0.708	
Plastic Surgery	-0.021	0.09	-0.23	0.81	-0.198	0.156	
Spinal Surgery	-0.077	0.105	-0.74	0.46	-0.282	0.128	
Transplant Surgery	-0.306	0.515	-0.59	0.55	-1.317	0.706	
Trauma Surgery	-0.013	0.125	-0.11	0.92	-0.259	0.233	
Urology	0.083	0.106	0.78	0.43	-0.125	0.291	
Male (vs Female)	-0.14	0.035	-4.05	<0.001	-0.208	-0.072	***
Anesthesia Time (min)	0	0	1.59	0.11	0	0	
BMI	0.005	0.002	2.09	0.04	0	0.009	*
Highest Preprocedural Pain Score	0	0.006	-0.02	0.99	-0.011	0.011	
ASA Class	-0.072	0.031	-2.3	0.02	-0.133	-0.011	*
Age (yrs)	-0.002	0.001	-2.03	0.04	-0.004	0	*
Laparoscopic/Robotic Procedure	0.196	0.068	2.89	0.004	0.063	0.329	**
History of PONV	0.076	0.073	1.05	0.30	-0.067	0.219	
Postoperative Opioid Required	0.233	0.036	6.48	<0.001	0.162	0.303	***

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This table presents the results of a multiple linear regression model evaluating predictors of average rescue antiemetic doses administered in the Post-Anesthesia Care Unit (PACU). Coefficients represent the estimated change in antiemetic dose per case associated with each variable, adjusted for all other covariates in the model. Standard errors, *t*-statistics, and two-tailed *p*-values are reported. Statistically significant predictors are marked with an asterisk (*). Reference groups include: CA-1 (for resident level), General anesthesia (for anesthesia type), Female (for gender), and Non-White race/ethnicity. Binary variables such as postoperative opioid use, laparoscopic/robotic procedure, smoking status, and history of PONV were coded as present versus absent. Continuous predictors (e.g., age, BMI, ASA class, anesthesia time, and preprocedural pain score) were modeled as linear terms.

Abbreviations: PACU = Post-Anesthesia Care Unit; BMI = body mass index; ASA = American Society of Anesthesiologists; PONV = postoperative nausea and vomiting; MAC = Monitored Anesthesia Care

Significance thresholds: $p < 0.05$ = *, $p < 0.01$ = **, $p < 0.001$ = ***

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65 **Supplemental Table 5.** Multiple Linear Regression Analysis for PACU Recovery Time

Variable	Coefficient	Std Err	t	P>|t|	[0.025	0.975]	Signif.
Intercept	22.56	5.34	4.23	<0.001	12.09	33.04	***
CA-2 (vs CA-1)	3.4	3.09	1.1	0.27	-2.66	9.46	
CA-3 (vs CA-1)	2.3	3.25	0.71	0.48	-4.08	8.69	
Regional (vs General)	-27.09	38.23	-0.71	0.48	-102.11	47.93	
MAC (vs General)	0	0	1.47	0.14	0	0	
Never Smoker (vs Smoker)	0.3	4.07	0.07	0.94	-7.69	8.28	
Asian	4.07	6.36	0.64	0.52	-8.42	16.55	
Hispanic	-7.14	4.96	-1.44	0.15	-16.86	2.59	
Unknown	-1.69	3.72	-0.45	0.65	-8.99	5.62	
White	3.26	3.16	1.03	0.30	-2.94	9.46	
Electrophysiology	-7.76	19.7	-0.39	0.69	-46.43	30.9	
General Surgery	8.11	6.5	1.25	0.21	-4.64	20.86	
Gynecology	7.64	7.48	1.02	0.31	-7.03	22.31	
Neurosurgery	6.6	6.18	1.07	0.29	-5.53	18.73	
Ophthalmology	9.05	12.97	0.7	0.49	-16.41	34.51	
Oral/Dental/Maxillofacial	19.06	7.8	2.44	0.01	3.75	34.37	*
Orthopedic Surgery	21.22	5.76	3.68	<0.001	9.92	32.52	***

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Otolaryngology	5.18	6.73	0.77	0.44	-8.03	18.39	
Pediatric Otolaryngology	-7.79	22.64	-0.34	0.73	-52.21	36.63	
Plastic Surgery	8.76	6.69	1.31	0.19	-4.37	21.89	
Spinal Surgery	22.96	7.75	2.96	0.003	7.75	38.17	**
Transplant Surgery	-13.44	38.21	-0.35	0.73	-88.43	61.54	
Trauma Surgery	27.13	9.29	2.92	0.004	8.91	45.36	**
Urology	1.12	7.87	0.14	0.89	-14.32	16.57	
Male (vs Female)	-5.77	2.56	-2.25	0.02	-10.79	-0.75	*
Anesthesia Time (min)	0.02	0.01	2.16	0.03	0	0.04	*
BMI	0.29	0.16	1.79	0.07	-0.03	0.6	
Highest Preprocedural Pain Score	0.83	0.41	2	0.045	0.02	1.63	*
ASA Class	-1.47	2.32	-0.63	0.53	-6.02	3.08	
Age (yrs)	0.05	0.08	0.65	0.51	-0.1	0.2	
Laparoscopic/Robotic Procedure	9.15	5.02	1.82	0.07	-0.7	19	
History of PONV	22.56	5.34	4.23	<0.001	12.09	33.04	***

This table presents the results of a multiple linear regression model evaluating predictors of PACU recovery time (length of stay in minutes). Coefficients represent the estimated change in recovery time associated with each variable, adjusted for all other covariates in the model. Standard errors, t-statistics, and two-tailed p-values are reported. Statistically significant predictors are denoted by an asterisk (*). Reference

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groups include: CA-1 (for resident level), General anesthesia (for anesthesia type), Female (for gender), Non-White race/ethnicity, and the absence of binary clinical features (e.g., laparoscopic procedure, smoking, PONV, or opioid use). Continuous variables such as age, BMI, ASA class, preprocedural pain score, and anesthesia time were modeled linearly.

Abbreviations: PACU = Post-Anesthesia Care Unit; BMI = body mass index; ASA = American Society of Anesthesiologists; PONV = postoperative nausea and vomiting; MAC = Monitored Anesthesia Care.

Significance thresholds: $p < 0.05$ = *, $p < 0.01$ = **, $p < 0.001$ = ***