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Of Rough Starts and Smooth Finishes: Correlations Between Post-Anesthesia Care Unit and Postoperative Days 1–5 Pain Scores

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Abstract

Objective—The goal of this project was to explore the association between post-anesthesia care unit (PACU) pain scores recorded within the first and second hour of the end of surgery with maximum and median pain scores recorded on postoperative days (PODs) 1 through 5.

Design—This study was a retrospective cohort study of clinically documented pain scores in a mixed surgical population.

Setting—This study was set in a single tertiary-care teaching hospital over a 1-year time period.

Patients—All patients were adult patients undergoing a single, non-ambulatory, non-obstetric surgical procedure.

Measures—Pain scores, measured using the numerical rating scale, from PODs 0 through 5 were obtained from an integrated data repository. Kendall's Tau-b correlations were then calculated between maximum pain scores occurring within each of the two PACU time periods and maximum and median pain scores in each of the five ensuing PODs.

Results—A total of 349,797 pain scores from 8,332 patients were reviewed. Correlations between maximum pain score by time period demonstrated a significant and high correlation at Tau-b = 0.86, between 1-hour PACU pain scores and 2-hour PACU pain scores. However, the correlation of maximum pain scores recorded in the PACU with those recorded on PODs 1 through 5 was significantly lower, ranging from 0.19 to 0.27. The correlation of maximum PACU pain score with median pain scores recorded on PODs 1 through 5 ranged from 0.22 to 0.29. The

correlation structures of the PODs 1 through 5 median pain scores may be consistent with an autoregressive pattern.

Conclusions—Maximum scores measured within the PACU likely reflect a set of circumstances distinct from those experienced on PODs 1 through 5.

Keywords

Pain; Surgery; Recovery Room; Anesthesia; Correlation Structure; Trajectory

Introduction

In the United States, over 70 million patients undergo surgery each year; surveys suggest that over 80% will experience postoperative pain, and 86% of these patients will suffer moderate to severe postoperative pain [1]. Poorly controlled postoperative pain, aside from its adverse neurohumoral, immunomodulatory, cardiovascular, and pulmonary side effects, has been associated with the development of chronic postsurgical pain, which afflicts up to 50% of surgical patients depending upon the type of surgery [2–10]. Aggressive multimodal postoperative pain control with regional anesthetics has been shown to substantially decrease many of these pain-related surgical complications [9]. However, regional anesthetic interventions are not without cost, complexity, and risk [11–15]. The ability to accurately predict which patients are at risk for severe acute postoperative pain would permit anesthesiologists and surgeons to appropriately target regional anesthetic interventions based upon appropriate risk stratification criteria [16,17].

Prior work in postoperative pain prediction has often used maximal pain scores measured in the post-anesthesia care unit (PACU) as the dependent outcome of interest [18–20]. However, recovery from anesthesia in the PACU is a dynamic time period replete with rapid titrations of analgesics for pain [21]. Therefore, early postsurgical pain scores measured in the PACU may not be predictive of pain scores obtained after PACU discharge. This is an important limitation because late pain scores may represent more clinically relevant outcomes, which could be largely independent of early pain scores measured in the PACU. This study aims to test the assumption underlying most prior research and practice—that early postoperative pain scores are predictive of late postoperative pain scores and thus provide sufficient information for planning postoperative pain interventions.

In this study, we reviewed over 300,000 pain measurements from over 8,000 surgical patients to determine how well early PACU pain scores related to later postoperative pain scores were measured on postoperative days (PODs) 1 through 5. The primary aim of this study was to examine bivariate correlations between maximum PACU pain scores, which have previously been measured as a primary outcome in prior work, and those maximum pain scores reported on PODs 1 through 5. The secondary aim of this study was to examine correlations between maximum PACU pain scores and those median pain scores reported on PODs 1 through 5. Together, these two aims will test the hypothesis that early maximum PACU pain scores fail to associate with maximum pain scores obtained on PODs 1 through 5, thus determining whether separate prediction models are necessary for early vs late postoperative pain experiences.

Methods

This was a retrospective cohort study approved by the University of Florida IRB-01. Informed consent was not required of patients. Study registration was not required given the retrospective nature of this project. All data were de-identified prior to analysis.

All data were obtained from the University of Florida Integrated Data Repository, an institution-wide clinical data warehouse for research. Subjects were those adult patients who received non-ambulatory surgery in a main operating room at Shands at the University of Florida over a 1-year period beginning in May 2011. Patients were excluded if they received multiple surgical procedures within the study period to avoid contamination of pain scores from time-domain interference with preceding or proceeding surgical procedures. Likewise, patients were excluded if their anticipated duration of hospitalization was less than 24 hours. Additional exclusion criteria included obstetric surgery, endoscopic and bronchoscopic procedures, and interventional radiology procedures.

All pain scores were recorded using the numeric rating scale (NRS), on an 11-point scale ranging from 0 to 10. Pain scores were generally recorded by protocol every 4 hours, with a repeat query within 1 hour after a dose of pain medication for breakthrough pain. Pain scores where the patient was listed as “asleep” were listed as “missing” rather than zero to account for the fact that some patients had received additional sedatives that may have facilitated sleep despite a strong nociceptive load. All pain scores were recorded with a corresponding date/time stamp. Pain scores were filtered to include only those obtained after the listed end-surgery time through the end of POD 5.

The type of surgical procedure was identified using current procedural terminology (CPT) codes. In the event of multiple CPT codes for a given patient, only the primary CPT code was used. To consolidate the raw CPT codes into a more manageable number for analysis purposes, CPT codes were aggregated according to anatomic location of surgery.

Statistical Analysis

To address the first aim, which was to examine correlations between maximum PACU pain scores and those maximum pain scores recorded on PODs 1 through 5, all pain scores were grouped into time periods for PODs 1 through 5, or within the first or second hour of the PACU recovery period. Kendall's Tau-b correlations were then calculated between pain scores occurring within each of the two PACU time periods and each of the five ensuing postoperative time periods. The Tau-b statistic was used because of concerns for nonlinear correlation patterns, given that unequal numbers of multiple pain scores were obtained across a combination of short (PACU 1- and 2-hour time intervals) and long (PODs 1–5) time intervals after surgery. Aggregate data from all included patients were used for this analysis. The second aim similarly examined correlations between maximum PACU pain scores and those median pain scores recorded on PODs 1 through 5. Given the large number of variables analyzed, statistical significance was set at $P = 0.01$. All analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC, USA).

Results

A total of 349,797 pain scores from 8,332 patients were reviewed. There were slightly more male (50.3%) than female patients (Table 1). The mean age was 56.1 ± 16.3 years and ranged from 21 to 97. The mean body mass index was 29.1 ± 8 . For the total number of comorbidities, the mean count was 9.6 ± 6.8 . Recorded comorbidity counts were empirically capped at 50. The mean number of procedures conducted within each surgery, as evaluated by CPT codes describing the surgery, was 1.7 ± 1.1 , and the recorded number of procedures per patient was capped at 10. A total of 1,177 different CPT-coded procedures were grouped into 17 different groups organized by anatomic differentiation.

The number of pain score observations decreased from 96,557 on POD 1 to 30,331 on POD 5 (Table 2). There were 51,177 scores in 7,599 subjects on POD 0 that were used to identify maximum PACU pain scores for each account. Most pain observations were recorded after musculoskeletal surgery (87,377), followed by cardiovascular procedures (68,163), and surgeries on the digestive system (63,280). Figure 1 compares the aggregate distribution of scores by anatomic grouping of the CPT code and by time period.

In the Kendall's Tau-b analysis of correlations between maximum PACU pain scores and maximum pain scores on PODs 1 through 5, all correlations were significantly greater than 0 at the $P < 0.0001$ level, likely due to the large number of observations. The correlations between maximum pain score by time period demonstrated a significant and high correlation, Tau-b = 0.86, between 1-hour PACU pain scores and 2-hour PACU pain scores (Table 3). However, the correlation of maximum pain scores recorded in the PACU with those recorded on PODs 1 through 5 was significantly lower, ranging from 0.19 to 0.27 (Figure 2). Within PODs 1 through 5, the correlation structure generally followed an autoregressive-like pattern, such that correlations were greater the closer together they were in time. For example, POD 3 pain scores were most highly correlated with POD 2 (0.49) and POD 4 (0.52) and less so with POD 1 (0.40) and POD 5 (0.45). Figure 3 shows those median observations of maximum pain scores on a per-procedural basis.

Similar to the above findings, the Kendall's Tau-b correlations between maximum PACU pain scores and median pain scores on PODs 1 through 5 demonstrated statistically significant correlations at the $P < 0.0001$ level, again likely due to the large number of observations. The correlation of maximum PACU pain score with median pain scores recorded on PODs 1 through 5 ranged from 0.22 to 0.29 (Table 4). No specific correlation structure was noted between the maximum PACU pain scores and ensuing median pain scores on PODs 1 through 5. However, for PODs 1 through 5, the correlation structures of the median pain scores each exhibited a pattern consistent with autocorrelation. For example, POD 3 median pain scores were most highly correlated with POD 2 (0.56) and POD 4 (0.56) and less so with POD 1 (0.45) and POD 5 (0.50).

Discussion

Our results show that early maximum postoperative pain scores measured in the PACU are not strongly associated with maximum pain scores measured on PODs 1 through 5.

Correlation testing demonstrated strong correlations within the two measured PACU pain scores, followed by a substantial decrease in correlation between the two PACU maximum pain scores and those maximum pain scores obtained on PODs 1 through 5.

Prior work in forecasting postoperative pain intensity has often used maximal pain scores in the PACU as the primary outcome of interest [19,20,22]. Empirical selection of this time point is quite logical, given that this represents the shortest interval from nociceptive loading to pain measurement. Furthermore, intraoperative titration of antinociceptive agents, such as opioids, is usually performed based on qualitative assessments of the hemodynamic and/or electroencephalographic responses to surgical nociception rather than direct patient assessments of pain intensity. This not uncommonly leads to early and rapid administration of strong opioids upon arrival in the PACU in response to patient complaints of pain [23].

Despite the attractiveness of PACU pain scores, these early pain scores may be suboptimal outcome measures for several reasons. First, pain measurement in the PACU presents many challenges by virtue of the rapid transition states encountered there. For instance, many patients will require additional time in the PACU to complete their emergence from general anesthesia. A “sleeping” patient may not be truly pain free, but instead may exhibit poor responsiveness due to residual inhalational anesthetics. Even those patients who receive a neuraxial anesthetic rather than general anesthesia can suffer from acute upswings in pain intensity as the spinal or epidural block resolves. Contrariwise, many patients receiving a single-injection peripheral nerve block for postoperative pain control may report zero pain for the duration of their PACU stay, only to suffer from severe pain 8–10 hours after PACU discharge upon resolution of their nerve block. Moreover, PACU pain scores may more closely reflect ongoing nociceptive drive, whereas later pain scores may reflect peripheral and/or central sensitization processes that may contribute more importantly to adverse pain-related outcomes.

The correlations shown in Table 3 and Figure 2 highlight the lack of association between pain scores between the PACU and PODs 1 through 5. Given the temporal proximity between the maximum PACU pain scores at 1 and 2 hours, the high degree of correlation found there is not surprising. However, when the number and magnitude of state transitions are considered, this correlation stands as notable, all the more so given that the maximum pain scores encountered at the 2-hour mark are greater than those at the 1-hour mark. If all patients arrived to the PACU at their true baseline maximum pain intensity score, we could have expected a negative estimate for the fixed effect of the 2-hour PACU pain score. Instead, the increase at the 2-hour mark points to additional factors that could explain the high correlation within the PACU time period aside from the temporal proximity. The change in correlations even across fixed time intervals, such as from PODs 1 to 5, was not uniformly symmetric about a given time interval. This heterogeneity, coupled with the lack of fixed time intervals in our data, suggests the need to use an unstructured covariance matrix if including PACU and PODs 1 through 5 data, or perhaps even an autocorrelation matrix for summary data on PODs 1 through 5, in modeling of the repeated measures.

Prior work by Chapman et al. in an elective surgery population of patients demonstrates a general trend in decreasing pain scores after surgery [24]. Importantly, they also identified a

large proportion of patients with stable slopes or even positive slopes denoting stable or increasing pain scores on PODs 1 through 6. Our results partially extend these findings by examining the correlation structure of pain scores across a large number of surgical cases. Correlation structure assessment is a necessary step for hierarchical modeling to account for different types of collinearity in analyses of repeated measures such as those implicit in studies of pain trajectories. Examination of the median observations of maximum pain scores across different surgeries at the measured time intervals in Figure 3 suggests that for many procedures, such as endocrine, pulmonary, and musculoskeletal procedures, the change in maximal pain scores over time may be nonlinear.

Our results suggest that the maximal pain scores are generally observed on POD 1. This differs from the findings of Pöpping et al., which demonstrated peak pain scores on the day of surgery [25]. However, that study did not account for differential rates of change by surgery. This may be due to the promotion of increased activity, such as getting out of bed, ambulation, and aggressive physical therapy, all of which are frequently encouraged until limited by reports of severe pain intensity. In our work, interpretation of the differences in least square means was hampered by non-estimable differences for several time period comparisons. Observed differences were sometimes separated by small yet dynamic time intervals, as in the case of the PACU. However, once out of the PACU, most patients exhibited an autocorrelation type of maximum and median pain scores for PODs 1 through 5, supporting the notion of a relatively stable recovery profile that is somewhat dependent on the type of surgery. Indeed, our study did not address pain scores on the day of surgery following discharge from the PACU upon arrival to the floor, given the fact that one criterion for discharge from PACU is satisfactory pain management, and that the determination of time from transfer from PACU to floor is sometimes delayed due to unavailability of bed space. Together, these issues raise the possibility that peak pain scores may occur between discharge from PACU and POD 1, a determination which will require a higher resolution analysis of pain trajectories. Regardless, our results suggest that future studies on pain trajectories may need to take into account procedure as well as patient factors.

Our study suffered from those limitations inherent to outcome studies conducted on large datasets. First, our focus on maximal pain scores was due to the fact that bouts of severe postoperative pain have been associated with the development of chronic postsurgical pain [26–28]. It is unclear whether a smoldering, moderately elevated median pain score is associated with similar outcomes. Second, we did not include data on analgesic administration. As an outcomes-based study, we examined pain outcomes on the presumption that hospital staff correctly applied standard, preexisting pain management protocols to all patients. Given the heterogeneity of responses to analgesics, it is impossible to account for the variance attributable to analgesic effectiveness at this scale. Further, the lack of correlation observed may be due to the fact that patients undergoing more painful procedures are pre-stratified to more aggressive analgesic regimens, thus permitting increased access to potent analgesic regimens once arriving on the hospital wards. The depiction of median observations of maximal pain scores was intended to partially account for this variance, demonstrating the high intensity of pain scores across tens of thousands of late pain intensity measurements. Each of these limitations represents a particular facet of

the weakness of the NRS as a metric of pain therapy, rather than functional indicators of pain management such as engagement with physical therapy, return of bowel function, inspiratory effort, etc. The choice of anatomic vs alternative methods of categorizing CPT codes was based on practicality; further work specifically examining differences in procedural outcome within separate surgical subspecialties would likely be of significant value. Last, further work is necessary to characterize pain trajectories within the context of patient demographics and comorbidities, a project that was not addressed in this particular set of hypotheses.

In conclusion, our data suggest that early postoperative pain scores do not correlate well with late postoperative pain scores. Maximum scores measured in the PACU likely reflect a set of circumstances distinct from those experienced on PODs 1 through 5. This carries important implications for future projects aimed at predicting postoperative pain outcomes. Further work is necessary to better characterize pain trajectories across a multitude of surgical procedures.

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Figure 1.

Distributions of pain scores by anatomic groups of primary CPT codes and postoperative Day. A total of 298,620 pain observations were recorded between postoperative days 1 through 5 using the numeric rating scale (NRS). Pain observations were compared between primary CPT code categories (Panel A) and postoperative day (Panel B). CPT = current procedural terminology.

Figure 2.

Kendall's Tau-b correlations between early and late postoperative pain scores. Kendall's Tau-b correlation coefficients were plotted from the 1-hour PACU time period through postoperative day (POD) 5 for maximum pain scores recorded within each time interval. All correlations shown are significant at the $P < 0.0001$ level. PACU = post-anesthesia care unit.

Figure 3.

Median observations of maximum pain scores in early vs late postoperative time periods. The median observation of the maximum pain scores reported at each postoperative time period by 8,332 subjects is plotted separately for 17 separate categories of primary CPT codes. Dashed vertical line represents the separation between pain scores recorded in the PACU and those recorded on postoperative days (PODs) 1 through 5. CPT = current procedural terminology; PACU = post-anesthesia care unit.

Table 1

Socio-demographic variables of subjects

Variable	Number of Subjects
Number of patients	8,332
Age (56.1 ± 16.3, mean ± SD)	
21–39	1,457 (18%)
40–64	4,022 (48%)
65–85	2,703 (32%)
>85	150 (2%)
Gender	
Female, no. (%)	4,142 (49.7%)
Male, no. (%)	4,190 (50.3%)
BMI	29.1 ± 8
<18.5	1,174 (14%)
18.5–24	1,687 (20%)
25–29	1,877 (23%)
30–39	2,032 (24%)
40	60 (7.3%)
Total number of ICD9 coded comorbidities	9.6 ± 6.8
<5	2,018 (24%)
5–9	2,875 (35%)
10–19	2,739 (33%)
20	700 (8%)
Total number of CPT coded procedures	1.7 ± 1.1
3	6,857 (82%)
3–5	1,338 (16%)
5	137 (2%)
CPT anatomic groupings	17
Auditory	16 (0.2%)
Cardiovascular	1,081 (13%)
Digestive	1,783 (21.4%)
Endocrine	84 (1%)
Eye and orbit	8 (0.1%)
Female genital	300 (3.6%)
Heme and lymphatic	52 (0.6%)
Integumentary	591 (7.1%)
Male genital	33 (0.4%)
Maternity care and delivery	24 (0.3%)
Mediastinum and diaphragm	16 (0.2%)
Musculoskeletal	1,981 (23.8%)
Nervous	1,180 (14.2%)
Other	260 (3.1%)

Variable	Number of Subjects
Pulmonary	302 (3.6%)
Reproductive system and intersex	2 (0.02%)
Urinary	619 (7.4%)
Time of observation	
Max 1-hour PACU pain score	5,819
Max 2-hour PACU pain score	6,257
POD 1	8,071
POD 2	6,593
POD 3	5,164
POD 4	3,872
POD 5	2,954

Number of subjects (percentage in category) unless otherwise noted.

BMI = body mass index; CPT = current procedural terminology; ICD9 = International Classification of Diseases, 9th Revision; PACU = post-anesthesia care unit; POD = postoperative day; SD = standard deviation.

Table 2

Counts of pain observations by procedure and time period

Category	Count of Pain Score Observations
Anatomic CPT Group	
Auditory	444 (0.13%)
Cardiovascular	68,163 (19.49%)
Digestive	63,280 (18.09%)
Endocrine	2,510 (0.72%)
Eye and orbit	296 (0.08%)
Female genital	7,846 (2.24%)
Heme and lymphatic	1,569 (0.45%)
Integumentary	22,844 (6.53%)
Male genital	1,036 (0.3%)
Maternity care and delivery	671 (0.19%)
Mediastinum and diaphragm	1,063 (0.3%)
Musculoskeletal	87,337 (24.97%)
Nervous	46,512 (13.3%)
Other	5,958 (1.7%)
Pulmonary	18,292 (5.23%)
Reproductive system and intersex	15 (0%)
Urinary	21,961 (6.28%)
Time of observation	349,797
Max 1-hour PACU pain score	230,683
Max 2-hour PACU pain score	261,047
POD 1	96,557
POD 2	75,362
POD 3	55,759
POD 4	40,611
POD 5	30,331

CPT = current procedural terminology; PACU = post-anesthesia care unit; POD = postoperative day.

Table 3

Kendall's Tau-b correlations of maximum pain score by time period

Time Period	Maximum 1-Hour PACU Pain Score	Maximum 2-Hour PACU Pain Score	Maximum Pain Score on POD 1	Maximum Pain Score on POD 2	Maximum Pain Score on POD 3	Maximum Pain Score on POD 4	Maximum Pain Score on POD 5
Maximum 1-hour PACU pain score	1	0.86	0.24	0.19	0.21	0.22	0.21
Maximum 2-hour PACU pain score	0.86	1	0.27	0.22	0.23	0.23	0.21
Maximum pain score on POD 1	0.24	0.27	1	0.47	0.40	0.36	0.34
Maximum pain score on POD 2	0.19	0.22	0.47	1	0.49	0.42	0.37
Maximum pain score on POD 3	0.21	0.23	0.40	0.49	1	0.52	0.45
Maximum pain score on POD 4	0.22	0.23	0.36	0.42	0.52	1	0.54
Maximum pain score on POD 5	0.21	0.21	0.34	0.37	0.45	0.54	1

All correlations were significant at the level of $P < 0.0001$.

PACU = post-anesthesia care unit; POD = postoperative day.

Table 4

Kendall's Tau-b correlations of maximum PACU pain scores and median pain scores on PODs 1 through 5

Time Period	Maximum 1-Hour PACU Pain Score	Maximum 2-Hour PACU Pain Score	Median Pain Score on POD 1	Median Pain Score on POD 2	Median Pain Score on POD 3	Median Pain Score on POD 4	Median Pain Score on POD 5
Maximum 1-hour PACU pain score	1	0.86199	0.26223	0.21534	0.22627	0.23822	0.24963
Maximum 2-hour PACU pain score	0.86199	1	0.29452	0.24355	0.25262	0.24768	0.25523
Median pain score on POD 1	0.26223	0.29452	1	0.5239	0.4524	0.4002	0.38595
Median pain score on POD 2	0.21534	0.24355	0.5239	1	0.55909	0.48968	0.46579
Median pain score on POD 3	0.22627	0.25262	0.4524	0.55909	1	0.56284	0.49961
Median pain score on POD 4	0.23822	0.24768	0.4002	0.48968	0.56284	1	0.59747
Median pain score on POD 5	0.24963	0.25523	0.38595	0.46579	0.49961	0.59747	1

All correlations were significant at the level of $P < 0.0001$.

PACU = post-anesthesia care unit; POD = postoperative day.