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Review

KSAP

Optimizing patient-controlled analgesia: a narrative review based on a single center audit process

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Intravenous patient-controlled analgesia (PCA) is valuable for delivering opioids in a flexible and timely manner. Although it is designed to offer personalized analgesia driven by the patients themselves, users often report insufficient pain relief, which can be addressed by optimizing its settings and multimodal analgesia. We adopted a systematic approach to modify PCA protocols by utilizing a serial audit process based on institutional PCA data. This review retrospectively examined the process, encompassing data from 13,230 patients who had used PCA devices. The two modifications to the fentanyl-based PCA protocols resulted in three distinct phases. In the first phase, high opioid consumption and unintended PCA withdrawal were the common issues. These were addressed in the second phase by omitting the routine use of basal infusion. However, this led to increased delivery-to-demand ratios, mitigated in the third phase by increasing the bolus dose from 15 μg to 20 μg. These serial protocol changes have produced varied outcomes across different surgical departments, underscoring the need for careful and gradual adjustments and thorough impact assessments. Drawing insights from this audit process, we incorporated findings from the literature on PCA settings and multimodal analgesic approaches. This review underscores the significance of iterative feedback and refinement of analgesic protocols to achieve optimal postoperative pain management. Additionally, it discusses critical considerations regarding the postoperative audit processes.

Keywords: Analgesia; Clinical audit; Pain management; Patient-controlled analgesia; Postoperative care; Postoperative pain.

INTRODUCTION

Current standards for perioperative analgesia have reduced opioid administration using intravenous patient-controlled analgesia (PCA) devices. These standards involve multimodal approaches incorporating proactive regional blocks and non-opioid analgesics [1]. Additionally, opioid-free and opioid-sparing strategies have been emphasized because of the global crisis of opioid misuse [2]. Nevertheless, opioids play a crucial role in rescue analgesia and should not be replaced indiscriminately [3,4]. PCA devices remain indispensable because they facilitate flexible and timely opioid administration [1,5] and offer significant benefits in terms of efficacy and patient satisfaction [6].

PCA protocols have been developed featuring various basal infusion rates and bolus doses of opioids, including fentanyl, sufentanil, remifentanil, morphine, hydromorphone, and oxycodone [7-14]. In addition, advanced ap-

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proaches using pharmacokinetic models and variable infusion rates with feedback mechanisms have shown promising results [15,16]. However, much of the evidence regarding PCA is outdated or limited to small-scale studies from single institutions, raising concerns about its generalizability across different clinical settings. Given the variations in population characteristics and clinical practices among institutions, establishing an institution-specific audit system to refine clinical practice would be beneficial. Unfortunately, routine extraction and registration of PCA data is not widely conducted, which limits the institutional audit process [17].

Several studies have utilized postoperative audits or PCA data to provide valuable insights into postoperative pain management [14,18,19]. However, these studies often focus on unidimensional outcomes and lack comprehensive analyses and detailed information on PCA use patterns. Most importantly, data on the interactive and stepwise development of analgesic protocols are scarce.

This review examined modifications to PCA regimens implemented at a single institution through a clinical audit process utilizing a PCA data repository. Rather than advocating for a specific PCA regimen, this review aims to share insights gained from the audit process, highlighting its utility, and offering valuable considerations for designing PCA protocols. Additionally, we provide a non-systematic literature review of significant issues concerning PCA settings within multimodal analgesic approaches for postoperative pain.

METHODS

The effects of changes in postoperative PCA regimens were retrospectively analyzed in 13,230 patients who used PCA devices (Woo Young Meditech) from January 2021 to February 2024 at Chungnam National University Hospital, Daejeon, South Korea, using postoperative data stored in the center's Data Repository for Postoperative Clinical Audit (DR. PCA) (approved by the Institutional Review Boards of Chungnam National University Hospital, IRB number: 2024-05-031) [20].

After reviewing the interim data, regimen changes were based on discussions among staff anesthesiologists. Three phases were identified, marked by two protocol modifications: 1) omission of the basal infusion and 2) an increase in the bolus dose.

Composition of the dataset

Upon completion of use, PCA devices were returned to a designated location for data extraction. AccuLinker (version 1.1), a data extraction program, was used to extract PCA data, and detailed log records were automatically saved to the repository server. The data management system primarily consists of four types of information: 1) patient-specific clinical information, 2) PCA device settings, 3) processed data regarding device use, and 4) postoperative clinical assessments (Table 1). On the evening of the surgery, the patients were evaluated by dedicated nurses from the PCA management team. Pain scores and side effects were assessed, such as dizziness and postoperative nausea and vomiting (PONV).

Statistical analysis

Basic descriptive statistics, including medians (1Q, 3Q) and numbers (%), were used to present the data. Correlation between continuous variables was assessed using Spearman's correlation coefficient (ρ). Outcome comparisons between two phases were made using the Mann–Whitney U test for continuous variables and χ^2 or Fisher's exact test for categorical variables.

OVERALL REVIEW OF THE DATASET

PCA use patterns

The cumulative doses of opioids administered via PCA

Table 1. Variables Included in the Data Repository for Postoperative Clinical Audit (DR. PCA)

Category	Variable
Clinical information	Demographic characteristics, surgery type/date/department,
	anesthesia type/duration, multimodal agents
Device setting	PCA drug, basal infusion, bolus dose, lockout interval, loading dose
Data regarding device use	Cumulative doses after 3, 6, 9, 12, 24, and 48 h, bolus delivered, bolus attempted (demand), delivery/demand ratio*
Postoperative assessments	PONV, dizziness, pain score (NRS)

PCA: patient-controlled analgesia, PONV: postoperative nausea and vomiting, NRS: numerical rating scale. *Proportion of delivered bolus doses to attempted bolus doses (%).

devices, processed at predetermined intervals of 3, 6, 9, 12, 24, and 48 h after surgery (Fig. 1), can be reviewed in the patient's electronic medical records. These opioid requirement patterns vary widely, highlighting the need for flexible tools, such as PCA devices.

Delivery/demand ratio

In addition to recording the loading doses of opioids and doses administered via basal infusion, the system also records patient demands (boluses attempted) and actual doses administered (boluses delivered). The calculated ratio of the administered to attempted doses (delivery/demand ratio) indicates the PCA system's adequacy and the device's effectiveness in meeting patient needs. Interestingly, a negative correlation ($\rho = -0.182$) was observed between the maximum pain score (numeric rating scale, NRS) on the day of surgery and the 24 h delivery/demand ratio. Furthermore, when ratios < 70% were stratified by the maximum NRS score on the day of surgery, an increasing trend was observed, with higher NRS scores (Fig. 2). These findings suggest that the adequacy of PCA device use may be lower in patients with higher levels of pain. This ratio is treated as a critical metric in the subsequent discussions.

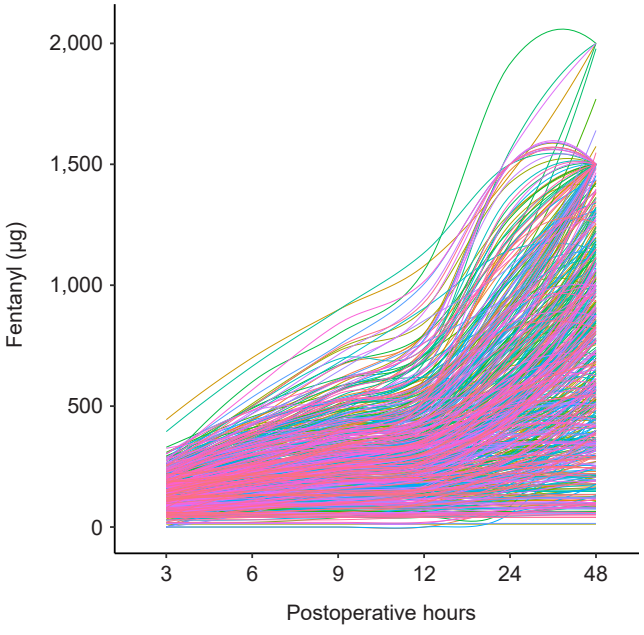

Fig. 1. Cumulative use over time of patient-controlled analgesia devices for 48 h postoperatively in patients who have undergone urologic procedures. Each line indicates the cumulative dose of fentanyl administered to each patient. Data from a single department are presented as an example. Total n = 583.

Postoperative pain in patients using PCA

The pain scores on the day of surgery varied within each surgical department and were particularly low in orthopedic surgery (Fig. 3). The lower pain scores in the orthopedic cases were primarily due to neuraxial or regional blocks. These variable pain scores highlight the need for a patient- or procedure-specific approach.

The PCA device offers several customizable settings, such as loading dose, basal rate, bolus dose, and lockout interval, which a physician adjusts. The PCA device functions as a patient-driven drug administration system. Patients experiencing pain can actively receive opioids by pressing a bolus button on the device. Therefore, although the severity of pain varies among patients, personalized drug delivery should be achieved if the device effectively meets the patient's demands, leading to an appropriate level of pain relief. However, most of our patients who utilized PCA devices after surgery under general anesthesia reported a median NRS score of 6 on the day of surgery, with over 50% of patients in most surgical departments having NRS scores ≥ 7 (Table 2).

FACTORS ASSOCIATED WITH ANALGESIC OUTCOMES

Patient factors associated with postoperative pain and opioid requirements include younger age, female sex, preoperative opioid use, substance use disorders, and psychological disorders [21,22]. While recognizing these patient factors provides valuable insights into postoperative pain and its management [23,24], many cannot be easily modified.

However, increased postoperative pain and opioid requirements may not be solely due to patient factors; external factors, such as suboptimal PCA settings and inconsistent perioperative multimodal analgesia, may also play a significant role. In particular, PCA settings are often fixed based on institutional standards or individual clinician preferences without proper feedback. The following section outlines the stepwise process our institution has undertaken to adjust PCA settings based on retrospective feedback from the DR. PCA.

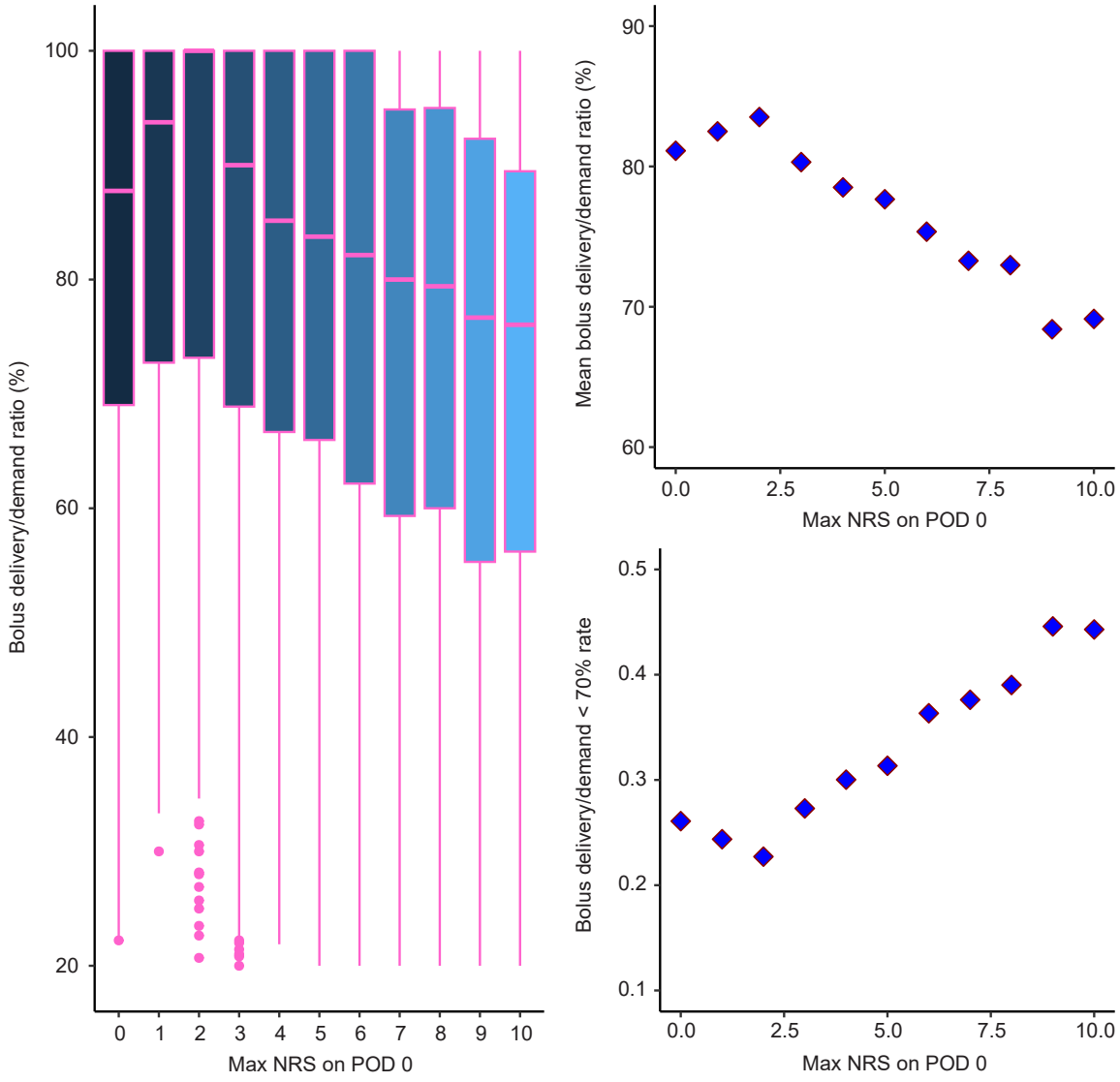

Fig. 2. Correlation between maximum pain score (NRS) and the ratio of delivery/demand on the day of surgery (POD 0). The boxplot represents the 24 h delivery/demand ratio (median [1Q, 3Q]) stratified by the maximum NRS on POD 0 (left). The ratio of delivery/demand in the plots indicates the proportion of delivered bolus doses among the attempted bolus doses during the first 24 h postoperatively. This ratio is an indicator of the adequacy of the PCA system, demonstrating the effectiveness of the device in meeting patient requirements. A negative correlation (ρ = -0.182) was observed between the maximum NRS on the day of surgery and the 24 h delivery/demand ratio. Each blue dot represents the mean value (upper right) or the rate (lower right) calculated for each NRS category. Total n=7,689. NRS: numerical rating scale, POD: postoperative day, PCA: patient-controlled analgesia.

STEPWISE MODIFICATION OF PCA PROTOCOLS

As mentioned previously, two PCA protocol modifications were implemented, resulting in three phases (Table 3). Notably, the protocols for each phase were established as the recommended default settings rather than strict rules, allowing for individual variation at the discretion of the attending anesthesiologist.

From phase 1 to 2

Until early 2021 (phase 1), a basal rate of 10 to 20 μg/h of fentanyl was routinely incorporated into most PCA regimens at our institution. Many patients withdraw from PCA owing to side effects such as PONV. Because few nurses in the wards were trained in using PCA devices, addressing these side effects usually involved the removal of the devices. This issue was mitigated by primarily focusing on gynecologic

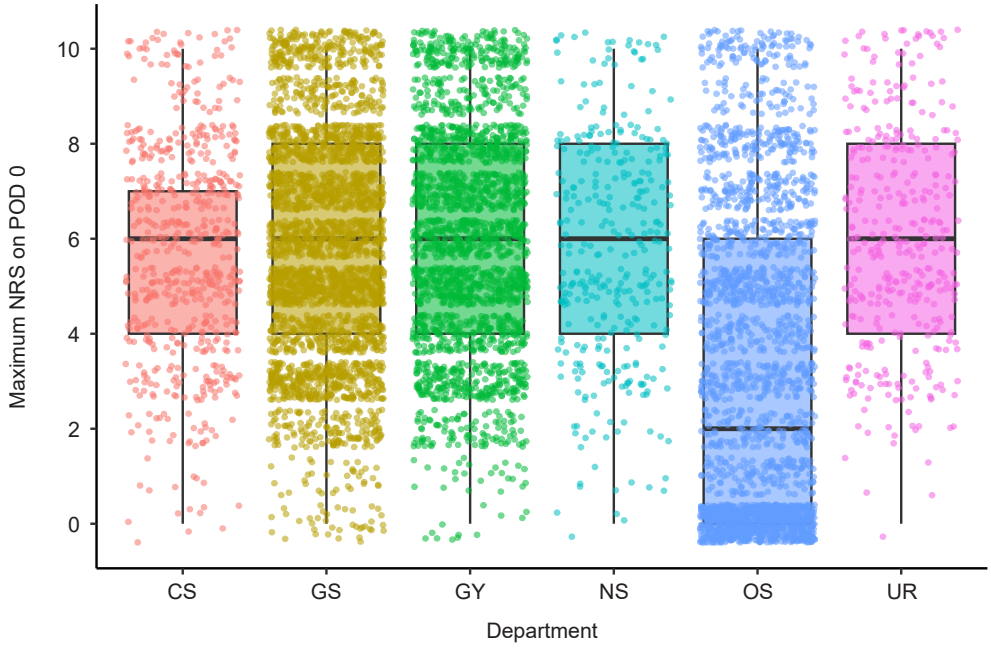

Fig. 3. Maximum pain scores (NRS; 0-10) on the day of surgery (POD 0). Each dot represents the maximum NRS score recorded for each patient on the day of surgery. Boxplot represents the median (1Q, 3Q) values. These scores were assessed during the evening postoperative rounds conducted by nurses dedicated to the PCA management team. NRS: numerical rating scale, POD: postoperative day, CS: cardiothoracic surgery, GS: general surgery, GY: gynecologic surgery, NS: neurosurgery, OS: orthopedic surgery, UR: urologic surgery. Total n = 8,759.

Table 2. Pain Scores (NRS) on the Day of Surgery Under General Anesthesia Stratified by Surgical Departments (n = 7,864)

Variable	Surgical departments					
	CS (n = 605)	GS (n = 2,936)	GY (n = 2,148)	NS (n = 341)	OS (n = 1,458)	UR (n = 376)
Maximum NRS	6.0 (4.0, 7.0)	6.0 (4.0, 8.0)	6.0 (4.0, 8.0)	6.0 (4.0, 8.0)	5.0 (1.0, 7.0)	6.0 (4.0, 8.0)
Minimum NRS	3.0 (2.0, 5.0)	3.0 (2.0, 5.0)	3.0 (2.0, 4.0)	3.0 (2.0, 5.0)	2.0 (0.0, 4.0)	3.0 (2.0, 5.0)
NRS ≥ 7	320 (52.9)	1,528 (52.0)	1,207 (56.2)	174 (51.0)	545 (37.4)	208 (55.3)

Values are presented as median (1Q, 3Q) or number (%). NRS: numerical rating scale, CS: cardiothoracic surgery, GS: general surgery, GY: gynecologic surgery, NS: neurosurgery, OS: orthopedic surgery, UR: urologic surgery.

Table 3. Patient-Controlled Analgesia Settings Stratified by the Phases (n = 13,230)

Settings	Phase 1 (n = 4,472)	Phase 2 (n = 6,098)	Phase 3 (n = 2,660)
Basal infusion			
Yes	3,335 (74.6)	459 (7.5)	65 (2.4)
No	1,137 (25.4)	5,639 (92.5)	2,595 (97.6)
Bolus dose (fentanyl)			
10 μg	1,200 (26.8)	884 (14.5)	362 (13.6)
15 μg	2,869 (64.2)	4,829 (79.2)	836 (31.4)
20 μg	403 (9.0)	385 (6.3)	1,462 (55.0)
Lock out			
10 min	4,375 (97.8)	6,043 (99.1)	2,653 (99.7)
15 min	89 (2.0)	51 (0.8)	6 (0.2)
Others	8 (0.2)	4 (0.1)	1 (0.0)

Values are presented as number (%).

surgical patients who are at high risk of PONV and, therefore, at a heightened risk of PCA discontinuation [25]. Beginning in April 2021 (phase 2), routine basal infusion was eliminated from the PCA regimens, and the clinical outcomes were compared between phases 1 and 2 (Table 4). The change in protocol reduced the rate of PCA discontinuation within 24 h from 23.2% to 6.5% and significantly reduced cumulative opioid consumption without increasing pain scores on the day of surgery. Moreover, there was no reduction in the 24 h or total PCA delivery/demand ratios and no increase in rescue opioid use.

After successful implementation in the gynecological surgical cohort, this protocol, with the omission of the basal fentanyl infusion, was extended to all other surgical depart-

Table 4. Postoperative Analgesic Outcomes Stratified by the Protocol Change in Patients Undergoing Gynecologic Surgery

Variable	Phase 1 (n = 177)	Phase 2 (n = 1,853)	P value
PCA stop within 24 h	41 (23.2)	120 (6.5)	< 0.001
PONV on POD0			< 0.001
No	111 (73.5)	1,327 (85.5)	
Yes	40 (26.5)	225 (14.5)	
Maximum NRS on POD0	6.0 (4.0, 9.0)	6.0 (4.0, 8.0)	0.534
24 h PCA use (fentanyl, μg)	366.0 (272.0, 489.0)	230.0 (130.0, 380.0)	< 0.001
48 h PCA use (fentanyl, μg)	583.0 (402.0, 759.0)	297.0 (155.0, 530.0)	< 0.001
24 h delivery/demand (%)*	81.8 (66.7, 100.0)	90.0 (73.9, 100.0)	0.016
Total delivery/demand (%)†	81.8 (68.8, 100.0)	90.5 (75.0, 100.0)	0.005
Ward rescue opioid (< 48 h)			0.099
None	169 (94.4)	1,798 (97.0)	
1–2	9 (5.1)	50 (2.7)	
> 2	1 (0.6)	5 (0.3)	

Values are presented as number (%) or median (1Q, 3Q). PCA: patient-controlled analgesia, PONV: postoperative nausea and vomiting, POD: postoperative day, NRS: numeric rating scale. Routine basal infusion was eliminated from the PCA regimen in phase 2. *Proportion of delivered bolus doses among attempted bolus doses during the first 24 h postoperatively. †Delivery/demand ratio during the entire period of PCA use.

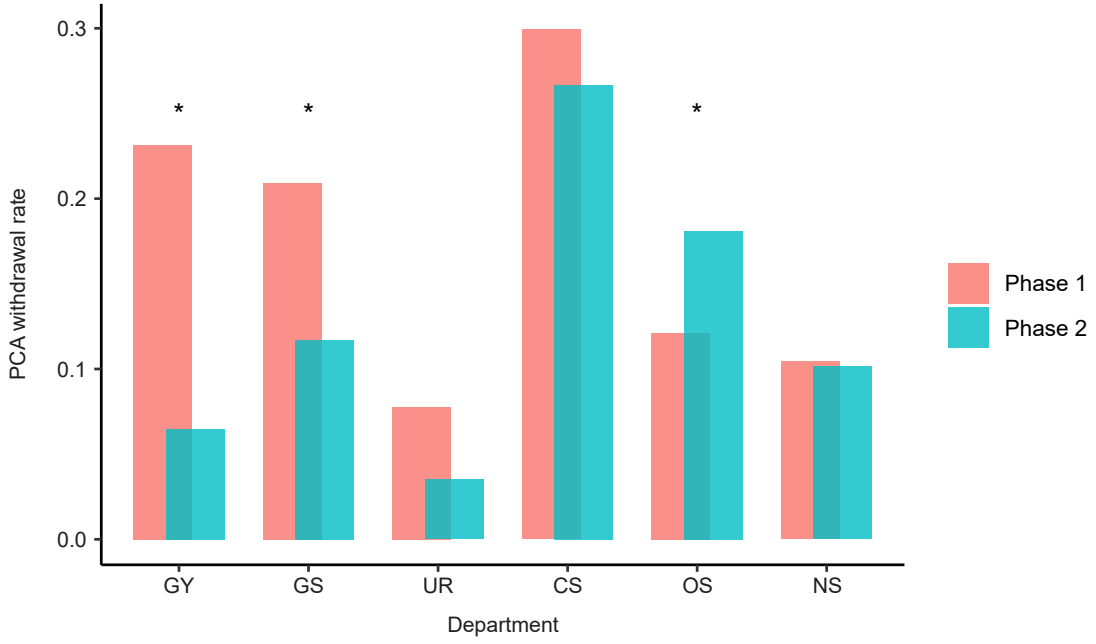

Fig. 4. PCA withdrawal within 24 h stratified by department and protocol (phase 1, routine basal infusion, n = 4,472; phase 2, without routine basal infusion, n = 6,098). The bar represents the rate of PCA withdrawal within 24 h in each department stratified by phase. PCA: patient-controlled analgesia, CS: cardiothoracic surgery, GS: general surgery, GY: gynecologic surgery, NS: neurosurgery, OS: orthopedic surgery, UR: urologic surgery. *P < 0.05.

ments in May 2022 (phase 2). PCA discontinuation rates decreased significantly in the gynecologic and general surgery departments, with other departments showing either slight reductions or even increased rates (Fig. 4).

The omission of the basal infusion resulted in a reduction in opioid consumption to almost half of that observed during phase 1 without increasing pain scores on the day of surgery (data not shown). However, the proportion of patients with a total delivery/demand ratio < 70% increased after the protocol change, particularly after urological surgery and neurosurgery (Fig. 5). These findings suggest that omission of basal infusion can have varying effects on post-

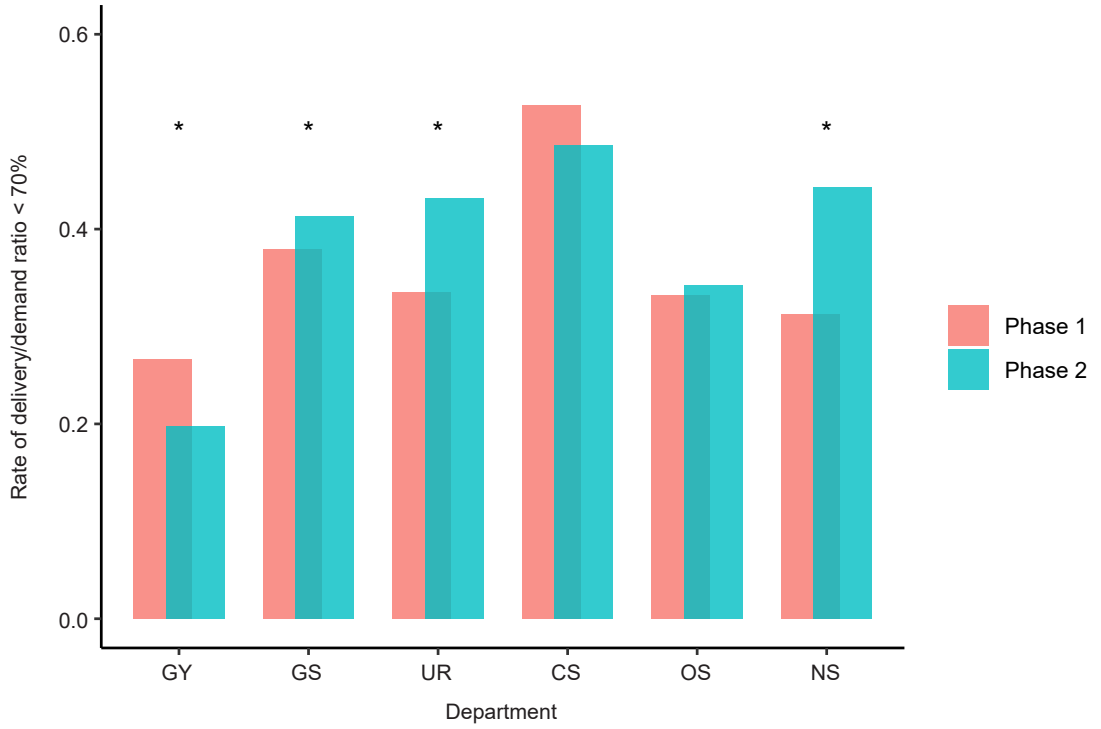

Fig. 5. Rates of total bolus delivery/demand ratio < 70% stratified by surgical departments and protocols (phase 1, routine basal infusion, n = 4,324; phase 2, without routine basal infusion, n = 6,003). The delivery/demand ratio in the plot indicates the proportion of delivered bolus doses among the attempted bolus doses during the entire period of PCA use. The bar represents the rate of delivery/demand ratio < 70% within each department, stratified by phase. PCA: patient-controlled analgesia, CS: cardiothoracic surgery, GS: general surgery, GY: gynecologic surgery, NS: neurosurgery, OS: orthopedic surgery, UR: urologic surgery. *P < 0.05.

operative analgesic outcomes across surgical departments.

From phase 2 to 3

During phase 2, the default bolus dose of fentanyl was 15 μg with a 10-min lockout interval. Except for patients who underwent gynecologic surgery, most departments had a > 30% rate of total bolus delivery/demand ratio < 70% (Fig. 5). To address this issue, the bolus dose of fentanyl was increased to 20 μg, maintaining the same lockout interval, beginning in August 2023 (phase 3). This adjustment reduced the rate of total bolus delivery/demand ratio < 70% in most departments (Fig. 6), with notable changes observed in the neurosurgery (Table 5) and general surgery (Table 6) departments. The pain scores on the day of surgery and the total bolus delivery/demand ratio showed favorable changes following an increase in the bolus dose. However, the incidence of PONV nearly doubled.

INSIGHTS FROM THE DR. PCA AND REVIEW OF RECENT LITERATURE

In this retrospective analysis, we analyzed the effects of progressive PCA setting adjustments on clinical outcomes. Based on the issues encountered, the protocols were changed and the effects of these changes were assessed. This iterative approach facilitated the gradual enhancement of the protocol. However, these changes in the protocol did not consistently result in the intended outcomes across all clinical scenarios, as both positive and negative outcomes were observed. This highlights the importance of careful and gradual protocol manipulation coupled with a thorough assessment of its impact. Unfortunately, the efficacy of PCA protocols has not been widely evaluated in many institutions in Korea [17].

Based on these findings, several issues should be considered when transitioning to the next phase of the analgesic protocol. In the following section, we discuss these issues while reviewing recent studies and guidelines on postoperative PCA regimens using a multimodal approach.

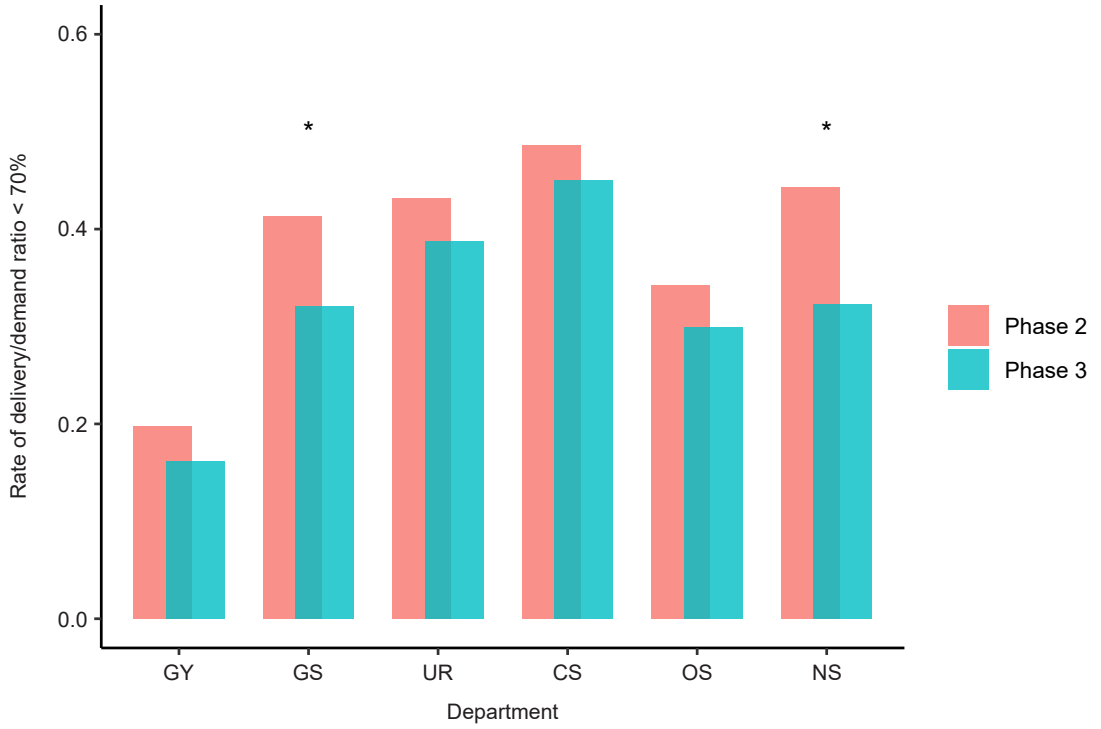

Fig. 6. Rates of total bolus delivery/demand ratio < 70% stratified by surgical departments and protocols (phase 2, fentanyl 15 μg bolus, n = 6,003; phase 3, fentanyl 20 μg bolus, n = 2,637). The delivery/demand ratio in the plot indicates the proportion of delivered bolus doses among the attempted bolus doses during the entire period of PCA use. The bar represents the rate of delivery/demand ratio < 70% within each department, stratified by phase. PCA: patient-controlled analgesia, CS: cardiothoracic surgery, GS: general surgery, GY: gynecologic surgery, NS: neurosurgery, OS: orthopedic surgery, UR: urologic surgery. *P < 0.05.

Table 5. Postoperative Analgesic Outcomes Stratified by the Protocol Change in Patients Who Underwent Neurosurgery

Variable	Phase 2 (n = 256)	Phase 3 (n = 134)	P value
PCA stop within 24 h	26 (10.2)	16 (11.9)	0.713
PONV on POD0			0.049
No	150 (92.0)	67 (82.7)	
Yes	13 (8.0)	14 (17.3)	
Maximum NRS on POD0	6.0 (4.0, 8.0)	5.0 (3.0, 7.0)	0.001
24 h PCA use (fentanyl, μg)	282.8 (160.5, 484.5)	273.0 (147.0, 489.0)	0.937
48 h PCA use (fentanyl, μg)	385.5 (194.2, 630.0)	390.8 (177.0, 742.5)	0.734
Total delivery/demand (%)*	72.5 (53.5, 87.8)	85.0 (61.0, 96.9)	< 0.001

Values are presented as number (%) or median (1Q, 3Q). PCA: patient-controlled analgesia, PONV: postoperative nausea and vomiting, POD: postoperative day, NRS: numeric rating scale. PCA (fentanyl) bolus dose was increased from 15 μg in phase 2 to 20 μg in phase 3. *Proportion of delivered bolus doses among the attempted bolus doses during the entire period of PCA use.

Basal (background) infusion of PCA

In general, routine basal infusion with PCA is not recommended because of the lack of a clear analgesic advantage and an increased risk of side effects such as PONV and respiratory depression [1]. Although much evidence on this issue stems from studies involving morphine [26], which has a different pharmacokinetic profile than fentanyl, a recent retrospective study involving fentanyl PCA also indicated an increase in opioid consumption and the occurrence of opioid-related side effects among patients receiving a basal infusion, suggesting a favorable outcome with the omission of basal infusion [8].

Results regarding the omission of basal infusion in PCA

Table 6. Postoperative Analgesic Outcomes Stratified by the Protocol Change in Patients Who Underwent General Surgery

Variable	Phase 2 (n = 1,826)	Phase 3 (n = 1,826)	P value
PCA stop within 24 h	214 (11.7)	98 (11.4)	0.841
PONV on POD0			< 0.001
No	1,247 (90.8)	403 (79.5)	
Yes	126 (9.2)	104 (20.5)	
Maximum NRS on POD0	6.0 (4.0, 7.0)	5.0 (4.0, 7.0)	0.001
24 h PCA use (fentanyl, μg)	219.5 (109.5, 409.5)	224.0 (118.5, 439.5)	0.289
48 h PCA use (fentanyl, μg)	292.5 (124.5, 585.0)	310.0 (130.0, 646.5)	0.128
Total delivery / demand (%)*	76.3 (52.6, 92.2)	83.7 (63.2, 96.9)	< 0.001

Values are presented as number (%) or median (1Q, 3Q). PCA: patient-controlled analgesia, PONV: postoperative nausea and vomiting, POD: postoperative day, NRS: numeric rating scale. Bolus dose of PCA (fentanyl) was increased from 15 μg in phase 2 to 20 μg in phase 3. *Proportion of delivered bolus doses among the attempted bolus doses during the entire period of PCA use.

settings are inconclusive. Although there were clear positive effects, such as decreased rates of unintended discontinuation of PCA and a considerable opioid-sparing effect, the decrease in discontinuation rates was inconsistent across surgical departments. In addition, in some subgroups, the delivery/demand ratio increased, which may have indicated inadequate analgesia. However, the authors still advocate omitting basal infusion in PCA settings because of the clear benefit of decreasing opioid consumption, which aligns with the current opioid-sparing and early recovery themes of perioperative care [23,24,27,28]. This approach can be supplemented by proactive multimodal strategies, including regular non-opioid analgesics and regional block techniques [29].

PCA lockout interval

A single fixed lockout interval of 10 min was used almost exclusively for the audit data. A lockout interval is required as a safety measure to limit the frequent delivery of bolus doses. It should be sufficiently long to allow for the full analgesic effect of each bolus dose, thus preventing the accumulation of doses known as "stacking" [30]. However, if the lockout interval is excessively long, the effectiveness of the PCA may be compromised, potentially leading to an increased delivery/ demand ratio. While one study suggested that the lockout interval (5 min vs. 8 min) of fentanyl-based PCA had little impact on postoperative pain or the delivery/ demand ratio [31], it was a small study and may deviate from the current medical context with multimodal analgesia. Given the rapid onset of intravenous fentanyl [32], further comparison of shorter lockout intervals (e.g., 5 min) with longer intervals in the current clinical setting is warranted.

Implications of sex

After excluding patients who underwent gynecological and breast surgeries in phases 2 and 3, male patients showed significantly higher opioid consumption than female patients during the first 48 h postoperatively (Fig. 7). Furthermore, a comparison of male and female patients undergoing cardiothoracic and general surgery revealed that the bolus delivery/ demand ratios were lower in male patients (Fig. 7). These findings suggest the need for a differentiated approach based on sex, particularly in these surgical groups. Moreover, since female sex is an inarguable risk factor for PONV [33], a sex-differentiated approach would be beneficial.

Dexamethasone

Currently, at our institution, intraoperative dexamethasone is not routinely administered, except in patients undergoing gynecologic surgery or some types of orthopedic surgery. As most female patients using PCA devices can be considered a high-risk group [33], further extension of intraoperative dexamethasone may be considered. The incidence of PONV in female patients who underwent gynecologic surgery during phases 2 and 3 was significantly lower in those who did not receive intraoperative dexamethasone (12.1% vs. 17.6%, P = 0.004). Because the incidences of PONV in patients undergoing general surgery and neurosurgery were higher during phase 3 than during phase 2, adding intraoperative dexamethasone to the phase 3 protocol may reduce these rates in the future. Currently, pre- or intra-operative dexamethasone is widely recommended for PONV prevention and its analgesic effect [28,33-38].

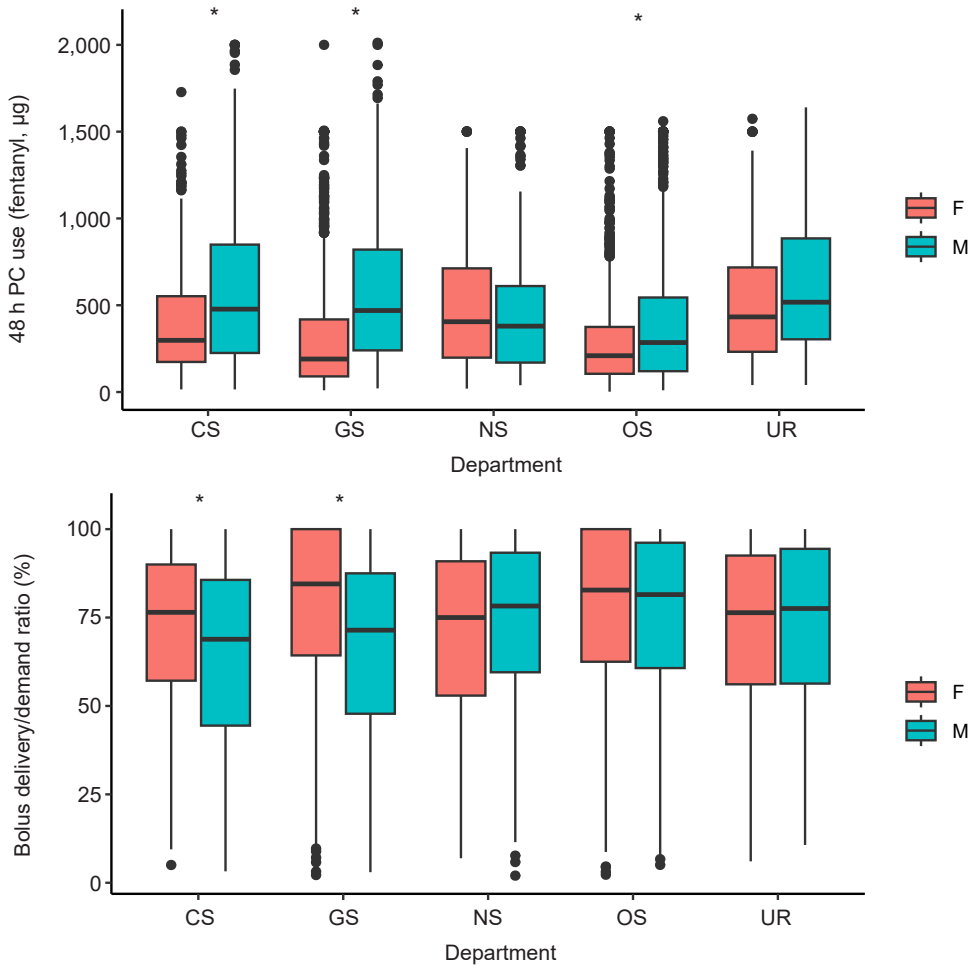

Fig. 7. Postoperative opioid consumption (48 h) and bolus delivery/demand ratios stratified by sex and department. The delivery/demand ratio in the plot (lower) indicates the proportion of delivered bolus doses among the attempted bolus doses during the entire period of PCA use. The plots were derived from phases 2 and 3 after excluding patients who underwent gynecological and breast surgeries. PCA: patient-controlled analgesia, CS: cardiothoracic surgery, GS: general surgery, GY: gynecologic surgery, NS: neurosurgery, OS: orthopedic surgery, UR: urologic surgery. *P < 0.05.

Multimodal agents

Due to consistent efforts to incorporate multimodal analgesia in addition to PCA, the intraoperative administration of multimodal agents, including intravenous paracetamol, non-steroidal anti-inflammatory drugs (NSAIDs), nefopam, and magnesium, has been successful at our institution (Fig. 8).

Most guidelines recommend the use of paracetamol and/or NSAIDs as a basic non-opioid analgesic after surgery in the absence of contraindications [1,28,34-38]. Additionally, the combination of paracetamol and NSAIDs may provide a superior analgesic effect than either drug alone [39].

Nefopam is a centrally acting non-opioid analgesic agent that has been used since the mid-1970s [40]. Its analgesic and opioid-sparing effects have been well established in several studies [40-43]. Owing to its distinct analgesic mechanism, anti-shivering properties, and absence of respiratory depressant effects, it is an attractive component of a multimodal regimen [44]. In particular, it can serve as a good alternative when paracetamol and/or NSAIDs are contraindicated.

Although not widely incorporated into procedure-specific guidelines, magnesium presents an appealing multimodal component that offers an additional mechanistic pathway for analgesia [45]. Several meta-analyses have demonstrated its significant analgesic and opioid-sparing effects after surgery [46-49]. Interestingly, intraoperative magnesium administration also appears to offer other clinical benefits such as reducing PONV [49] and shivering [50], which are import-

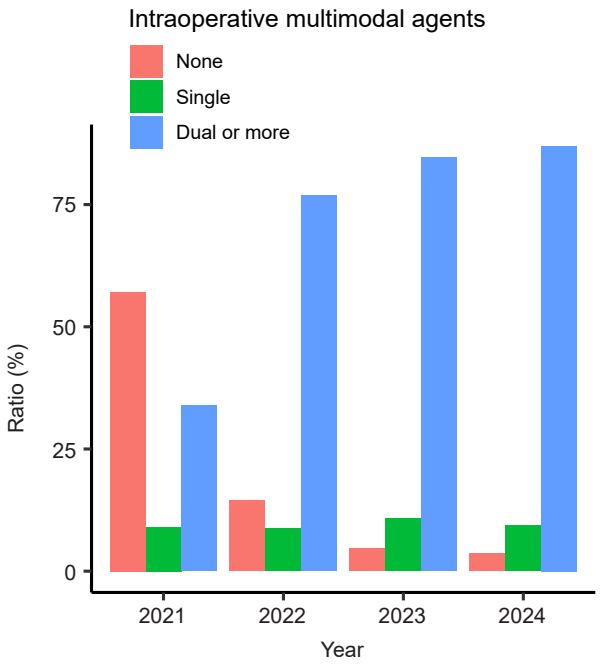

Fig. 8. Use of intraoperative multimodal agents stratified by year. The intraoperative administration of multimodal agents, including intravenous paracetamol, nonsteroidal anti-inflammatory drugs, nefopam, and magnesium, was stratified based on the number of agents used: none, single, and dual or more. There has been an increasing trend in the use of multimodal analgesia consisting of two or more agents. Conversely, the absence of multimodal agents decreased over time.

ant considerations for postoperative patients.

REMAINING ISSUES

A seamless transition of the intraoperative multimodal protocol into a postoperative analgesic protocol in the ward has not yet been achieved at our institution. For effective postoperative pain control with PCA, particularly protocols without basal infusion, it is crucial to consistently incorporate basic multimodal agents, such as paracetamol and NSAIDs, in the ward setting rather than relying solely on PCA. This requires effective communication and result sharing between different departments (i.e., anesthesiology and surgery), emphasizing a team-based approach [51].

Other issues that remain unaddressed include determining the optimal administration of the loading dose; understanding the implications of multimodal agents and regional blocks; developing further detailed protocols that are both procedure-and patient-specific; integrating more comprehensive metrics for postoperative patient assessment, such as the quality of recovery-15 [52] or the functional activity scale [23,53]; and extending outcome assessments beyond the day of surgery.

The current audit system has three critical limitations that warrant separate commentary. First, the results of the audit process should not be viewed as refined, protocol-specific outcomes. Instead, they reflected a mix of results from various protocols, as we allowed flexibility based on specific case considerations. The true effect size of each protocol would be better evaluated after adjusting for multiple relevant clinical factors, or ideally, through a prospective randomized trial. Secondly, constructing an analgesic protocol based solely on pain scores is not advisable. Despite being considered the "5th vital sign," focusing exclusively on pain scores can be counterproductive for both clinicians and patients. Blindly titrating analgesic regimens based on pain scores may improve pain levels, but could potentially lead to unwanted side effects [53]. Postoperative recovery encompasses various clinical aspects beyond pain scores, including PONV, ambulation, dietary intake, sense of well-being, and most importantly, the ability to return to daily activities. Therefore, it is preferable to assess and target a more comprehensive set of metrics, as suggested previously. Finally, the outcomes should be assessed beyond the day of surgery. Patient status can change during the hospital stay, making an evaluation based solely on the outcomes assessed on the day of surgery overly simplistic and unable to reflect the overall clinical trajectory [22].

CONCLUSION

This review highlights the importance of careful adjustments in PCA settings through institutional audit processes. This is not a final step but rather an ongoing journey of continuous refinement and evolution. We believe that this method is the key to optimizing postoperative analgesia and consequently enhancing recovery after surgery. We strongly encourage readers to establish institutional feedback processes for using PCA.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

DATA AVAILABILITY STATEMENT

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

Writing - original draft: Chahyun Oh. Writing - review & editing: Chahyun Oh, Woosuk Chung, Boohwi Hong. Formal analysis: Chahyun Oh. Methodology: Chahyun Oh. Project administration: Chahyun Oh, Woosuk Chung, Boohwi Hong. Visualization: Chahyun Oh. Investigation: Chahyun Oh, Woosuk Chung. Software: Boohwi Hong. Supervision: Woosuk Chung, Boohwi Hong.

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