The Usefulness of Dual Channel Elastomeric Pump for Intravenous Patient-Controlled Analgesia in Geriatrics: A Randomized, Double-Blind, Prospective Study

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Research Article

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Abstract

Background: Intravenous patient-controlled analgesia (IV-PCA) is well applied in postoperative period. However, determining an appropriate opioid dose was difficult. A previous study suggested the usefulness of variable-rate feedback infusion. In this study, we used a dual-channel elastomeric infusion pump to provide changes in PCA infusion rate by pain feedback.

Methods: 90 patients of ASA I-III and 65 to 79 years undergoing orthopedic surgery were participated in the study. All patients were applied a dual-chamber PCA. Patients were randomly allocated into treatment group (Group D; PCA drugs were divided into both chambers.) or control group (Group C; PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber.) The primary outcome was the amount of fentanyl consumption via PCA bolus. The secondary outcome variables were pain score, total fentanyl consumption, rescue analgesic use, patient satisfaction, recovery scores and adverse events including postoperative nausea and vomiting (PONV).

Results: Group D showed decreased fentanyl consumption in PCA bolus. Moreover, group D showed in a decrease in rescue analgesic use and better patient satisfaction. The incidence of PONV was much higher in group C. There was no difference in other adverse events.

Conclusions: We showed the usefulness of dual chamber IV-PCA to change the flow rate to the pain feedback without any complication. Our results suggested noble implications that may improve existing IV-PCA equipment.

Clinical trial registration: The study registered at UMIN clinical trial registry (registered date: 05/03/2020, registration number: UMIN000039702).

Introduction

Bolus dose and continuous infusion are two methods of IV drug administration. As many clinicians know, both methods have limitations from the point of view of pharmacokinetics. If the target value of opioid plasma concentration is given, a sufficient bolus dose shows exponential decays with transiently higher plasma concentration, followed by lower concentration than the target level [1]. Therefore, single bolus dose of opioid may cause complications in the early phase and insufficient pain control in the later phase. On the contrary, continuous infusion maintains a consistent level of plasma concentration. But there is a delay before reaching that level [1] which means difficulty in early pain control.

Among the numerous pain control methods, opioid-based intravenous patient-controlled analgesia (IV-PCA) is commonly used to relieve postoperative pain [2, 3]. IV-PCA provides both of two methods described above, which make up for the shortcomings of each method and seems appropriate and plausible. However, there were still problems in many clinical situations. Too low dose of basal infusion may cause pain and require more opioid bolus while too high dose of basal infusion may cause PCA

cessation. Moreover, optimal level of opioid concentration is not constant because there are many factors including pain level, intraindividual and interindividual differences [4].

Many types of PCA device have been used and developed since the 1960s [5]. In the early days, most type of PCA was electronic, but now non-electronic, elastomeric types are widely used. Compared to electronic type, elastomeric type has several advantages of being light and easy to carry, disposable, simple manipulation, no need for power and no program error [6, 7]. However, most non-electric IV-PCA devices has a single elastomeric pump, which is difficult to change the preset rate. We observed a phenomenon in which the pain score was high on the first day after surgery which indicates a shortage of analgesic dose while the pain score decreased on the second day with increased frequency of opioid complications. We assumed that pain management would be optimized by increasing analgesic dose on the first day and decreasing dose on the second day according to the pain level of each patient.

The Bellomic®M (Cebika, Uiwang-si, Gyeonggi-do, Republic of Korea) was a newly designed IV-PCA device that consists of a dual infusion elastomeric pump with two balloon chambers. One channel contained a continuous flow-rate chamber and a bolus function, while the other channel contained an adjustable flow-rate chamber without a function of bolus.

The purpose of this study was to apply this dual channel elastomeric IV-PCA in elderly patients undergoing orthopedic surgery and evaluate the efficacy of dual-channel IV-PCA compared to single-channel IV-PCA and single placebo channel through PCA opioid consumption, postoperative pain, rescue analgesic, subjective satisfaction of the patient and other adverse events. We hypothesized that more efficient pain management would be achieved if the flow rates were adjusted according to patient pain feedback using this dual-channel IV-PCA device.

Material And Methods

Design

This study was a single-center prospective randomized controlled trial conducted from 2019 to 2020. We followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines when designing this study. After approving the institutional review board, it was registered at UMIN clinical trial registry (registered date: 05/03/2020, registration number: UMIN000039702).

The elderly patients 65–79 years of age, in ASA class I - III, undergoing orthopedic surgery excluding patients with BMI > 35, drug abuse or dependence, history of drug allergy (to fentanyl, ramosetron, nefopam and other nonsteroidal anti-inflammatory drugs), cognitive disorder, dementia, other psychiatric disease, speech impairment and severe chronic pain other than the surgical site were included. Written informed consents were obtained from all the subjects. Demographic data including age, sex, weight, height, American Society of Anesthesiologists physical status classification (ASA class) and underlying diseases including hypertension, diabetes mellitus and cerebrovascular accident were collected from all the patients.

All patients were applied a dual-chamber PCA just after arrival of post-anesthesia care unit (PACU). Patients were randomly allocated into treatment group (Group D; PCA drugs were divided into both chambers.) or control group (Group C; PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber.), and they were unaware of the group assignment. One independent investigator was responsible for the generation of random allocation sequence and the group assignment of patients. Randomization was done in two blocks using a web-based computer-generated list (www.randomization.com). The subject numbers, which were kept in opaque, sealed envelopes, were checked only by an independent anesthesiologist who did not play a role other than making PCA in the operating room. Both the patients and other clinical investigators were blinded to the group allocation.

The primary outcome in this study was the amount of fentanyl consumption via PCA bolus. A power analysis proposed that a sample size of at least 40 patients for each group would be required with a significance level of 5% to achieve 80% power. An effect size was calculated from the PCA consumption (volume delivered at 12-24 hour) presented in the previous study [8] which compared constant-rate and variable-rate infusion. To allow for an exclusion rate, the study population was prospectively set at 90 patients.

IV-PCA device and regimen

The Bellomic®M (Cebika, Uiwang-si, Gyeonggi-do, Republic of Korea) has dual channel infusion elastomeric pump. The basal-bolus channel consists of a 2 mL/h of fixed flow rate infusion and a bolus function (1ml of the bolus volume, 10 mins of lock-out period). The other selector channel can be set to 0, 1, 2 ml/hr with adjustable flow rate without bolus function. The maximum volume of each chamber is 100 ml.

In the Group D, IV-PCA contained fentanyl 13.3 ug/kg + ramosetron 0.4 mg with normal saline to a total volume of 100 ml in the basal-bolus channel with a constant rate of 2 ml/hr and fentanyl 6.7 ug/kg + ramosetron 0.2 mg with normal saline to a total volume of 50 ml in the selector channel with adjustable rates of 0-2 ml/hr. In the Group C, IV-PCA contained fentanyl 20 ug/kg + ramosetron 0.6 mg with normal saline to a total volume of 100 ml in the basal-bolus channel with a constant rate of 2 ml/hr and 50 ml of normal saline in the selector channel with adjustable rates of 0-2 ml/hr. In both group, initial rate of selector channel was 1. When the pain score (visual analogue scale, VAS) was 7 or more in the PACU and 5 or more in the ward, the flow rate of selector channel was increased by 1 (maximum 2), and when the pain score was 3 or less, the rate was decreased by 1 (minimum 0) (see the perioperative management in the method section). If the flow rate is fixed at 1 without no adjustment, except for an additional bolus dose, the amount and infusion rate of fentanyl used in Group D and Group C are exactly the same. A schematic of the IV-PCA regimen is shown in the Fig. 1.

Perioperative management

All patients were monitored with pulse oximetry, electrocardiography, automatic noninvasive blood pressure measurement, bispectral index (BIS), capnography, end-tidal concentration of volatile anesthetics, and train-of-four (TOF). Blood pressure was monitored at 5-min intervals and heart rate was monitored continuously. After preoxygenation, anesthesia was induced with an intravenous 2 mg/kg of propofol bolus by rocuronium 0.6 mg/kg. After loss of consciousness, tracheal intubation was performed. Patients received 0.6-2 vol% of sevoflurane with remifentanyl infusion for maintenance of anesthesia. The depth of anesthesia was adjusted during surgery to keep BIS values of 40 to 60 and mean blood pressures at 80 to 120% of the baseline value. Minute ventilations were adjusted to maintain normocapnia with an FiO_2 of 0.5, and 3 l/min of fresh gas flow rate during surgery. Initial settings of tidal volume were 8 ml/kg, I:E of 1:2, and airway pressure that was adjusted not to exceed 25 cmH₂O. At the end of surgery, all anesthetics were stopped, and ventilator settings were changed to FiO_2 1.0 and 8 l/min of fresh gas flow rate. 2 mg/kg of sugammadex was administered. Return of neuromuscular function was confirmed using TOF peripheral nerve stimulation. Before extubation, four equal twitches in the TOF were required. Extubation was performed when a patient was awake (defined as spontaneous eye opening or purposeful movements to verbal commands).

IV-PCA was initiated just after arrival on PACU. A simple mask with an oxygen flow rate of 5 l/min was applied to the patients in the PACU. The pain score, the level of consciousness and the modified Aldrete post-anesthesia recovery score (PARS) were evaluated every 5 minutes. The pain score was evaluated using the visual analogue scale (VAS) range from 0-10 points. When the pain score (VAS) was 7 or more, the flow rate of selector channel was increased by 1 (maximum 2) and fentanyl 1 ug/kg was intravenously administered as a rescue analgesic. Rescue analgesic can be administered up to twice (maximum fentanyl 2 ug/kg, at least 15 minutes interval) in the PACU. When the pain score was 3 or less, the flow rate of selector channel was decreased by 1 (minimum 0). The Richmond Agitation and Sedation Scale (RASS) and the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) were used for the level of consciousness and delirium assessments. Any adverse events including postoperative nausea/vomiting (PONV), dizziness, dry mouth, episode of bronchospasm, laryngospasm, or oxygen desaturation ($\text{SpO}_2 < 95\%$) were recorded. 0.075mg of palonosetron was administered in the patients with PONV. If there was no abnormality, the patients stayed in the recovery room for 60 minutes and then moved to the ward.

At 6, 12, 24, 36, 48 hours after arriving PACU, pain scores and fentanyl consumption in PCA were evaluated. In addition, the patient's subjective satisfaction and any side effects including nausea/vomiting, dizziness, dry mouth, respiratory depression, hypotension, and other complications were recorded. The patient satisfactions were assessed by a 5-point rating scale (1=very dissatisfied, 2=dissatisfied, 3=neutral, 4=satisfied, 5=very satisfied). When the pain score was 5 or higher in the ward, increase the flow rate of the selector channel by 1 (maximum 2), and administered nefopam 20 mg as a rescue analgesic intravenously over 15 minutes.

Statistic methods

After confirming normality by the Kolmogorov-Smirnov test, data expressed as mean $\pm$ SD were compared between the two groups using independent t-tests or Mann-Whitney U test where appropriate. Data expressed as the number of patients were compared using chi-square analysis when any cells with expected values below 5 did not exceed 20% in the contingency table or Fisher's exact test where appropriate. Repeated measures analyses of variance (RM-ANOVA) were applied in the repeated measured variables including fentanyl consumption in PCA and pain score for analysis of group effects. We adopted the results of tests showing within-subjects' effect when the sphericity condition of data was satisfied or the results from multivariate analyses.

Statistical analyses were performed using the Statistical Package for Social Sciences, version 22.0. P-values below 0.05 were considered statistically significant.

Results

A total of 87 patients were enrolled in this study excluding 3 patients who withdrew consent (43 patients for group D and 44 patients for group C) (Appendix). There was no significant difference on the demographic data between the two groups (Table 1). Total anesthesia time, operation time, fluid input and output, recovery profiles including PARS, RASS, CAM-ICU; and fentanyl consumption in PACU were not different between the two groups. The rescue analgesics in the ward were more required in group C (Table 2).

Table 1
Demographic data

	Group D (n = 43)	Group C (n = 44)
Age (years)	70.93 $\pm$ 3.81	70.39 $\pm$ 3.90
Sex (M/F)	17 / 26	16 / 28
Weight (kg)	62.59 $\pm$ 11.91	63.96 $\pm$ 10.78
Height (cm)	158.34 $\pm$ 8.55	160.16 $\pm$ 8.40
ASA class (II/III)	35 / 8	39 / 5
Hypertension (Y/N)	28 / 15	26 / 18
DM (Y/N)	11 / 32	10 / 34
CVA (Y/N)	6 / 37	3 / 41
Values are either the mean $\pm$ SD or the number of patients. Group D: PCA drugs were divided into both chambers. Group C: PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber. There was no significant difference between the two groups. ASA class: American Society of Anesthesiologists physical status classification. DM: diabetes mellitus. CVA: cerebrovascular accident.		

Table 2
Perioperative outcomes and recovery profiles

	Group D (n = 43)	Group C (n = 44)
Anesthetic time (min)	152.44 ± 63.34	169.09 ± 90.85
Operation time (min)	104.49 ± 55.60	117.02 ± 81.43
Transfusion (Y/N)	0 / 43	1 / 43
Colloid use (Y/N)	0 / 43	1 / 43
Total fluid (mL)	741.63 ± 381.31	902.16 ± 638.94
Blood loss (mL)	118.14 ± 84.30	156.82 ± 152.82
Urine output (mL)	200.81 ± 207.26	251.93 ± 314.15
PARS in PACU at 1 hr	9.91 ± 0.29	9.89 ± 0.32
RASS in PACU at 1 hr	-0.09 ± 0.29	-0.09 ± 0.29
CAM-ICU in PACU at 1 hr (positive/negative)	4 / 39	4 / 40
Fentanyl bolus in PACU (mg)	56.51 ± 48.62	69.77 ± 54.25
The number of fentanyl bolus in PACU	0.95 ± 0.79 17.67 ± 23.99*	1.11 ± 0.84 29.55 ± 30.95
Nefopam as rescue analgesics in the ward (mg)	4.14 ± 0.83	4.02 ± 1.00
Patient satisfaction on POD 1	4.44 ± 0.70*	4.00 ± 0.99
Patient satisfaction on POD 2		
Values are mean ± SD or number of patients. *p < 0.05 compared to the group C. Group D: PCA drugs were divided into both chambers. Group C: PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber. There was no significant difference between the two groups. PARS: modified Aldrete post-anesthesia recovery score. PACU: post-anesthesia care unit. RASS: Richmond agitation and sedation scale. CAM-ICU: confusion assessment method for the ICU. POD: postoperative day		

Group D showed a significantly lower pain score at 6 hours after arrival of PACU compared to the group C ($p < 0.001$). However, multivariate analysis did not reveal any significant differences in the changes of pain intensity between the two groups ($p = 0.081$) (Fig. 2). Even there were no differences in total fentanyl consumption, the amount of fentanyl administered as bolus were not same at all the time points between the two groups ($p = 0.315$, < 0.001 , respectively) (Fig. 3).

The amounts of fentanyl administered as bolus during postoperative 1-6, 6-12, and 12-24 hours were much lower in the group D compared to the group C (Fig. 3). Patient satisfactions were much higher in the group D compared to the group C (Table 2).

At postoperative day 2, PONV incidence decreased compared to operation day in group D (20.9% on operation day to 4.7% at postoperative day 2, $p=0.049$), but not in group C (18.2% on operation day to 18.2% at postoperative day 2). There were no significant differences for other complications (Table 3).

Table 3
Postoperative complications

	Group D (n = 43)	Group C (n = 44)
	Operation day / Postoperative day 1 / Postoperative day 2	Operation day / Postoperative day 1 / Postoperative day 2
Nausea/vomiting	9 / 8 / 2 [†]	8 / 9 / 8
Dizziness	2 / 4 / 2	2 / 4 / 5
Dry mouth	12 / 6 / 6	9 / 5 / 4
Desaturation ($<95\%$)	5 / 0 / 0	2 / 0 / 0
Profound hypotension	1 / 0 / 0	2 / 0 / 0
Profound hypertension	0 / 0 / 0	1 / 0 / 0
Chest discomfort	1 / 0 / 0	0 / 0 / 0
Shivering	2 / 0 / 0	0 / 0 / 0
Dysuria	0 / 0 / 1	1 / 0 / 0
Sleep apnea	1 / 0 / 0	0 / 0 / 0
Sweating	0 / 0 / 0	0 / 1 / 1
Constipation	0 / 0 / 1	0 / 0 / 0
Values are number of patients. [†] $p < 0.05$ compared to operation day. Group D: PCA drugs were divided into both chambers. Group C: PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber.		

Discussion

In this study, we suggested the usefulness of dual-chamber IV-PCA with a feedback control infusion rate. There were significant decreases in the amount of fentanyl bolus and rescue analgesic with higher patient satisfaction when the dual channels of PCA are both activated.

Postoperative pain can be classified into musculoskeletal, visceral and persistent post-surgical pain. In the case of acute pain, the primary afferent nociceptors A-delta and C fiber plays an important role [9].

Under acute pain, the process of depolarization of A-delta and C fiber nociceptor, which called transduction, are developed. Nociceptive input to dorsal horn also increases a sympathetic activity in spinal cord and sympathetic ganglia. Mostly, the threshold of pain is stimulus-specific and reproducible both in different individual and in the same individuals at different times. However, the mechanisms of postoperative pain are more complex. Repetitive nociceptive stimuli may lead to central sensitization [10]. The sensitization and primary hyperalgesia occur as a decreased in the threshold for pain. Pain tolerance is also dependent upon the psychological factors as well as the stimulus itself. These made it difficult to set the endpoint of pain control.

A concept of minimum effective analgesic concentration (MEAC) may help to establish a strategy for pain management. MEAC explains the phenomenon that pain decreases dramatically at specific point as a result of administering the drug in small increments [11]. Considering the existence of inter- and intra-individual difference, the MEAC cannot be determined from the plasma concentration of opioids [12]. Consequently, titration of drugs should be performed individually to find MEAC. It is also necessary to maintain a constant plasma concentration with avoiding too high or low levels. Considering these characteristics, IV-PCA seemed better than IM injection or pro re nata (prn) bolus.

Next step was to select the drugs and the dose for IV-PCA. There were many references to determine the ideal IV-PCA regimen [13, 14]. In this study, we used fentanyl in IV-PCA. For its rapid onset and short duration of action, fentanyl is preferred than morphine in IV-PCA [4]. Shin et al [4] presented lower background infusion rate, younger age and absence of adjuvant analgesics as independent risk factors for rescue analgesic administration. Contrary, higher background infusion rate, female gender and absence of 5HT₃ receptor blocker were the independent risk factors for rescue antiemetics administration. Higher background infusion rate may affect increased daily opioid consumption, and consequently may increase the incidence of adverse effects. On the other hand, higher background infusion rate did not always lead to better pain relief and improved sleep patterns [15]. Shin et al [4] recommended a proper background infusion rate of fentanyl ranging from 0.12 to 0.67 mcg/kg/hr. In our regimen, background infusion rates of fentanyl were calculated as 0.4 mcg/kg/hr for group C and 0.26, 0.4 or 0.54 mcg/kg/hr for group D, which were within their recommendation range.

Lee et al [8] applied variable-rate feedback infusion in IV-PCA. They suggested pain management through change of background infusion rate according to the patient's pain level and needs would be more efficient with lower dosages of analgesics. Their study had an important influence on the design of our study. They showed variable-rate feedback infusion provided significant decreases in number of bolus and volume delivered in PCA. In our study, our methods also produced decreases in the amount of fentanyl bolus even there was no difference in the total fentanyl consumption. Rather than pressing the bolus button because of extreme pain, we assumed that maintaining a certain level of the required drug concentration through variable rate control in advance would have beneficial effects on pain control or patient satisfaction [16].

We also assumed that as the pain intensity steeply decreased, adverse effects including PONV and dizziness may become troublesome. To reduce PONV, we mixed ramosetron in PCA and used prn palonosetron in PACU with considering their pharmacokinetic properties [17]. Looking at our results, PONV difference was occurred two day after the surgery. We thought adjustment of PCA infusion rate may reduce unnecessary opioid infusion. Also, in Lee's study [8], the PONV risk was reduced 33 to 18% during whole period. Even mild PONV may cause longer length of stay in the hospital, lower patient satisfaction, and more medical cost [18]. From the anesthesiologist's point of view, many side effects on the day after surgery may be easily overlooked. However, these side effects have a great influence on the patients' recovery [19].

It is natural that efficient pain control and lack of side-effects induce higher patient satisfaction. Chumbley et al [20] identified three factors - having better pain relief, not worrying about 'giving oneself too much drug' and not experiencing feeling 'peculiar in the head' - that make the patient feel positive about PCA. To add to the explanation, dizziness, hallucinations and nightmares are within 'peculiar in the head'. Although the incidence of dizziness was not sufficient to show the difference between the two groups, it was clear that the satisfaction level was falling among the patients who complained of dizziness (data not shown).

Another thing we focused on this study was the occurrence of delirium because old age and inadequate pain control was known as factors of delirium [21]. 8 cases were reported as positive CAM-ICU in PACU transiently. However, there was no case about delirium during the follow-up period of up to 7 days since the day after operation. This was thought to be because most of the patients were relatively healthy and there were few cases of massive bleeding during surgery. In high-risk patients, there may be different consequences, so further studies are required.

There were other limitations. We did not consider adjuvant analgesics in the PCA although we usually use the combination of fentanyl, hydromorphone, ketorolac or nefopam. When we designed this study, we chose the simplest regimen to avoid ambiguous interpretation. However, to fully utilize our dual channel, it was likely that additional experiments with a combination of several drugs will be required. That is, this experiment alone was not enough to show all the usefulness of dual channel PCA pump. In addition, because we simply target the pain score as the feedback, there was no discrimination of opioid tolerance or opioid induced hyperalgesia. In this case, it might have been better to use other analgesic instead of opioid. We used nefopam as a rescue medication in ward. A previous study [22] reported a 20 mg of nefopam is equal to 12 mg of morphine. We could have converted 1 mg of nefopam to 6 mcg of fentanyl, but we excluded the use of nefopam when calculating the total amount of fentanyl used because of drug interaction potential [23].

Nevertheless, this study introduced the successful application of new developmental form of IV-PCA. Considering there were few studies have used dual chamber PCA, our regimen would be helpful to the clinicians in application of similar type of PCA. By applying dual-chamber PCA, the lost advantages by giving up the electronic PCA can be re-applied to some extent in elastomeric pump again without giving

up the simplicity. Our findings will make a significant impact on the development of the PCA device, which has been stagnant for many years. The efforts to improve postoperative pain control would be meaningful as long as there exist uncomfortable patients.

Conclusions

In conclusion, this study introduced a clinical application of new form of IV-PCA in geriatrics. Dual chamber IV-PCA by changing the flow rate to the pain feedback provided efficient analgesia, reducing PONV and high patient satisfaction without severe complication.

Abbreviations

ASA class: American Society of Anesthesiologists physical status classification, BIS: bispectral index, CAM-ICU: Confusion Assessment Method for the Intensive Care Unit, IV-PCA: intravenous patient-controlled analgesia, MEAC: minimum effective analgesic concentration, PACU: post-anesthesia care unit, PARS: modified Aldrete post-anesthesia recovery score, PONV: postoperative nausea/vomiting, RASS: Richmond Agitation and Sedation Scale, RM-ANOVA: Repeated measures analyses of variance, TOF: train-of-four, VAS: visual analogue scale

Declarations

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Availability of data and materials

The datasets generated and analyzed in this study are available in the UMIN-ICDR Case data repository, [https://upload.umin.ac.jp/cgi-bin/icdr_e/ctr_dl_his_list.cgi?recptno=R000045281].

Authors' contributions

CHL assisted with data analysis and drafting of the manuscript. SAC assisted with data collection and positioning of our findings in clinically-relevant context. SKO assisted with data collection and analysis and revisioning of the manuscript. SSC and MHK assisted with study design, data analysis and revisioning of the manuscript. YSK assisted with study design, data interpretation and revisioning of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable, no individual data was reported.

Ethics approval and consent to participate

The study was approved by Korea University Medical Center Guro Hospital Institutional Review Board (K2019-0952-003), and all subjects provided written informed consent prior to enrollment.

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Figures

Figure 1

A schematic of the dual chamber IV-PCA regimen. This figure shows compositions of the dual chamber IV-PCA device and our regimen. The IV-PCA consists of two channels: a basal-bolus channel with a fixed flow rate infusion and a bolus function and the other selector channel with adjustable flow rate without bolus function. Group D: PCA drugs were divided into both chambers. Group C: PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber.

Figure 2

Changes in pain scores in the postoperative periods. There were no significant effects on the pain score observed between the two groups ($p=0.081$, multivariate analysis). Only at 6 hours after arrival of PACU, pain score in group D was lower than group C ($p<0.001$). Group D: PCA drugs were divided into both chambers. Group C: PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber.

Figure 3

Changes in fentanyl consumption in the postoperative periods. A. total fentanyl consumption. There were no differences in total fentanyl consumption ($p=0.315$, multivariate analysis). B. fentanyl consumption via bolus. fentanyl consumption used as boluses were different between the two groups ($p<0.001$, multivariate analysis). The amounts of fentanyl administered as bolus during postoperative 1-6, 6-12, and 12-24 hours were significantly lower in the group D compared to the group C. Group D: PCA drugs were divided into both chambers. Group C: PCA drugs were contained only in the constant flow chamber, but normal saline was contained in the adjustable flow chamber.

Supplementary Files

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- [Appendix.jpg](#)
- [OS2chPCAconsort2010checklist.doc](#)