Obesity Surgery (2022) 32:3368–3374
https://doi.org/10.1007/s11695-022-05894-4

ORIGINAL CONTRIBUTIONS

# Effect of Dexmedetomidine Compared to Remifentanil During Bariatric Surgery on Postoperative Nausea and Vomiting: a Retrospective Study

Sun Woo Nam[1] · Ah-Young Oh[1,2] · Bon-Wook Koo[1] · Bo Young Kim[1] · Jiwon Han[1] · Jiwon Yoon[1]

Received: 15 September 2021 / Revised: 31 December 2021 / Accepted: 11 January 2022 / Published online: 17 August 2022
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2022

## Abstract

**Purpose** Postoperative nausea and vomiting (PONV) occurs frequently after bariatric surgery and is a major cause of adverse outcomes. This retrospective study investigated whether opioid-restricted total intravenous anesthesia using dexmedetomidine as a substitute for remifentanil can reduce PONV in bariatric surgery.

**Materials and Methods** The electronic medical records of adult patients who underwent laparoscopic bariatric surgery between January and December 2019 were reviewed. The patients were divided into two groups according to the agents used for anesthesia: Group D, propofol and dexmedetomidine; Group R, propofol and remifentanil.

**Results** A total of 134 patients were included in the analyses. The frequency of postoperative nausea was significantly lower in Group D than that in Group R until 2 h after discharge from the postanesthesia care unit (PACU) ($P=0.005$ in the PACU, $P=0.010$ at 2 h after PACU discharge) but failed to significantly reduce the overall high incidence rates of 60.5% and 65.5%, respectively ($P=0.592$). Postoperative pain score was significantly lower in Group D until 6 h after PACU discharge. The rates of rescue antiemetic and analgesic agent administration in the PACU were significantly lower in Group D than those in Group R.

**Conclusion** Opioid-restricted total intravenous anesthesia using dexmedetomidine reduces postoperative nausea, pain score, antiemetic, and analgesic requirements in the immediate postoperative period after bariatric surgery.

**Keywords** Bariatric surgery · Dexmedetomidine · Postoperative nausea and vomiting

## Introduction

In the Asian population, obesity-related cardiovascular mortality and morbidity are more frequent and occur at a lower body mass index (BMI), compared to the non-Asian populations. Therefore, surgical treatment of obesity is increasingly being incorporated into clinical guidelines and public health policy in many Asian countries [1]. In the Republic of Korea, bariatric and metabolic surgeries have been covered by the national health insurance system since January 2019, which led to an increase in the number of bariatric surgeries from 139 to 2529 per year between 2003 and 2019. A recent report from Korea showed significantly higher cost-effectiveness of bariatric and metabolic surgeries compared to that of non-surgical treatment of obesity [2]. With the increasing demand for and accessibility of bariatric surgery, clinical management of obese patients has become a major area of focus.

**Key Points**
- The incidence of postoperative nausea following bariatric surgery is very high.
- Opioid-restricted anesthesia using dexmedetomidine reduces postoperative nausea.
- Opioid-restricted anesthesia using dexmedetomidine reduces postoperative pain score.

✉ Ah-Young Oh
ohahyoung@hanmail.net

[1] Department of Anesthesiology and Pain Medicine, Seoul National University Bundang Hospital, 13620, Gumi-ro 137-82, Bundang-gu, Seongnam-si, Gyeonggi-do, Republic of Korea

[2] Department of Anesthesiology and Pain Medicine, Seoul National University College of Medicine, Seoul, Republic of Korea

The incidence of postoperative nausea and vomiting (PONV) is higher after bariatric surgery than that after other surgeries, including non-bariatric gastric surgery; thus, it is a major factor associated with adverse outcomes [3, 4]. For example, PONV is the most common cause of readmission after bariatric surgery, increases medical costs, delays recovery and dietary progression, and can cause a number of complications, including dehydration, malnutrition, wound complications, and even anastomosis rupture [5, 6].

Opioid reduction using various non-opioid adjuncts, including dexmedetomidine, is a commonly recommended method of PONV prophylaxis, along with total intravenous anesthesia (TIVA) [7]. Dexmedetomidine, an alpha-2 adrenergic agonist, is a non-narcotic agent that has anesthetic and analgesic properties with a low rate of respiratory depression. As an advanced form of opioid reduction, it has recently been highlighted that opioid-restricted anesthetic regimens using dexmedetomidine reduce PONV and provide better postoperative pain control [8, 9]. The use of dexmedetomidine during bariatric surgery is associated with reduced intraoperative volatile anesthetic requirement, perioperative opioid use, and postoperative pain scores. However, studies have shown conflicting results regarding the effects on PONV and recovery time [10–13].

This retrospective study investigated whether an opioid-restricted total intravenous anesthetic regimen using dexmedetomidine as a substitute for remifentanil can reduce PONV in bariatric surgery.

## Materials and Methods

### Study Design

The Institutional Review Board of Seoul National University Bundang Hospital approved this retrospective, observational single-center study and waived the requirement for written informed consent because of the retrospective nature of the study.

The electronic medical records of patients who underwent elective laparoscopic bariatric surgery between January 2019 and December 2019 were reviewed. Inclusion criteria were patients aged 19–75 years who received propofol-based total intravenous anesthesia, including either dexmedetomidine or remifentanil. Exclusion criteria were patients who received inhalation anesthetics during surgery, who did not use patient-controlled analgesia (PCA) devices after surgery, who were transferred to the intensive care unit (ICU) due to problems during surgery or recovery, and who underwent reoperation due to surgical complications during the hospital stay after surgery.

### Anesthetic Protocol

The patients were divided into two groups according to the agents used for anesthesia: Group D, propofol and dexmedetomidine; Group R, propofol and remifentanil. In Group D, anesthesia was induced with 1–2-mg/kg propofol and dexmedetomidine loading at a dose of 0.5 μg/kg for 5–10 min. To alleviate hemodynamic changes caused by endotracheal intubation, a single dose of 0–1000-μg alfentanil was administered. Anesthesia was maintained with continuous infusion of propofol (6–12 mg/kg/h) and continuous infusion of dexmedetomidine (0.1–0.6 μg/kg/h), without any additional opioids. In Group R, anesthesia induction and maintenance were achieved by continuous infusion of propofol (6–12 mg/kg/h) and target-controlled infusion (TCI; Minto model) of remifentanil.

In both groups, 0.6–1.2-mg/kg rocuronium was administered for endotracheal intubation, and 50 mg/kg of magnesium sulfate was loaded over 10 min. After completion of magnesium sulfate loading, it was infused continuously at a rate of 15 mg/kg/h. Dexamethasone (5 mg) and ketorolac (30 mg) were given after the induction of anesthesia as components of multimodal analgesia. Local anesthetic was not infiltrated into the incision site. At the end of surgery, sugammadex or a combination of neostigmine and glycopyrrolate was administered based on the results of train-of-four (TOF) monitoring. Patient-controlled analgesia (PCA) was composed of a mixture of fentanyl (1500–2000 μg) and normal saline in a total volume of 100 mL. Ramosetron (0.3 mg) was given when the PCA device was connected.

### Postoperative Protocol

Patients recovered their oral diet starting with sips of water at postoperative day (POD) 1, a soft fluid diet (SFD) at POD 2, and were discharged on POD 3 if there were no adverse events. From the day of surgery, 40-mg pantoprazole was administered once a day parenterally or orally depending on the patient's diet status. A dose of 0.075-mg palonosetron was administered parenterally on POD 1. After the patients started SFD, tramadol (37.5 mg)/acetaminophen (325 mg) and Beszyme (a mixture of 30-mg bromelain, 40-mg dimethicone, and 400-mg pancreatin) were administered orally three times a day.

### Data Acquisition

Nausea, vomiting, postoperative pain score (expressed on an 11-point numerical rating scale [NRS]), administration of rescue antiemetic, and pain medication were investigated

in the postanesthesia care unit (PACU) and at 2 h, 2–6 h, 6–24 h, and 24–48 h after PACU discharge.

### Statistical Analysis

The primary outcome was the incidence of nausea in the postoperative period. The secondary outcomes were incidence of vomiting, rescue antiemetic administration, postoperative pain score, and rescue pain medication administration. The groups were compared using Student's *t* test or the Mann–Whitney U test for continuous variables and $\chi^2$ test or Fisher's exact test for categorical variables, with SPSS 25.0 software for Windows (SPSS Inc., Chicago, IL, USA). In all analyses, $P < 0.05$ was taken to indicate statistical significance.

**Table 1** Patient characteristics

| | Group D ($n=76$) | Group R ($n=58$) | *P*-value |
|---|---|---|---|
| Age (years) | 40.1 (11.5) | 37.1 (10.1) | 0.126 |
| Sex (male/female) | 28/48 | 17/41 | 0.360 |
| Height (cm) | 167.0 (8.7) | 165.1 (8.3) | 0.943 |
| Weight (kg) | 107.7 (18.6) | 105.3 (18.9) | 0.681 |
| BMI ($kg{\cdot}m^{-2}$) | 38.4 (5.0) | 38.5 (5.6) | 0.378 |
| ASA physical status (II/III) | 38/38 | 32/26 | 0.553 |
| Hypertension | 40 | 25 | 0.274 |
| Diabetes | 28 | 16 | 0.258 |
| Smoking (no/yes) | 54/22 | 39/19 | 0.635 |

Continuous values are shown as the mean (SD). Categorical variables are expressed as number of patients. *ASA*, American Society of Anesthesiologists. *BMI*, body mass index

## Results

A total of 140 patients who underwent laparoscopic bariatric surgery under propofol-based total intravenous anesthesia during the target period were identified. Four patients were excluded from the analysis because they were transferred to the ICU postoperatively. One patient who underwent bleeding control surgery in the immediate postoperative period and one patient who refused to use the PCA device were also excluded. Therefore, the final analysis was performed in 134 patients, consisting of 76 patients in Group D and 58 patients in Group R. No patients was given both dexmedetomidine and remifentanil (Fig. 1).

There was no significant differences in patient characteristics between the two groups (Table 1). Of the risk factors included in the simplified Apfel score, previous history of PONV or motion sickness could not be identified in the records of most patients, but one patient in Group D mentioned a history of PONV in the preanesthetic evaluation.

Table 2 shows the surgery and recovery characteristics of the two groups. The type of bariatric surgery performed at our institution is divided into two basic categories: sleeve gastrectomy and intestinal bypass, including duodenojejunal bypass, Roux-en-Y gastric bypass, or biliopancreatic diversion. There was no differences between the two groups in the composition of surgery type, surgery, or recovery time.

Table 3 shows the number of patients with PONV and rescue antiemetics during each time interval. Significantly fewer patients in Group D had nausea and needed antiemetic medication in the PACU and for 2 h following discharge. After 2 h, there was no differences between the two groups.

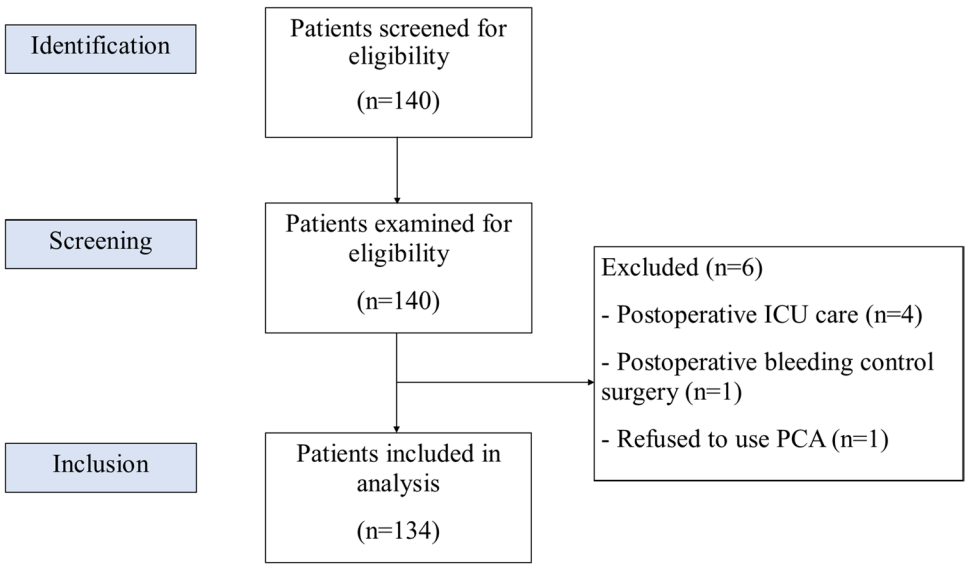


**Fig. 1** STROBE flow diagram. ICU, intensive care unit. PCA, patient-controlled analgesia

**Table 2** Surgery and recovery characteristics

| | Group D ($n=76$) | Group R ($n=58$) | *P*-value |
|---|---|---|---|
| Type of surgery (SG/IB) | 65/11 | 49/9 | 0.867 |
| Duration of surgery (min) | 105.0 (95.0–123.8) | 105.0 (83.8–120.0) | 0.369 |
| Duration of anesthesia (min) | 145.0 (135.0–170.0) | 147.5 (123.8–170.0) | 0.428 |
| Duration of PACU stay (min) | 33.0 (27.3–42.3) | 35.0 (29.8–43.5) | 0.319 |
| Postoperative hospital stay (days) | 3.0 (3.0–3.0) | 3.0 (3.0–3.0) | 0.516 |

Continuous values are shown as the median (25th–75th percentile). Categorical variables are expressed as number of patients. *IB*, intestinal bypass; *PACU*, postanesthesia care unit; *SG*, sleeve gastrectomy

The overall incidence of vomiting was low and showed no difference between groups throughout the whole period.

Table 4 shows the maximum and average pain scores over time. Both maximum and average pain scores were significantly low in the PACU and at 2 h and 2–6 h after PACU discharge in Group D. There was no differences between the two groups after 6 h. In addition, the number of patients requiring rescue pain medication and antiemetic agent was significantly lower in the PACU in Group D. There was no differences between the groups after PACU discharge, but the difference in PACU led to an overall reduction in number of patients requiring rescue pain medication in Group D.

**Table 3** Incidence of postoperative nausea, vomiting, and antiemetic administration

| | Group D ($n=76$) | Group R ($n=58$) | *P*-value |
|---|---|---|---|
| Nausea | | | |
| PACU | 2 (2.6%) | 10 (17.2%) | 0.005 |
| PACU–2 h | 5 (6.6%) | 13 (22.4%) | 0.010 |
| 2–6 h | 16 (21.1%) | 16 (27.6%) | 0.418 |
| 6–24 h | 37 (48.7%) | 26 (44.8%) | 0.658 |
| 24–48 h | 21 (27.6%) | 21 (36.2%) | 0.348 |
| Overall | 46 (60.5%) | 38 (65.5%) | 0.592 |
| Vomiting | | | |
| PACU | 1 (1.3%) | 3 (5.2%) | 0.316 |
| PACU–2 h | 0 (0.0%) | 2 (3.4%) | 0.186 |
| 2–6 h | 3 (3.9%) | 4 (6.9%) | 0.466 |
| 6–24 h | 9 (11.8%) | 5 (8.6%) | 0.546 |
| 24–48 h | 4 (5.3%) | 2 (3.4%) | 0.698 |
| Overall | 14 (18.4%) | 10 (17.2%) | 1.000 |
| Incidence of antiemetic administration | | | |
| PACU | 2 (2.6%) | 7 (12.1%) | 0.040 |
| PACU–2 h | 4 (5.3%) | 9 (15.5%) | 0.075 |
| 2–6 h | 12 (15.8%) | 9 (15.5%) | 1.000 |
| 6–24 h | 29 (38.2%) | 15 (25.9%) | 0.133 |
| 24–48 h | 12 (15.8%) | 8 (13.8%) | 0.811 |
| Overall | 37 (48.7%) | 27 (46.6%) | 0.862 |

Values are presented as number of patients (%). *PACU*, postanesthesia care unit

## Discussion

We found that PONV and pain after bariatric surgery can be reduced through opioid-restricted TIVA using dexmedetomidine compared to opioid-included TIVA using remifentanil. Some conflicting evidence has been reported regarding the benefits of opioid-free anesthesia in bariatric surgery in various anesthetic settings. For example, it seems that the use of dexmedetomidine as an adjunct to volatile anesthetics reduces PONV, antiemetic requirement, postoperative pain, and rescue pain medication requirement compared to that of remifentanil or fentanyl [10, 12]. In the case of intravenous anesthesia, Ziemann-Gimmel reported that opioid-free TIVA reduced

**Table 4** Postoperative pain scores (11-point NRS) and incidence of rescue analgesic administration

| | Group D ($n=76$) | Group R ($n=58$) | *P*-value |
|---|---|---|---|
| Maximum NRS | | | |
| PACU | 5.2 (2.4) | 6.9 (1.4) | < 0.001 |
| PACU–2 h | 3.7 (1.1) | 4.4 (1.5) | 0.003 |
| 2–6 h | 3.6 (1.2) | 4.3 (1.5) | 0.009 |
| 6–24 h | 4.3 (1.5) | 4.0 (1.4) | 0.267 |
| 24–48 h | 3.6 (1.2) | 3.7 (1.3) | 0.623 |
| Mean NRS | | | |
| PACU | 3.8 (1.6) | 5.1 (1.2) | < 0.001 |
| PACU–2 h | 3.5 (0.9) | 4.0 (0.9) | 0.010 |
| 2–6 h | 3.4 (0.8) | 3.8 (1.1) | 0.004 |
| 6–24 h | 3.4 (0.6) | 3.4 (0.6) | 0.967 |
| 24–48 h | 3.0 (0.4) | 3.1 (0.5) | 0.698 |
| Incidence of analgesic administration | | | |
| PACU | 49 (64.5%) | 55 (94.8%) | < 0.001 |
| PACU–2 h | 17 (22.4%) | 21 (36.2%) | 0.078 |
| 2–6 h | 15 (19.7%) | 17 (29.3%) | 0.244 |
| 6–24 h | 39 (51.3%) | 21 (36.2%) | 0.081 |
| 24–48 h | 17 (22.4%) | 13 (22.4%) | 0.995 |
| Overall | 63 (82.9%) | 57 (98.3%) | 0.004 |

NRS values are shown as the mean (SD). Incidence of analgesic administration is expressed as number of patients (%). *NRS*, numerical rating scale

the incidence and severity of PONV assessed in the morning on POD 1 [13]. By contrast, another study showed that TIVA with propofol and dexmedetomidine reduced opioid requirement in the PACU but did not reduce the incidence of PONV [11]. However, in these two studies, opioid-free TIVA was compared to anesthesia using volatile-based opioids. This could be a major confounding factor because TIVA is a known prophylactic measure for PONV compared to volatile anesthesia. By contrast, in the present study, TIVA was used in both groups, allowing us to assess the effects of opioid-free anesthesia without such confounding factors.

In our study, dexmedetomidine was used for intraoperative analgesia as a substitute for remifentanil. Therefore, the PONV-reducing effect in the opioid-restricted anesthesia group can be explained by two factors: exclusion of remifentanil and addition of dexmedetomidine. Remifentanil is an ultra-short–acting μ-opioid receptor agonist with a consistently short context-sensitive half-life. This trait has raised questions regarding whether intraoperative remifentanil administration induces PONV similar to other opioid analgesics. Some studies have suggested that intraoperative remifentanil does not increase PONV or result in a lower incidence of PONV compared to fentanyl [14–17] or alfentanil [18–22]. It has also been reported that remifentanil increases PONV in a dose-dependent manner [23]. On the other hand, the PONV-reducing effects of dexmedetomidine can be mainly explained by the indirect effects of sparing opioid and inhaled anesthetic agents, although some groups have suggested that α-2 agonists may directly contribute to PONV reduction by decreasing catecholamine levels and sympathetic tone [24, 25]. Our results support the suggestion that replacement of remifentanil with dexmedetomidine could be beneficial in populations at high risk for PONV, at least during the immediate postoperative period.

In Group D, a possible confounding factor was the use of a bolus dose of alfentanil to alleviate intubation stimulation; therefore, the anesthetic regimen was not completely opioid-free. However, alfentanil was administered as a single dose only during induction. In addition, alfentanil has very low potency compared to remifentanil (1:20–1:30) [26]. Considering the terminal elimination half-life of alfentanil of 111 min and average anesthesia time in Group D of 145 min, it was highly unlikely that alfentanil influenced the incidence of PONV [27]. However, alfentanil could be replaced by bolus doses of other drugs, such as propofol, to achieve opioid-free anesthesia in future studies.

By subdividing the evaluation time, we examined when PONV occurred most frequently in bariatric surgery and for how long it can be affected by the anesthetic management. About 60% of the patients developed PONV within 0–24 h, and the incidence decreased by half within 24–48 h but was still high at around 30%. The PONV-reducing effect lasted for up to 2 h after PACU discharge but failed to significantly affect the overall incidence. This seemed to have been largely because the opioid-restricted protocol was only applied intraoperatively, which allowed administration of opioid analgesics without limitation after patients had entered the PACU.

Overall, a very high incidence of PONV was observed in both groups, even after triple prophylaxis with dexamethasone, ramosetron, and total intravenous anesthesia. This is consistent with previous studies indicating that bariatric surgical patients are not only susceptible to PONV but also appear to be less responsive to traditional PONV prophylaxis using TIVA or antiemetic agents [3, 4, 28, 29]. The estimated causes of the high incidence of PONV after bariatric surgery can be divided into patient factors and surgical factors. First, high-risk patients, such as women and younger patients, account for a large proportion of patients undergoing bariatric surgery [30]. Second, in addition to laparoscopic surgery being a known risk factor for PONV, many surgical factors can also cause PONV [31]. Biochemically, it has been suggested that intraoperative gastric manipulation triggers emesis by stimulating the enterochromaffin cells of the stomach to secrete 5-hydroxytryptamine [5, 28, 32]. Surgical injuries to the stomach and gastric vagal afferent branches can decrease gastric motility [5, 33]. Furthermore, bariatric surgery is a restrictive surgery that reduces gastric volume and increases intragastric pressure, which can also contribute to PONV after commencement of oral diet [6]. With regard to specific categories of bariatric surgery, sleeve gastrectomy has a higher incidence of PONV than Roux-en-Y gastric bypass, which can be explained by delayed gastric emptying depending on whether the pylorus is preserved [5, 29]. In this study, the proportion of patients undergoing sleeve gastrectomy was large, which may have contributed to the observed high incidence of PONV.

The pain score significantly decreased until 6 h after PACU discharge in Group D. The significant reduction of pain score immediately after surgery may have been attributable to the analgesic effects of dexmedetomidine itself and prevention of opioid-induced hyperalgesia through exclusion of remifentanil. The incidence of rescue analgesic requirement was significantly decreased in the PACU (from about 95 to 65%), which led to a significant reduction in overall incidence. However, rescue analgesic agents were eventually administered in 90% of all patients despite use of intravenous fentanyl PCA, which raises the question of whether the postoperative pain control was appropriate. Bolus-only PCAs were used in all except three patients in Group D and one patient in Group R to reduce the side effects of continuous infusion of opioids. Nevertheless, a significant number of patients turned off their PCA devices intermittently due to PONV, which led to use of other types of rescue pain control, mainly consisting of opioid analgesics. This implies

that the management of PONV and effective pain control are interactive.

Our findings suggest that a multidisciplinary approach to pain control while reducing PONV not only in the operating room, but also in the postoperative period, is essential in this patient group. Pain control by combination or replacement of regimens using non-opioid analgesic agents, and other multimodal analgesic measures, such as transversus abdominis plane (TAP) block and epidural analgesia could be applied. As not only anesthetic components but also the characteristics of the surgical procedure and diet resumption can contribute to PONV, more intense and prolonged antiemetic regimens should be included in the postoperative care protocols.

This study had some limitations. First, because of the retrospective nature of the study, some information that could have been helpful in interpreting the results could not be obtained, such as the severity of PONV, the patients' previous history of PONV or motion sickness, and the dose of fentanyl PCA used during each time interval. Second, as PONV was detected by a review of the medical records, the incidence may have been underestimated. However, in cases of undocumented PONV, it is possible that it may have been minor and did not cause serious discomfort to the patient or require treatment.

## Conclusions

Opioid-restricted total intravenous anesthesia using dexmedetomidine reduces PONV, pain score, and rescue antiemetic and analgesic requirements in the immediate postoperative period after bariatric surgery.

**Author Contribution** The authors have contributed equally to this work.

## Declarations

**Ethics Approval** All procedures in this study were performed in accordance with the ethical standards of the institutional and/or national research committee, the 1964 Declaration of Helsinki and its later amendments, and/or comparable ethical standards.

**Consent to Participate** Informed consent does not apply.

**Conflict of Interest** The authors declare no competing interests.

## References


1. Ohta M, Seki Y, Wong SKH, et al. Bariatric/metabolic surgery in the Asia-Pacific region: APMBSS 2018 Survey. Obes Surg. 2019;29(2):534–41. https://doi.org/10.1007/s11695-018-3539-7.
2. An SN, Park HY, Oh SH, et al. Cost-effectiveness of bariatric surgery for people with morbid obesity in South Korea. Obes Surg. 2020;30(1):256–66. https://doi.org/10.1007/s11695-019-04122-w.
3. Groene P, Eisenlohr J, Zeuzem C, et al. Postoperative nausea and vomiting in bariatric surgery in comparison to non-bariatric gastric surgery. Videosurg Miniinv. 2019;14(1):90–5. https://doi.org/10.5114/wiitm.2018.77629.
4. Halliday TA, Sundqvist J, Hultin M, et al. Post-operative nausea and vomiting in bariatric surgery patients: an observational study. Acta Anaesth Scand. 2017;61(5):471–9. https://doi.org/10.1111/aas.12884.
5. Suh S, Helm M, Kindel TL, et al. The impact of nausea on post-operative outcomes in bariatric surgery patients. Surg Endosc. 2020;34(7):3085–91. https://doi.org/10.1007/s00464-019-07058-5.
6. Pandolfino JE, Krishnamoorthy B, Lee TJ. Gastrointestinal complications of obesity surgery. MedGenMed. 2004;6(2):15.
7. Gan TJ, Belani KG, Bergese S, et al. Fourth consensus guidelines for the management of postoperative nausea and vomiting. Anesth Analg. 2020;131(2):411–48. https://doi.org/10.1213/Ane.0000000000004833.
8. Frauenknecht J, Kirkham KR, Jacot-Guillarmod A, et al. Analgesic impact of intra-operative opioids vs. opioid-free anaesthesia: a systematic review and meta-analysis. Anaesthesia. 2019;74(5):651–62. https://doi.org/10.1111/anae.14582.
9. Grape S, Kirkham KR, Frauenknecht J, et al. Intra-operative analgesia with remifentanil vs. dexmedetomidine: a systematic review and meta-analysis with trial sequential analysis. Anaesthesia. 2019;74(6):793–800. https://doi.org/10.1111/anae.14657.
10. Hamed JME, Refaat HSM, Al-Wadaani H. Dexmedetomidine compared to remifentanil infusion as adjuvant to sevoflurane anesthesia during laparoscopic sleeve gastrectomy. Anesth Essays Res. 2019;13(4):636–42. https://doi.org/10.4103/aer.AER_126_19.
11. Kruthiventi SC, Hofer RE, Warner ME, et al. Postoperative nausea and vomiting after bariatric surgery and dexmedetomidine anesthetic: a propensity-weighted analysis. Surg Obes Relat Dis. 2020;16(4):545–53. https://doi.org/10.1016/j.soard.2020.01.007.
12. Tufanogullari B, White PF, Peixoto MP, et al. Dexmedetomidine infusion during laparoscopic bariatric surgery: the effect on recovery outcome variables. Anesth Analg. 2008;106(6):1741–8. https://doi.org/10.1213/ane.0b013e318172c47c.
13. Ziemann-Gimmel P, Goldfarb AA, Koopman J, et al. Opioid-free total intravenous anaesthesia reduces postoperative nausea and vomiting in bariatric surgery beyond triple prophylaxis. Brit J Anaesth. 2014;112(5):906–11. https://doi.org/10.1093/bja/aet551.
14. Watanabe T, Moriya K, Tsubokawa N, Baba H. Effect of remifentanil on postoperative nausea and vomiting: a randomized pilot study. J Anesth. 2018;32(5):781–5. https://doi.org/10.1007/s00540-018-2550-4.
15. Oh AY, Kim JH, Hwang JW, et al. Incidence of postoperative nausea and vomiting after paediatric strabismus surgery with sevoflurane or remifentanil-sevoflurane. Br J Anaesth. 2010;104(6):756–60. https://doi.org/10.1093/bja/aeq091.
16. Rama-Maceiras P, Ferreira TA, Molins N, et al. Less postoperative nausea and vomiting after propofol plus remifentanil versus propofol plus fentanyl anaesthesia during plastic surgery. Acta Anaesth Scand. 2005;49(3):305–11. https://doi.org/10.1111/j.1399-6576.2005.00650.x.
17. Hara R, Hirota K, Sato M, et al. The impact of remifentanil on incidence and severity of postoperative nausea and vomiting in a university hospital-based ambulatory surgery center: a retrospective observation study. Korean J Anesthesiol. 2013;65(2):142–6. https://doi.org/10.4097/kjae.2013.65.2.142.
18. Apfel CC, Bacher A, Biedler A, et al. A factorial trial of six interventions for the prevention of postoperative nausea and vomiting. Results of the International Multicenter Protocol to

assess the single and combined benefits of antiemetic strategies in a controlled clinical trial of a 2x2x2x2x2x2 factorial design (IMPACT). Anaesthesist. 2005;54(3):201–9. https://doi.org/10.1007/s00101-005-0803-8.
19. Kars MS, Mori BV, Ahn S, et al. Fentanyl versus remifentanil-based TIVA for pediatric scoliosis repair: does it matter? Region Anesth Pain M. 2019;44(6):627–31. https://doi.org/10.1136/rapm-2018-100217.
20. Dershwitz M, Michalowski P, Chang YC, et al. Postoperative nausea and vomiting after total intravenous anesthesia with propofol and remifentanil or alfentanil: how important is the opioid? J Clin Anesth. 2002;14(4):275–8. https://doi.org/10.1016/S0952-8180(02)00353-7.
21. Del Gaudio A, Ciritella P, Perrotta F, et al. Remifentanil vs fentanyl with a target controlled propofol infusion in patients undergoing craniotomy for supratentorial lesions. Minerva Anestesiol. 2006;72(5):309–19.
22. Gaszynski TM, Strzelczyk JM, Gaszynski WP. Post-anesthesia recovery after infusion of propofol with remifentanil or alfentanil or fentanyl in morbidly obese patients. Obes Surg. 2004;14(4):498–503; discussion 4. https://doi.org/10.1381/096089204323013488.
23. Hozumi J, Egi M, Sugita S, Sato T. Dose of intraoperative remifentanil administration is independently associated with increase in the risk of postoperative nausea and vomiting in elective mastectomy under general anesthesia. J Clin Anesth. 2016;34:227–31. https://doi.org/10.1016/j.jclinane.2016.04.018.
24. Li SS, Liu TJ, Xia JM, Jia J, Li WX. Effect of dexmedetomidine on prevention of postoperative nausea and vomiting in pediatric strabismus surgery: a randomized controlled study. Bmc Ophthalmol. 2020;20(1):86. https://doi.org/10.1186/s12886-020-01359-3.
25. Song Y, Shim JK, Song JW, et al. Dexmedetomidine added to an opioid-based analgesic regimen for the prevention of postoperative nausea and vomiting in highly susceptible patients a randomised controlled trial. Eur J Anaesth. 2016;33(2):75–83. https://doi.org/10.1097/Eja.0000000000000327.
26. Egan TD, Minto CF, Hermann DJ, et al. Remifentanil versus alfentanil - comparative pharmacokinetics and pharmacodynamics in healthy adult male volunteers. Anesthesiology. 1996;84(4):821–33. https://doi.org/10.1097/00000542-199604000-00009.
27. Kapila A, Glass PSA, Jacobs JR, et al. Measured context-sensitive half-times of remifentanil and alfentanil. Anesthesiology. 1995;83(5):968–75. https://doi.org/10.1097/00000542-199511000-00009.
28. Bataille A, Letourneulx JF, Charmeau A, et al. Impact of a prophylactic combination of dexamethasone-ondansetron on postoperative nausea and vomiting in obese adult patients undergoing laparoscopic sleeve gastrectomy during closed-loop propofol-remifentanil anaesthesia: a randomised double-blind placebo-controlled study. Eur J Anaesth. 2016;33(12):898–905. https://doi.org/10.1097/Eja.0000000000000427.
29. Aftab H, Fagerland MW, Gondal G, et al. Pain and nausea after bariatric surgery with total intravenous anesthesia versus desflurane anesthesia: a double blind, randomized, controlled trial. Surg Obes Relat Dis. 2019;15(9):1505–12. https://doi.org/10.1016/j.soard.2019.05.010.
30. Apfel CC, Laara E, Koivuranta M, et al. A simplified risk score for predicting postoperative nausea and vomiting - conclusions from cross-validations between two centers. Anesthesiology. 1999;91(3):693–700. https://doi.org/10.1097/00000542-199909000-00022.
31. Apfel CC, Heidrich FM, Jukar-Rao S, et al. Evidence-based analysis of risk factors for postoperative nausea and vomiting. Br J Anaesth. 2012;109(5):742–53. https://doi.org/10.1093/bja/aes276.
32. Gan TJ. Mechanisms underlying postoperative nausea and vomiting and neurotransmitter receptor antagonist-based pharmacotherapy. CNS Drugs. 2007;21(10):813–33. https://doi.org/10.2165/00023210-200721100-00003.
33. Horn CC, Wallisch WJ, Homanics GE, et al. Pathophysiological and neurochemical mechanisms of postoperative nausea and vomiting. Eur J Pharmacol. 2014;722:55–66. https://doi.org/10.1016/j.ejphar.2013.10.037.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.