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Determinants of Early Pulmonary Function After Laparoscopic Sleeve Gastrectomy: Comparison of Epidural and Intravenous Analgesia

Esra Kongur

esrakongur@hotmail.com

Trabzon University, Kanuni Training and Research Hospital

Aydın Aktaş

Trabzon University, Kanuni Training and Research Hospital

Zübeyir Sivrikaya

Trabzon University, Kanuni Training and Research Hospital

Abdullah Özdemir

Trabzon University, Kanuni Training and Research Hospital

Ahmet Şen

Trabzon University, Kanuni Training and Research Hospital

Gülgün Elif Aksoy

Trabzon University, Kanuni Training and Research Hospital

Pınar Duman Aydın

Trabzon University, Kanuni Training and Research Hospital

Seyhan Sümeyra Aşçı

Trabzon University, Kanuni Training and Research Hospital

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Abstract

Background: This study aimed to compare the effects of epidural and intravenous analgesia on postoperative pulmonary function in patients undergoing laparoscopic sleeve gastrectomy (LSG), and to evaluate patient and perioperative factors determining early postoperative pulmonary function changes.

Methods: In this retrospective, observational study, a total of 106 patients who underwent laparoscopic sleeve gastrectomy (LSG) between January and October 2025 were evaluated. Patients were divided into two groups according to the analgesia method: in the epidural group (EA, n = 53), an epidural catheter was placed at the T7–T9 level, and an infusion of 0.125% bupivacaine with 1.25 µg/mL fentanyl was administered. In the intravenous group (IV, n = 53), postoperative tramadol-based intravenous patient-controlled analgesia (PCA) was administered following intraoperative remifentanil infusion. Pulmonary function tests were performed using spirometry in the preoperative period and at 24 hours postoperatively. The primary outcome of the study was defined as the change in forced expiratory volume in one second (ΔFEV1). The secondary outcomes were recorded as the change in forced vital capacity (ΔFVC), ΔFEV1/FVC, 24-hour postoperative pain scores, additional opioid consumption, and intraoperative ventilation pressures.

Results: Demographic and preoperative characteristics were found to be similar between the groups. No significant difference was found between the EA and IV analgesia groups in terms of the primary outcome, ΔFEV1 ($p = 0.285$). Similarly, no significant differences were found between the groups in terms of ΔFVC and ΔFEV1/FVC values ($p > 0.05$). In multivariate regression analysis, preoperative FEV1 ($p=0.003$) and body mass index (BMI) ($p=0.002$) were identified as independent predictors of ΔFEV1, while the method of analgesia had no significant effect ($p=0.627$). Intraoperative Ppeak (Peak Pressure)and Pplateau (Plateau Pressure) values were found to be higher in the IV analgesia group ($p <0.05$). Additionally, 24-hour postoperative Numeric Rating Scale (NRS) and additional opioid consumption were found to be higher in the EA group ($p <0.05$).

Conclusion: In patients undergoing LSG, EA did not demonstrate superiority over IV analgesia in terms of early postoperative pulmonary function. Patient-related factors, particularly preoperative FEV1 and BMI, were more determinant of postoperative changes in pulmonary function than the analgesia method.

Introduction

Obesity has become a global health problem and exerts adverse effects on multiple organ systems, particularly the respiratory and cardiovascular systems. Morbid obesity is defined as a body mass index (BMI) ≥ 40 kg/m², or a BMI ≥ 35 kg/m² in the presence of obesity-related comorbidities such as hypertension, diabetes, cardiovascular diseases, and hyperlipidemia (1). Bariatric surgery is one of the most effective treatments for morbid obesity, and laparoscopic sleeve gastrectomy (LSG) has become one of the most commonly performed surgical techniques in recent years (2). LSG not only provides significant and sustainable weight loss but also significant improvement in obesity-related comorbidities (3). Respiratory physiology in obese patients is characterized by decreased functional residual capacity,

increased airway resistance, and impaired lung compliance (4). These changes predispose patients in the postoperative period to the development of postoperative pulmonary complications (PPCs), such as atelectasis, hypoxemia, and pneumonia (4). Although laparoscopic surgery has been shown to be associated with lower rates of PPCs compared to open surgery, this risk is not completely eliminated in obese patients (5). Preoperative determination of patients' respiratory risk profiles is critical for preventing postoperative pulmonary complications and reducing postoperative respiratory morbidity (6). In this context, preoperative pulmonary assessment plays a key role in identifying high-risk patients and optimizing perioperative management strategies (6,7). Postoperative pain management also plays a critical role in preventing pulmonary complications. Inadequate analgesia increases the risk of pulmonary complications by causing shallow breathing, reduced cough reflex, and delayed mobilization (8). Epidural analgesia is a recommended method, particularly in high-risk surgical patients, due to its superior analgesic efficacy, its ability to reduce opioid consumption, and its beneficial effects on respiratory mechanics (9). In contrast, although intravenous analgesia is more commonly used, side effects related to systemic opioids, such as respiratory depression and sedation, may increase the risk of pulmonary complications (10).

In bariatric surgery patients, the literature on analgesic methods predominantly focuses on postoperative pain control and opioid consumption; however, the effects of these methods on postoperative pulmonary function remain relatively underexplored (4,11). In particular, data on the comparative effects of epidural and intravenous analgesia on pulmonary function in patients undergoing LSG are limited. Therefore, this study aimed to compare the effects of epidural and intravenous analgesia on postoperative pulmonary function in patients undergoing LSG. It has been hypothesized that epidural analgesia will better preserve postoperative lung function and reduce pulmonary complications compared to intravenous analgesia. In addition, this study aimed not only to compare epidural and intravenous analgesia methods but also to evaluate patient-related and perioperative factors determining early postoperative changes in pulmonary function in patients undergoing laparoscopic sleeve gastrectomy. This approach aims to contribute to identifying the key determinants affecting postoperative respiratory function beyond the choice of analgesia method.

Methods

Study Design and Ethical Approval

This study was conducted as a retrospective, observational comparison of two groups. Ethical approval was obtained from the Non-Interventional Scientific Research Ethics Committee of our institution (Decision No: 2025/25038; November 3, 2025). Study data were obtained through retrospective review of the medical records of patients who underwent LSG at our institution between January and October 2025. The study was conducted in accordance with the protocol approved by the ethics committee, and only the presentation of the results was restructured during manuscript preparation. The study was performed in accordance with the ethical principles of the Declaration of Helsinki and complied with Good Clinical Practice guidelines.

Study Population

A total of 106 patients were included in the study, with 53 patients in each group. The inclusion criteria were as follows: age between 18 and 65 years; ASA physical status III; availability of both preoperative and postoperative pulmonary function tests (PFTs); arterial blood gas analysis performed; and receipt of postoperative epidural or intravenous patient-controlled analgesia (PCA). The exclusion criteria were defined as follows: ASA physical status IV; age < 18 or > 65 years; presence of chronic lung diseases such as COPD, asthma, or interstitial lung disease; active smoking within the last 6 months; oxygen saturation < 90%; significant restrictive or obstructive pattern on preoperative pulmonary function tests; diagnosis of obstructive sleep apnea syndrome; conversion to open surgery; need for re-intubation or intensive care in the postoperative period; development of complications due to additional systemic diseases; and incomplete data.

Patients were divided into two groups according to the analgesia method applied: the Epidural Analgesia Group (EA) and the Intravenous Analgesia Group (IV). In the EA group, following placement of the epidural catheter at the T7–T8 or T8–T9 intervertebral space, an epidural bolus of 8 mL of 0.125% bupivacaine was administered. Following anesthesia induction, it was determined that a solution containing 0.125% bupivacaine and 1.25 µg/mL fentanyl was administered for epidural PCA as a continuous infusion at a rate of 5 mL/hour during both the intraoperative and postoperative periods, with an additional 3 mL bolus dose available every 30 minutes as needed.

In the IV group, it was recorded that a remifentanil infusion (0.05–0.3 µg/kg/min) was initiated following anesthesia induction and titrated according to the hemodynamic response during the intraoperative period. It was determined that 100 mg tramadol and 1000 mg paracetamol were administered intravenously approximately 30 minutes before the completion of surgery. Postoperative analgesia was provided using intravenous PCA containing tramadol. It was recorded that a solution containing tramadol at a concentration of 5 mg/mL was used for PCA, with the device set to deliver a 10 mg bolus dose and a 20-minute lockout interval; the continuous infusion rate was adjusted to 5–10 mg/hour. It was determined that the maximum daily tramadol dose was limited to 400 mg, and the maximum dose allowed within a 6-hour period was restricted to 100 mg.

In cases of inadequate analgesia, it was observed that intravenous tramadol, pethidine, paracetamol, or nonsteroidal anti-inflammatory drugs were administered as rescue analgesia in both groups. It was determined that the doses of additional analgesics administered and the total opioid consumption over 24 hours were recorded.

Anesthesia and Mechanical Ventilation Management

It was recorded that standard general anesthesia was administered to all patients. It was noted that intravenous midazolam (0.02 mg/kg) was administered prior to anesthesia induction. It was observed that anesthesia induction was performed using propofol (2 mg/kg, based on lean body weight), fentanyl

(1 μg/kg), and rocuronium (0.6 mg/kg, based on ideal body weight). It was noted that intravenous lidocaine (1 mg/kg) was administered to attenuate the intubation response. Anesthesia maintenance was achieved using sevoflurane inhalation (approximately 2% end-tidal concentration) in a mixture of 50% oxygen and 50% air.

It was observed that anesthesia depth was monitored using bispectral index (BIS) monitoring and maintained between 40 and 60. Neuromuscular blockade was monitored using train-of-four (TOF) monitoring.

It was determined that mechanical ventilation was applied in volume-controlled mode, with the PEEP value set at 5 cmH_2O in all patients. It was observed that intra-abdominal pressure was standardized at 15 mmHg for pneumoperitoneum during laparoscopic surgery. It was recorded that tidal volume and respiratory rate were adjusted to maintain normocapnia. It was determined that Ppeak and Pplateau values were recorded at specific intraoperative time points (at 1, 5, 10, 15, 30, and 60 minutes).

Data Collection and Study Outcomes

Study data were retrospectively obtained from hospital records and patient follow-up forms. Demographic variables, including age, sex, body mass index (BMI), and American Society of Anesthesiologists (ASA) score, were recorded. Pulmonary function parameters, including FEV1 and FVC values measured preoperatively and at 24 hours postoperatively, as well as the FEV1/FVC ratio, were evaluated. To assess postoperative change, ΔFEV1 was calculated as the directional difference between postoperative (24-hour) and preoperative FEV1 values (postoperative – preoperative), expressed as % predicted values.

Ppeak and Pplateau values were recorded as part of intraoperative mechanical ventilation parameters. Postoperative pain intensity at 24 hours was assessed using the 11-point Numeric Rating Scale (NRS) based on patient records, where 0 indicates “no pain” and 10 indicates “worst imaginable pain.” Additional opioid requirements within the first 24 hours were recorded. Additional opioid consumption (tramadol and pethidine) was converted to morphine milligram equivalents (MME) using a fixed conversion ratio (1:10). Arterial PaO_2 values were not included in the statistical analysis, as they were not obtained under standardized conditions.

The primary outcome was ΔFEV1, reflecting early postoperative changes in pulmonary function. Secondary outcomes included ΔFVC, ΔFEV1/FVC, the 24-hour postoperative Numeric Rating Scale (NRS) score, additional opioid requirement within the first 24 hours, and intraoperative Ppeak and Pplateau values measured at the 30th minute. For the evaluation of intraoperative ventilatory parameters, 30-minute values were used, as they reflect a more stable period after pneumoperitoneum and minimize the influence of early fluctuations following induction.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA).

The normality of continuous variables was assessed using the Shapiro–Wilk test and visual inspection of histogram plots. Normally distributed data were expressed as mean ± standard deviation (SD), whereas non-normally distributed data were presented as median (interquartile range, IQR). Comparisons between two independent groups were performed using the independent samples t-test for normally distributed data and the Mann–Whitney U test for non-normally distributed data. Categorical variables were presented as number (n) and percentage (%), and were compared using the Pearson chi-square test. Fisher's exact test was used when the expected cell count was less than 5.

Multivariable linear regression analysis was performed to identify independent variables associated with ΔFEV1. Age, BMI, duration of surgery, analgesia group (epidural vs. intravenous), and preoperative FEV1 were included in the model. To account for potential baseline differences between groups, preoperative pulmonary function parameters were included as covariates. Due to the potential risk of multicollinearity between preoperative FEV1 and the FEV1/FVC ratio, these variables were not included in the same model. The primary model included preoperative FEV1 as a measure of baseline pulmonary function. Additionally, a separate model including the FEV1/FVC ratio was constructed for sensitivity analysis. A p-value < 0.05 was considered statistically significant.

Results

A total of 106 patients were included in the study, with 53 patients in each group.

Table 1
Baseline Demographic and Preoperative Characteristics

Variable	Epidural (n = 53)	Intravenous (n = 53)	p
Age (years)	35.89 ± 11.31	36.17 ± 12.13	0.901
BMI (kg/m²)	47.15 ± 5.58	47.99 ± 6.48	0.475
Operation duration (min)	65.09 ± 15.45	63.02 ± 11.32	0.432
Female sex, n (%)	45 (84.9%)	43 (81.1%)	0.605
FEV1 (% predicted, preoperative)	92.60 ± 14.11	88.75 ± 14.64	0.171
FVC (% predicted, preoperative)	86.13 ± 17.68	80.66 ± 13.91	0.080
FEV1/FVC (% predicted, preoperative)	110.83 ± 7.70	115.40 ± 5.92	**0.001**

Values are presented as mean ± standard deviation or number (%). Continuous variables were compared using the Student's t-test. Categorical variables were compared using the chi-square test. A p-value < 0.05 was considered statistically significant.

No statistically significant differences were found between the groups in terms of age, sex distribution, BMI, and duration of surgery ($p > 0.05$). All patients were classified as ASA III.

No significant differences were found between the groups in terms of preoperative FEV1 and FVC values ($p > 0.05$). However, the preoperative FEV1/FVC ratio was significantly higher in the IV group compared to the epidural group ($p = 0.001$).

Table 2
Postoperative Pulmonary Function Outcomes

Parameter	Epidural (n = 53)	IV (n = 53)	p
ΔFEV1 (% predicted change)	-22 (-39.5 to -12)	-21(-29 to -11)	0.285
ΔFVC (% predicted change)	-22 (-37 to -12)	-18 (-24.5 to -10)	0.157
ΔFEV1/FVC (% predicted change)	0 (4 to -5)	-1 (-6.5 to 3)	0.342

Values are presented as median (Q1–Q3). The Mann–Whitney U test was used.

No significant difference was found between the epidural and intravenous analgesia groups in terms of the primary outcome, postoperative change in FEV1 (ΔFEV1) ($p = 0.285$).

When secondary respiratory outcomes were evaluated, no significant differences were found between the groups in terms of postoperative changes in FVC and FEV1/FVC ($p = 0.157$ and $p = 0.342$, respectively).

Table 3
Multivariable Linear Regression Analysis of Factors Associated with ΔFEV1

Variable	Model 1	p	Model 2	p
Preoperative FEV1 (% predicted)	-0.339 (− 0.557 to − 0.120)	**0.003**	—	—
Preoperative FEV1/FVC (% predicted)	—	—	-0.116 (− 0.593 to 0.362)	0.632
BMI (kg/m²)	0.836 (0.314 to 1.358)	**0.002**	0.886 (0.341 to 1.430)	**0.002**
Analgesia method (Epidural vs IV)	1.542 (− 4.732 to 7.816)	0.627	3.393 (− 3.450 to 10.237)	0.328
Age (years)	0.054 (− 0.214 to 0.322)	0.693	0.064 (− 0.218 to 0.346)	0.653
Operation duration (min)	0.063 (− 0.169 to 0.296)	0.590	0.094 (− 0.148 to 0.336)	0.443

Values are presented as unstandardized regression coefficients (B) with 95% confidence intervals. Model 1 included preoperative FEV1, Model 2 included preoperative FEV1/FVC in place of FEV1. (Model 1: $R^2 = 0.194$, Adjusted $R^2 = 0.154$, $F(5,100) = 4.826$, $p = 0.001$, Model 2: $R^2 = 0.120$, Adjusted $R^2 = 0.076$, $F(5,100) = 2.729$, $p = 0.024$)

In the multivariable linear regression analysis constructed to evaluate independent predictors of ΔFEV1 (including age, BMI, duration of surgery, analgesia method, and preoperative FEV1), the overall model was statistically significant (Model 1) ($F(5,100) = 4.826$, $p = 0.001$) and explained 19.4% of the variance in ΔFEV1 ($R^2 = 0.194$; adjusted $R^2 = 0.154$). In this model, preoperative FEV1 was independently and negatively associated with ΔFEV1 (i.e., patients with higher preoperative FEV1 exhibited a greater postoperative decline in FEV1) (β = −0.339, 95% CI: −0.557 to − 0.120, $p = 0.003$). BMI was identified as an independent predictor with a positive association (i.e., as BMI increased, the postoperative decline in FEV1 was less pronounced) (β = 0.836, 95% CI: 0.314 to 1.358, $p = 0.002$). Analgesia method, age, and duration of surgery were not independently associated with ΔFEV1 ($p > 0.05$).

Due to the potential risk of multicollinearity between preoperative FEV1 and the FEV1/FVC ratio, these two variables were not included in the same model. The alternative model including the FEV1/FVC ratio instead of preoperative FEV1 was also statistically significant (Model 2) ($F(5,100) = 2.729$, $p = 0.024$), but had lower explanatory power ($R^2 = 0.120$; adjusted $R^2 = 0.076$). In this model, the FEV1/FVC ratio was not independently associated with ΔFEV1 (β = −0.116, 95% CI: −0.593 to 0.362, $p = 0.632$), and BMI remained the only independent predictor ($p = 0.002$). The primary model demonstrated higher explanatory power compared to the alternative model.

Table 4
Pain and opioid outcomes

Outcome	Epidural	IV	p
Postoperative 24-hour NRS	2 (2–3)	2 (1–2)	**0.002**
24-hour Additional Opioid Consumption (mg morphine equivalents)	20 (6,5–30)	5 (0–11)	**0.001**

Values are presented as median (Q1–Q3). Mann–Whitney U test was used. Additional opioid consumption was converted to morphine milligram equivalents (MME).

The NRS score measured at postoperative 24 hours was significantly higher in the epidural group compared to the IV group (p = 0.002). Additionally, the additional opioid requirement within the first 24 hours was significantly higher in the epidural group than in the IV group (p = 0.001).

Table 5
Intraoperative Ventilatory Parameters

Parameter (30th min)	Epidural (n = 53)	IV (n = 53)	p
Ppeak (cmH_2O)	29 (28–30)	30 (30–32)	**0.001**
Pplateau (cmH_2O)	28 (27–30)	30 (28–30)	**0.012**

Values are presented as median (Q1–Q3). Mann–Whitney U test was used.

When intraoperative ventilation parameters were analyzed, Ppeak and Pplateau values measured at the 30th minute after pneumoperitoneum were significantly higher in the IV group compared to the epidural group (p = 0.001 and p = 0.012, respectively).

Discussion

In this study, the effects of epidural and intravenous analgesia on postoperative pulmonary function were evaluated in patients undergoing laparoscopic sleeve gastrectomy. The main finding of the study is that the analgesic method has no significant effect on the postoperative change in FEV1. In contrast, preoperative FEV1 and BMI were identified as independent predictors of postoperative changes in FEV1. These findings suggest that changes in respiratory function in the early postoperative period are not solely dependent on the analgesic method used, and that patient characteristics and baseline pulmonary function may play a more determining role.

The absence of significant differences between the groups in terms of demographic characteristics and baseline clinical variables supports the comparability of the results. However, the preoperative FEV1/FVC ratio was found to be significantly higher in the intravenous group. Despite this, multivariable analysis showed that this parameter was not independently associated with the postoperative decline in FEV1. Recent studies have reported that, in non-pulmonary surgeries, preoperative spirometric parameters—

particularly FEV1 and the FEV1/FVC ratio—have limited value in predicting postoperative respiratory outcomes, and this association is often not found to be statistically significant (12). This suggests that an obstructive pattern may not have a determining effect on changes in pulmonary function in the early postoperative period.

Although epidural analgesia is expected to provide better pain control and improve respiratory mechanics by preserving diaphragmatic function, no significant difference in ΔFEV1 was found between the epidural and intravenous analgesia groups. It has been shown that changes in pulmonary function in the early postoperative period depend not only on patient characteristics but also on the type of surgery and perioperative management strategies (5,7). Although recent studies have reported that epidural analgesia improves postoperative pulmonary function and oxygenation in certain patient groups, this effect appears to be limited particularly in minimally invasive surgeries and does not always result in clinically significant differences (13). Additionally, the standardization of intraoperative ventilation strategies and the relatively short duration of surgeries may have prevented differences between the groups from becoming apparent.

In the study, BMI was consistently identified as an independent predictor in both the main model, which included preoperative FEV1, and the alternative model, which included the FEV1/FVC ratio. This finding indicates that the relationship is independent of other respiratory parameters in the model and that BMI is a strong and reliable determinant of ΔFEV1. Studies conducted in the bariatric surgery population have shown that changes in pulmonary function are heterogeneous; while some studies report increases in FEV1 and FVC, no significant change in the FEV1/FVC ratio has been observed (14,15). In our multivariable analysis, preoperative FEV1 was identified as the strongest independent predictor of postoperative changes in FEV1 ($p < 0.005$), which is fully consistent with risk prediction models reported in the literature (12). As emphasized by Tuna and Akgün (6), preoperative spirometric measurements are an integral component of standard assessment algorithms used to predict postoperative respiratory performance and the risk of PPCs. These findings demonstrate that baseline pulmonary function is a primary factor in determining the extent of postoperative functional decline in obese patients undergoing bariatric surgery. In addition, the identification of BMI as a significant predictor further supports the association between obesity and respiratory complications. The 'J-shaped' risk model described by Wang et al. (16) and Qin et al. (17) shows that the effect of BMI increase on postoperative pulmonary complications is not linear, and the risk increases exponentially after a certain threshold. This finding provides a scientific basis for why preoperative pulmonary function may play a more critical protective role in patients with higher BMI in our study. It has also been reported that the relationship between BMI and postoperative pulmonary outcomes is not always linear and may be attenuated, particularly in homogeneous surgical populations (17,18). Additionally, it has been suggested that, due to reduced functional residual capacity in obese patients, the magnitude of absolute postoperative changes may be limited, which may in turn influence early postoperative changes in pulmonary function (19). In this context, the unexpected relationship observed between BMI and ΔFEV1 in our study may be explained by both patient selection and the use of ΔFEV1 as an absolute change parameter.

In our study, the finding that BMI was a strong independent predictor of ΔFEV1 (p = 0.002) is consistent with the phenomenon discussed in the literature as the “obesity paradox,” which suggests that certain postoperative clinical outcomes may unexpectedly be more favorable in patients with higher BMI values (20,21). In obese patients, decreased chest wall compliance, increased intra-abdominal pressure, and the resulting chronic restrictive changes keep the baseline functional capacity of the lungs at an already reduced level (4). In this bariatric surgery population, low preoperative pulmonary reserves may result in mathematically smaller postoperative respiratory losses; this can be explained by the “floor effect,” where changes appear smaller than they actually are due to already low baseline values (17,18). Current data supporting this argument were also presented by Wang et al. (16). These studies emphasize that the relationship between BMI and the risk of postoperative pulmonary complications follows a “J-shaped” pattern (16,17). According to this model, patients who are overweight or have class I obesity may exhibit a lower risk profile for postoperative pulmonary complications compared to those who are of normal weight or morbidly obese (16). Taken together, these findings suggest that, in bariatric surgery patients, patient-related factors should be prioritized over the choice of analgesic technique when interpreting postoperative pulmonary outcomes.

One of the most notable findings of the study is that preoperative FEV1 was independently and negatively associated with the change in postoperative FEV1. This finding indicates that patients with better baseline pulmonary function experience a greater postoperative decline, suggesting that initial lung reserve plays a crucial role in determining postoperative respiratory outcomes. The literature also reports that preoperative pulmonary function—particularly FEV1—is one of the key determinants of postoperative pulmonary outcomes, and that lower preoperative FEV1 values are associated with an increased risk of pulmonary complications (12,22). However, when absolute change is considered, it has also been reported that patients with higher baseline FEV1 values may exhibit a more pronounced decline in FEV1 (23). In contrast, some patients with lower baseline FEV1 values may even demonstrate an increase in FEV1 during the postoperative period (23). This may explain why a greater measurable decline is observed in patients with higher baseline FEV1 values.

In this study, the finding that postoperative 24-hour NRS scores and additional opioid requirements were higher in the epidural analgesia group compared to the intravenous group suggests that the expected superior analgesic efficacy of epidural analgesia was not demonstrated in this patient population. This unexpected finding may be explained by potential technical variability in epidural catheter placement and the limited benefit of epidural analgesia in minimally invasive bariatric surgery. Moreover, objective confirmation of epidural block adequacy (e.g., dermatomal sensory level assessment) was not systematically documented, which may have contributed to suboptimal analgesic efficacy. Current Enhanced Recovery After Surgery (ERAS) recommendations for bariatric surgery indicate that routine use of epidural analgesia—particularly in laparoscopic procedures—is not necessary, and that less invasive analgesic techniques may provide comparable efficacy (11). As highlighted by Kumar et al. (24), thoracic epidural failure may result from multifactorial causes such as anatomical variations, technical difficulties, equipment-related issues, or catheter misplacement and migration, thereby increasing the incidence of inadequate analgesia. Reports in the literature indicating that primary failure rates of

thoracic epidural analgesia may exceed 20% provide a plausible clinical explanation for the higher pain scores and increased opioid requirements observed in the epidural group in our study (24,25). These findings support that, in the bariatric surgery population, factors such as the technical precision required for epidural catheter placement and inadequate block spread may reduce analgesic efficacy to suboptimal levels. The literature reports that the analgesic superiority of epidural analgesia over intravenous PCA is limited and clinically variable, particularly in laparoscopic procedures (11,25,26). In our study, the observation of higher pain scores and increased opioid requirements in the epidural group may be interpreted as a concrete reflection of this variability reported in the literature; this finding may be explained by the relatively high technical failure rates of thoracic epidural procedures—reported to exceed 20%—as well as anatomical challenges related to catheter placement (24,25).

When intraoperative ventilation parameters were evaluated, Ppeak and Pplateau values were found to be lower in the epidural analgesia group compared to the intravenous group. This finding may be explained by the improvement in respiratory mechanics resulting from reduced abdominal muscle tone and increased chest wall compliance with thoracic epidural block. Indeed, recent studies have demonstrated that thoracic epidural anesthesia may have beneficial effects on intraoperative respiratory mechanics and can improve ventilatory parameters, particularly driving pressure (27). However, this improvement may not always translate into postoperative pulmonary function or clinical outcomes; indeed, the protective effect of epidural analgesia on pulmonary complications appears to be more pronounced in thoracic and major open abdominal surgeries (e.g., esophagectomy), where surgical trauma and the risk of pulmonary morbidity are substantially higher, rather than in laparoscopic abdominal approaches such as in our study (28). This observation appears consistent with our findings, in which no significant difference in postoperative pulmonary function was detected despite improvements in intraoperative ventilation parameters.

The retrospective design of this study and the 24-hour postoperative follow-up period limited the ability to systematically capture clinical pulmonary complications such as atelectasis, pneumonia, or hypoxemia. Additionally, the fact that not all blood gas analyses were based on arterial samples made it difficult to directly assess arterial oxygenation values. Given these limitations, rather than directly comparing the incidence of postoperative pulmonary complications, our study focused on objective physiological parameters such as pulmonary function tests (FEV1, FVC) for evaluation. While the importance of perioperative strategies in preventing postoperative pulmonary complications is emphasized in the literature, early changes in respiratory function are recognized as important early warning indicators for predicting the development of clinical complications (7). In this context, the clinical strength of our study lies in objectively demonstrating the early effects of different analgesic techniques on postoperative pulmonary function and in providing insights into mechanisms that may influence the development of longer-term complications.

Strengths and Limitations of the Study

Among the strengths of this study is the evaluation of a homogeneous surgical population (ASA III patients undergoing laparoscopic sleeve gastrectomy) and the use of standardized anesthesia and mechanical ventilation strategies in all patients. This approach allowed for a clearer assessment of the effects of the analgesic techniques. Furthermore, the use of an objective parameter such as ΔFEV1 to assess respiratory function, along with the application of multivariable analysis, strengthens the study.This study has several important limitations. First, the retrospective and single-center design limits the ability to establish causal relationships and reduces generalizability. Due to the retrospective nature of the study, patients could not be randomized according to analgesic technique, which may have introduced potential selection bias. Second, technical variables that could directly affect the clinical efficacy of epidural analgesia—such as the vertebral level of epidural catheter placement, the technique used, and the experience of the anesthesia team performing the procedure—could not be controlled. The literature reports that primary failure or suboptimal efficacy of thoracic epidural analgesia may largely be attributed to such technical variations and clinician-related factors (25). The lack of standardization of these technical parameters is an important factor that should be considered when interpreting the results of respiratory function and pain scores between the analgesia groups.

Conclusion

In conclusion, in patients undergoing laparoscopic sleeve gastrectomy, epidural analgesia did not demonstrate superiority over intravenous analgesia in terms of either preservation of pulmonary function or analgesic efficacy. Multivariable analysis findings revealed that patient-related factors, particularly preoperative FEV1 and BMI, rather than the choice of analgesic technique, were the main determinants of postoperative changes in pulmonary function. These findings suggest that patient-related factors may play a more important role than the choice of analgesic technique in determining early postoperative pulmonary outcomes. However, prospective, randomized studies are needed to confirm these findings.

Abbreviations

ASA
American Society of Anesthesiologists
BMI
Body Mass Index
EA
Epidural Analgesia
FEV1
Forced Expiratory Volume in 1 second
FVC
Forced Vital Capacity
IV
Intravenous
LSG

Laparoscopic Sleeve Gastrectomy
NRS
Numeric Rating Scale
PCA
Patient–Controlled Analgesia
Ppeak
Peak Airway Pressure
Pplateau
Plateau Pressure
MME
Morphine Milligram Equivalent

Declarations

Acknowledgments: The authors would like to thank the staff of the study center for their contributions to data collection and patient care.

AI Statement: The authors used an AI-assisted language tool to improve the clarity and readability of the manuscript. All scientific content, analysis, and conclusions were developed by the authors.

Author Contributions: All authors contributed substantially to the study. One author designed the study, developed the methodology, performed the statistical analyses, supervised the study, and wrote the manuscript. Another author contributed to the study design, coordinated project management, validated the analyses and data integrity, and reviewed the manuscript. One author contributed to data collection, prepared the visualizations, and reviewed the manuscript. Several authors contributed to data collection and reviewed the manuscript. All authors reviewed and approved the final version of the manuscript.

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Data Availability: All data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Ethics Statement: This study was approved by the local Non-Interventional Clinical Research Ethics Committee (Decision No: 2025/25038; Date: November 3, 2025). Due to the retrospective nature of the study, informed consent was not required. All data were anonymized prior to analysis. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Consent for Publication: Not applicable.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

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