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ORIGINAL ARTICLE

The Effect of Positive End-expiratory pressure (PEEP) on Postoperative Pulmonary Complications and Mortality in Major Abdominal Cancer Surgery

ABSTRACT

Objectives: Postoperative pulmonary complications (PPCs) significantly contribute to morbidity and mortality, particularly in patients undergoing major abdominal cancer surgery. Bronchospasm, atelectasis, pneumonia, and respiratory failure occur more frequently in cancer patients due to immunosuppression, reduced physiological reserves, and surgical complexity. Positive end-expiratory pressure (PEEP) is used during mechanical ventilation to reduce atelectasis and improve lung compliance; however, its effect on PPCs and mortality remains unclear. This study aims to investigate the relationship between PEEP levels, PPC occurrence, and their impact on mortality rates.

Methods: In this retrospective study, 410 patients who underwent major abdominal cancer surgery between January 2019 and December 2020 were analyzed. Patients were divided into two groups based on intraoperative PEEP levels: Group 1 (0-5 cm H2O PEEP) and Group 2 (6 cm H2O and above). Patient demographics, including age, sex, ASA scores, duration of surgery, body mass index (BMI), administered PEEP values, ARISCAT scores, as well as preoperative SpO2 and hemoglobin levels were documented, and their association with PPC was analyzed using appropriate statistical methods.

Results: The overall PPC rate was found to be 12%, with a significantly higher incidence in Group 2 (23%) compared to Group 1 (9%) ($p<0.05$). However, no significant difference in 30-day mortality was observed between the two groups ($p>0.05$). Additionally, co morbidities and preoperative pulmonary dysfunction were strongly associated with an increased risk of PPCs.

Conclusion: Although lung-protective strategies like low tidal volume and PEEP are commonly recommended, the findings indicate that higher PEEP levels might be linked to a higher incidence of PPCs, possibly due to hemodynamic instability. However, no definitive correlation between PEEP levels and mortality was observed. Individualized PEEP settings may be critical in minimizing the risk of PPCs and improving outcomes in major abdominal cancer surgeries.

Keywords: Mortality, patient outcomes, positive end-expiratory pressure (PEEP), postoperative pulmonary complications

Postoperative pulmonary complications (PPCs) refer to respiratory system issues that arise after surgical procedures. These complications are a major contributor to both morbidity and mortality, with incidence rates reported in the literature as high as 19% (1,2). PPC encompasses many conditions, including bronchospasm, atelectasis, exacerbations of chronic lung diseases, infections (such as bronchitis and pneumonia), prolonged mechanical ventilation, and respiratory failure. Major abdominal cancer surgeries are quite common, and the rate of PPC development in these patients is higher than in the general population. The primary reasons for this increased risk include the immunosuppressive effects of cancer and its treatment processes, decreased physiological reserves, and the lengthy and complication-prone nature of such operations.

Efforts to reduce the risk of postoperative pulmonary complications (PPC) typically begin in the preoperative period. PPC risk factors are examined under two main categories: Preoperative and intraoperative periods. Preoperative risk factors encompass elements related to medical history, including age, body weight, American Society of Anesthesiologists (ASA) status, functional dependency, hypoalbuminemia, chronic kidney disease, congestive heart failure, chronic obstructive pulmonary disease (COPD), asthma, interstitial lung disease, pulmonary hypertension, and obstructive sleep apnea (OSA) (3). Intraoperative risk factors encompass variables such as the type of surgical procedure, the length of the operation,

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ventilation settings, the volume of fluids administered, and postoperative pain management. These factors can result in unexpected admissions to the intensive care unit, extended hospital stays, and heightened morbidity and mortality rates.

Therefore, lung-protective ventilation during the perioperative period is critical for accelerating patient recovery and preventing pulmonary complications. Pulmonary protective ventilation, including intraoperative low tidal volume (6–8 mL/kg) and positive end-expiratory pressure (PEEP), has been found beneficial in all intubated patients under general anesthesia (4). Clinical studies have demonstrated that a PEEP level of 10 cm H_2O prevents atelectasis, increases compliance, and improves lung function without increasing alveolar dead space (5,6). However, the PEEP level should be adjusted according to the individual characteristics of each patient and the surgical context.

In this study, we analyzed the relationship between intraoperative PEEP values (0–5 cm H_2O and ⩾6 cm H_2O) and the development of postoperative pulmonary complications (PPC) and mortality in patients who underwent major abdominal cancer surgery.

METHODS

Following the approval of the ethics committee (2024-04/48), patients who underwent major abdominal cancer surgery under general anesthesia in the general operating room of SBU Dr. A.Y. Oncology Training and Research Hospital between January 2019 and December 2020 were retrospectively reviewed and included in the study. The patients' data were recorded by retrieving information from intraoperative anesthesia monitoring and postoperative follow-up forms. All patients were selected from those receiving lung-protective ventilation, with tidal volumes set between 5–7 mL/kg, ensuring a standardized approach to mechanical ventilation. Based on the applied PEEP values, the patients were divided into two groups: Group I consisted of patients who received 0–5 cm H_2O PEEP, while Group II comprised patients who received 6 cm H_2O or higher PEEP.

Inclusion Criteria

- Age 18 or older
- Undergoing major abdominal cancer surgery
- Planned to receive general anesthesia
- ASA (American Society of Anesthesiologists) physical status classification between 1 and 4
- Elective surgery

Exclusion Criteria and Data Collection

Patients with acute or chronic respiratory failure, patients who were intubated before surgery, those with severe cardiac disease, and hemodynamic instability were excluded from the study. The patients' age, gender, ASA scores, duration of surgery, body mass index (BMI), applied PEEP values, Ariscat scores, preoperative SpO_2, and hemoglobin levels were recorded from the anesthesia forms. Postoperative follow-up forms and computerized records were reviewed to collect data on postoperative pulmonary complications (PPCs) and 30-day mortality. PPCs were defined based on new findings occurring within the first five days after surgery. The European Perioperative Clinical Outcome Definitions (EPCO) were used as the basis for this definition (7). Respiratory failure, airway infections, aspiration pneumonia, pleural effusion, pneumothorax, atelectasis, bronchoconstriction, pneumonia, acute respiratory distress syndrome (ARDS), and pulmonary embolism were documented as postoperative pulmonary complications (PPCs).

Statistical Analysis

The data were analyzed using SPSS version 22. The normality distributions of the data were tested with the Kolmogorov-Smirnov and Shapiro-Wilk tests, after which appropriate analyses were conducted. The patients' demographic data were evaluated for similarity using the Mann-Whitney U and chi-square tests. Differences between the groups were investigated using the Student's t-test. The chi-square test (Fisher's exact test) was employed to assess significant differences between the groups, with a p-value of <0.05 considered to indicate statistical significance.

RESULTS

A total of 410 patients were included in the study based on a retrospective data review. The patients were categorized as 0–5 PEEP (Group 1, 320 patients) and PEEP ⩾6 (Group 2, 90 patients). There were no significant differences between the groups regarding age, gender, ASA scores, Ariscat scores, duration of surgery, preoperative SpO_2 values, or preoperative hemoglobin levels ($p>0.05$). A significant difference in body mass index (BMI) was observed between the groups ($p<0.05$), with 18% of patients in Group 2 having a BMI of 35 or above, compared to only 5% in Group 1 (Table 1).

Postoperative pulmonary complications within the first five days after surgery were recorded in 51 (12%) of 410 patients. A chi-square test was performed to examine the relationship between PEEP levels and the incidence of PPC. The analysis revealed a significant association between the patients' PEEP levels and the occurrence of PPC ($p<0.001$). Additionally, Cramer's V test results indicated a moderate correlation between the two variables ($r=0.375$, $p<0.001$). Based on frequency and percentage distributions, a higher incidence of PPCs was observed in the high PEEP group (23% compared to 9%) (Table 2).

The relationship between preoperative dyspnea and PPC showed strong significance, as well as a positive correlation between the two variables (Spearman rho=0.273, $p<0.05$) (Table 3). Additionally, a weak positive correlation was observed between comorbidities and PPC (Spearman rho=0.180, $p<0.05$) (Table 4). We found that patients with comorbidities developed PPC at a higher rate.

The analysis of postoperative pulmonary complications (PPC) in relation to the surgical technique (open vs. laparoscopic) and the levels of PEEP (0–5 cm H_2O vs. ⩾6 cm H_2O) revealed no statistically significant differences between the groups (Table 5, $p>0.05$). Specifically, among patients who underwent open surgery, PPCs occurred in 10% of those receiving low PEEP (0–5 cm H_2O), compared to 27% in the high PEEP group (⩾6 cm H_2O). Similarly, in laparoscopic surgeries, PPCs were observed in 7% of the low PEEP group and 15% in the high PEEP group.

The 30-day mortality rate in our patients was 3.4% (14 patients), with 64% of these patients in the low PEEP group and 36% in the PEEP ⩾6 group. However, no significant differences were identified between the two groups ($p>0.05$) (Table 6).

Table 1. Demographic data

n, (mean) (SS)	Group 1 (0-5 PEEP) (3) (1.3) n= 320	Group 2 (6 and above PEEP) (7) (0.4) n= 90	p
Age, mean (SD), years	60 (12)	61 (12)	0.789*
Gender, n (%)			
Male	177 (45)	48 (53)	0.739+
Female	143 (55)	42 (47)	
BMI, mean (%)			**0.000+**
0-20	35 (11)	7 (8)	
21-35	269 (84)	67 (74)	
>35	16 (5)	16 (18)	
ASA Score, n (%)			0.073+
1	12 (4)	1 (1)	
2	154 (48)	40 (40)	
3	143 (45)	45 (50)	
4	11 (3)	8 (9)	
Ariscat Score, mean (SS)	35 (15)	37 (14)	0.410*
Surgery Duration, n (%)			0.313+
<2 hours	37 (12)	8 (9)	
2-3 hours	185 (58)	47 (52)	
3 hours and over	98 (30)	35 (39)	
Preoperative SPO_2 (SS)	94 (3)	94 (3)	0.642*
Hemoglobin, mean (SS), g/dl	12.4 (2.2)	12.6 (2.1)	0.609*
Operation type, n (%)			0.821+
Open Surgery	220 (69)	63 (70)	
Laparoscopic	100 (31)	27 (30)	

*Mann-Whitney U; +Chi-square; n: number of patients, data presented as n (%) and mean (standard deviation); PEEP: Positive End-expiratory pressure; American Society of Anesthesiologists; BMI: Body mass index.

Table 2. Postoperative pulmonary complications rate between groups

			Grup 1 0-5 PEEP	Grup 2 PEEP≥6	Total	p
PPC	Yes	n (%)	30 (9)	21 (23)	51 (12)	0.001*
	No	n (%)	290 (91)	69 (77)	359 (88)	
Total		n (%)	320 (100)	90(100)	410 (100)	

*Chi-square; PEEP: Positive End-expiratory pressure; PPC: Postoperative pulmonary complications.

Table 3. Relationship between patients' pulmonary functions and postoperative pulmonary complications

	PPC		Total	p
	Yes	No		
No dyspnea, n (%)	31 (10)	293 (90)	324 (100)	0.000*
Dyspnea on Exertion, n (%)	16 (20)	64 (80)	80 (100)	
Dyspnea at rest, n (%)	2 (66)	1 (34)	3 (100)	
Dyspnea all the time, n (%)	2 (66)	1 (34)	3 (100)	
Total, n (%)	51 (14)	359 (86)	410 (100)	

* Fisher's exact test.

Table 4. Relationship between postoperative pulmonary complications and comorbidities

Comorbidities	PPC		Total	p
	Yes	No		
No ilness, n (%)	12 (7)	172 (93)	184	0.001*
Hypertension, n (%)	13 (14)	80 (86)	93	
Coronary Artery Disease, n (%)	3 (10)	26 (90)	29	
Asthma, n (%)	1 (5)	19 (95)	20	
Chronic Obstructive Pulmonary Disease, n (%)	11 (42)	15 (58)	26	
Diabetes, n (%)	9 (21)	34 (79)	43	
Kidney Disease, n (%)	0 (0)	2 (100)	2	
Psychological Disease, n (%)	0 (0)	3 (100)	3	
Neurological Disease, n (%)	2 (25)	6 (75)	8	
Hematological Disease, n (%)	0 (0)	2 (100)	2	
Total, n (%)	51 (12)	359 (88)	410	

*Chi-square

Table 5. Relationship between PPCs and surgical technique in patients with low PEEP (0-5) and high PEEP (≥6)

Operation Type	Low PEEP (0-5)				High PEEP (≥6)			
	PPC		Total	p	PPC		Total	p
	Yes	No			Yes	No		
Open, n (%)	23 (10)	197 (90)	220 (100)	**0.326***	17 (27)	46 (73)	63(100)	**0.211***
Laparoscopic, n (%)	7 (7)	93 (93)	100 (100)		4 (15)	23 (85)	27(100)	
Total, n (%)	30 (9)	290 (91)	320 (100)		21 (23)	69 (67)	90(100)	

*Chi-square; PEEP: Positive End-expiratory pressure; PPC: Postoperative pulmonary complications.

Table 6. Relationship between mortality and PEEP

Mortality	Grup 1 0-5 PEEP	Grup 2 PEEP≥6	Total	p
Yes, n (%)	9 (64)	5 (36)	14 (100)	0.172*
No, n (%)	311 (78)	85 (22)	396 (100)	
Total, n (%)	320 (78)	90 (22)	410 (100)	

*Fisher's exact test; PEEP: Positive End-expiratory pressure.

DISCUSSION

Postoperative pulmonary complications are undesirable events that occur more frequently than cardiac complications and significantly increase mortality and morbidity. Numerous studies have reported the incidence of PPC following cancer surgery to be between 20% and 69% (8–11). Our study includes a retrospective analysis of 410 patients who underwent major abdominal cancer surgery between 2019 and 2020. The overall incidence of PPC in our study was found to be 12%, with a higher occurrence of PPC in the high PEEP group (23% compared to 9%).

The assessment of mechanical ventilation strategies following general anesthesia is of paramount importance for anesthesiologists to minimize postoperative complications (12). Mechanical ventilation and general anesthesia under neuromuscular blockade can lead to changes in pulmonary physiology, reductions in lung volume, and atelectasis, resulting in impaired intraoperative pulmonary mechanics and gas exchange (13). The role of a protective intraoperative ventilation strategy is to maintain functional residual capacity (FRC) and to keep the patient's lungs open by adjusting appropriate tidal volume settings and optimal PEEP levels. In this study, a higher incidence of postoperative pulmonary complications (PPC) was observed in the group with elevated PEEP levels. Although low PEEP or inadequate PEEP is considered a risk factor for PPC, there are studies in the literature that report varying results regarding this issue (14,15).

Additionally, a separate study compared intermittent high PEEP with low PEEP and observed a significantly higher incidence of PPC in the low PEEP group (4). There are numerous conflicting studies in the literature on this topic. A large-scale randomized controlled double-blind trial found no significant difference in the rates of PPC between low and high PEEP groups within five postoperative days following open abdominal surgery under general anesthesia (15). Notably, two-thirds of the patient population in that study consisted of cancer patients. The results of this multicenter study, conducted with a group partially similar to ours, also indicated no significant relationship between PEEP levels and PPC in cancer patients.

Bluth et al. (14) found no significant difference in PPC between low and high PEEP in obese patients with a BMI of 35 or higher undergoing non-cardiac abdominal surgery. In our study, we found that

the occurrence of PPCs was more frequent in the high PEEP group than in the low PEEP group in obese patients with a BMI of 35 or higher. A meta-analysis involving approximately 4,000 patients also reported findings similar to ours, indicating a higher occurrence of PPC in the high PEEP group (16). These results may be attributed to the increased incidence of hypotension and the side effects associated with a greater use of vasoactive medications in the high PEEP group.

Our findings showed a significant relationship between preoperative dyspnea and postoperative pulmonary complications (PPC), with a positive correlation. This suggests that patients experiencing breathing difficulties before surgery are more likely to develop complications afterward. This is consistent with previous studies, which also highlight the risk posed by pre-existing respiratory issues. Patients with reduced lung function may struggle during recovery because their respiratory system is already compromised (17,18). This underlines how important it is to thoroughly assess a patient's breathing before surgery, especially for those undergoing major procedures like abdominal or thoracic surgery. By tailoring ventilation strategies to the patient's needs—such as adjusting PEEP levels—we can help reduce the risk of these complications and improve recovery outcomes (19,20).

The presence of comorbidities in patients is a significant risk factor for the development of PPC. In our study, a notable significance was found between PPC and comorbidities. It was observed that 77% of the patients who developed PPC had pre-existing comorbidities prior to the operation. Those with an ASA score of II or higher, or those diagnosed with chronic obstructive pulmonary disease (COPD), congestive heart failure, or chronic liver disease, are considered independent risk factors for PPC (21,22).

The selection of PEEP levels should be based on patient characteristics, surgical site, patient positioning, and hemodynamic status (23). In our study, the relationship between surgical technique and PPCs was examined separately for patients in the low and high PEEP groups; however, no significant results were found. In a meta-analysis conducted by Campos et al. (16), no association was found between PEEP levels and PPCs in patients undergoing open surgery, while high PEEP was associated with a reduced incidence of PPC only in patients undergoing laparoscopic surgery. The formation of atelectasis and ventilation/perfusion mismatch has been linked to impaired pulmonary function in patients undergoing laparoscopic surgery under general anesthesia. Additionally, during laparoscopy, the use of pneumoperitoneum with carbon dioxide can accelerate atelectasis development and decrease respiratory compliance, leading to postoperative pulmonary complications. Clinical studies indicate that PEEP plays a crucial role in reducing atelectasis, enhancing lung compliance, and maintaining end-expiratory lung volume (EELV) without increasing dead space. Although results in the literature predominantly indicate that higher PEEP levels are associated with a lower incidence of PPC, many studies support the opposite view. The arbitrary selection of PEEP levels in different patient populations and surgical types may contribute to the variability in these results (24).

Mortality is increased in both the short and long term in patients who develop a PPC (10). In our study, no significant relationship was found between the PEEP levels and 30-day mortality. Although there was no statistically significant difference, the 30-day mortality was half that in the high PEEP group. Similarly, a multicenter study yielded comparable results (4). Additionally, a meta-analysis also concluded that PEEP levels did not have a significant impact on mortality, aligning with our findings (25).

Hong et al. (26) demonstrated significantly increased bronchiolar inflammatory markers in pigs exposed to high PEEP levels in comparison to the low PEEP group after 8 hours of low-volume ventilation without surgery, suggesting that lung injury might result from high PEEP. The use of intraoperative high levels of PEEP may prevent the development of lung atelectasis, homogenize ventilation, and minimize the repetitive opening and closing of lung units, which could mitigate the development of pulmonary complications. However, the use of high levels of PEEP can also have adverse effects, including increased static stress and strain, inflammation, impaired hemodynamics, and decreased lung lymphatic drainage.

CONCLUSION

As a result, it has been determined that high PEEP levels do not reduce postoperative complications but rather increase them in patients undergoing major abdominal cancer surgery. Additionally, no significant relationship has been found between PEEP levels and 30-day mortality. These findings highlight the need for careful evaluation of mechanical ventilation strategies and indicate that PEEP applications may not always be effective in improving surgical patients' outcomes. Future studies should comprehensively investigate the effects of PEEP applications, considering different patient populations and surgical techniques.

Ethics Committee Approval: This study was conducted with the permission of the SBU Dr. Abdurrahman Yurtaslan Ankara Oncology SUAM Non-Interventional Clinical Research Ethics Committee (decision no: 2024-04/48, date: 04.04.2024)

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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REFERENCES

1. Canet J, Paluzie G, Valle J, Castillo J, Sabate S. Prediction of postoperative pulmonary complications in a population-based surgical cohort. Anesthesiology 2010;113(6):1338-50. [CrossRef]
2. Brooks-Brunn JA. Predictors of postoperative pulmonary complications following abdominal surgery. Chest 1997;111(3):564-71. [CrossRef]
3. Diaz-Fuentes G, Hashmi HRT, Venkatram S. Perioperative evaluation of patients with pulmonary conditions undergoing non-cardiothoracic surgery. Health Serv Insights 2016;9(Suppl 1):9-23. [CrossRef]
4. Güldner A, Kiss T, Serpa Neto A, Hemmes SNT, Canet J, Spieth PM, et al. Intraoperative protective mechanical ventilation for prevention of postoperative pulmonary complications: A comprehensive review of the role of tidal volume, positive end-expiratory pressure, and lung recruitment maneuvers. Anesthesiology 2015;123(3):692-713. [CrossRef]

5. Neumann P, Rothen HU, Berglund JE, Valtysson J, Magnusson A, Hedenstierna G. Positive end-expiratory pressure prevents atelectasis during general anaesthesia even in the presence of a high inspired oxygen concentration. Acta Anaesthesiol Scand 1999;43(3):295-301. [CrossRef]
6. Reinius H, Jonsson L, Gustafsson S, Sundbom M, Duvernoy O, Pelosi P, et al. Prevention of atelectasis in morbidly obese patients during general anesthesia and paralysis: A computerized tomography study. Anesthesiology 2009;111(5):979-87. [CrossRef]
7. Jammer I, Wickboldt N, Sander M, Smith A, Schultz MJ, Pelosi P, et al. Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions. Eur J Anaesthesiol 2015;32(2):88-105. [CrossRef]
8. Yang CK, Teng A, Lee DY, Rose K. Pulmonary complications after major abdominal surgery: National Surgical Quality Improvement Program analysis. J Surg Res 2015;198(2):441-9. [CrossRef]
9. Özdilekcan Ç, Songur N, Berktaş BM, Dinç M, Üçgül E. Risk factors associated with postoperative pulmonary complications following oncological surgery. Tuberk Toraks 2004;52(3):248-55.
10. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317-34. [CrossRef]
11. Lusquinhos J, Tavares M, Abelha F. Postoperative pulmonary complications and perioperative strategies: A systematic review. Cureus 2023;15(5):e38786. [CrossRef]
12. Choi JY, Al-Saedy MA, Carlson B. Positive end-expiratory pressure and postoperative complications in patients with obesity: A review and meta-analysis. Obesity 2023;31(4):955-64. [CrossRef]
13. Bigatello L, Pesenti A. Respiratory physiology for the anesthesiologist. Anesthesiology 2019;130(6):1064-77. [CrossRef]
14. Bluth T, Serpa Neto A, Schultz MJ, Pelosi P, Gama de Abreu M, Bobek I, et al. Effect of intraoperative high positive end-expiratory pressure with recruitment maneuvers vs low PEEP on postoperative pulmonary complications in obese patients: A randomized clinical trial. JAMA 2019;321(23):2292-305. [CrossRef]
15. Schultz MJ, Hemmes SNT, de Abreu MG, Pelosi P, Severgnini P, Hollmann MW, et al. High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): A multicentre randomised controlled trial. Lancet 2014;384(9942):495-503. [CrossRef]
16. Campos NS, Bluth T, Hemmes SNT, Librero J, Pozo N, Ferrando C, et al. Intraoperative positive end-expiratory pressure and postoperative pulmonary complications: A patient-level meta-analysis of three randomised clinical trials. Br J Anaesth 2022;128(6):1040-51.
17. Imberger G, McIlroy D, Pace NL, Møller AM. Positive end-expiratory pressure during anaesthesia for the prevention of mortality and postoperative pulmonary complications. Cochrane Database Syst Rev. 2010;9:CD007922. [CrossRef]
18. Ahn HJ, Park M, Kim JA, Yang M, Yoon S, Kim BR, et al. Driving pressure guided ventilation. Korean J Anesthesiol 2020;73:194-204. [CrossRef]
19. Hol L, Nijbroek SGLH, Neto AS, de Abreu MG, Pelosi P, Hemmes SNT, et al. Driving pressure during general anesthesia for open abdominal surgery (DESIGNATION): Study protocol of a randomized clinical trial. Trials 2020;21(1):198. [CrossRef]
20. Wang QY, Ji YW, An LX, Cao L, Xue FS. Effects of individualized PEEP obtained by two different titration methods on postoperative atelectasis in obese patients: Study protocol for a randomized controlled trial. Trials 2021;22(1):704. [CrossRef]
21. Brueckmann B, Villa-Uribe JL, Bateman BT, Grosse-Sundrup M, Hess DR, Schlett CL, et al. Development and validation of a score for prediction of postoperative respiratory complications. Anesthesiology 2013;118(6):1276-85. [CrossRef]
22. Canet J, Sabaté S, Mazo V, Gallart L, de Abreu MG, Belda J, et al. Development and validation of a score to predict postoperative respiratory failure in a multicentre European cohort: A prospective, observational study. Eur J Anaesthesiol 2015;32(7):458-70. [CrossRef]
23. Ferrando C, Mugarra A, Gutierrez A, Carbonell JA, García M, Soro M, et al. Setting individualized positive end-expiratory pressure level with a positive end-expiratory pressure decrement trial after a recruitment maneuver improves oxygenation and lung mechanics during one-lung ventilation. Anesth Analg 2014;118(3):657-65. [CrossRef]
24. Edginton S, Kruger N, Stelfox HT, Brochard L, Zuege DJ, Gaudet J, et al. Methods for determination of optimal positive end-expiratory pressure: A protocol for a scoping review. BMJ Open 2023;13(8):e071871. [CrossRef]
25. Serpa Neto A, Schmidt M, Azevedo LCP, Bein T, Brochard L, Beutel G, et al. Associations between ventilator settings during extracorporeal membrane oxygenation for refractory hypoxemia and outcome in patients with acute respiratory distress syndrome: A pooled individual patient data analysis. Intensive Care Med 2016;42(11):1672-84. [CrossRef]
26. Hong CM, Xu DZ, Lu Q, Cheng Y, Pisarenko V, Doucet D, et al. Low tidal volume and high positive end-expiratory pressure mechanical ventilation results in increased inflammation and ventilator-associated lung injury in normal lungs. Anesth Analg 2010;110(6):1652-60. [CrossRef]