Two-Lung Ventilation: A Safer and More Efficient Method Than One-Lung Ventilation in Bilateral Video-Assisted Thoracoscopic Extended Thymectomy in Myasthenia Gravis

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Abstract

Background Myasthenia gravis (MG) is an autoimmune disease and early thymectomy has been recommended. After the introduction of VATS, the safety and effectiveness of carbon dioxide (CO₂) insufflation in thoracic cavity (capnothorax) has been continuously controversial. This study aimed to compare the safety and effectiveness of ventilation methods in bilateral video-assisted thoracoscopic extended thymectomy (BVET) with capnothorax.

Methods We retrospectively investigated the medical records of MG patients who underwent BVET between August 2016 and January 2018. Patients were divided into two groups: group D (n=26) for one-lung ventilation and group S (n=28) for two lung-ventilation. We set nine anesthesia time points (T0–T8) and collected respiratory and hemodynamic variables including arterial O₂ index (PaO₂/FiO₂).

Results The EtCO₂ at T0, T1–T4, and T7 were insignificantly higher in group D than those in group S. The SpO₂ at T1–T3 and T8 were significantly lower in group D than those in group S. The FiO₂ in group S was lower than that in group D at all-time points. The number of PaO₂/FiO₂ ≤ 300 and PaO₂/FiO₂ ≤ 200 were significantly higher in group D than those in group S. Hemodynamic variables were not insignificantly different between the two groups at all-time points. The duration of surgery and anesthesia was shorter in group S than that in group D.

Conclusions This retrospective study suggests that anesthesia using two-lung ventilation during BVET with capnothorax was a safe and effective method to improve lung oxygenation and reduce the operation and anesthesia time.

Introduction

Myasthenia gravis (MG) is an autoimmune disease that affects nicotinic acetylcholine receptors in neuromuscular junctions. It mainly affects women in their 20 s and 30 s and can be treated with medical or surgical treatment. Generally, for early-onset MG, early thymectomy has been recommended [1, 2].

After Dr. Alfred Blalock succeeded in performing thymectomy in thymomatous MG patients using upper partial midline sternotomy in 1936, thymectomy in MG patients began to be widely performed [3]. However, sternotomy was accompanied by several side effects such as bleeding, longer duration of hospitalization, and cosmetic problems. In the 1990s, video-assisted thoracic surgery (VATS) became popular and was introduced in various thoracic and mediastinal surgeries, such as sympathectomy, esophageal resection, and thymectomy. VATS has been reported to reduce postsurgical pain, hospitalization, and treatment costs, while showing similar therapeutic effects to open thymectomy [4]. Therefore, VATS and robotic-assisted thymectomy are used by an increasing number of centers and are usually preferred by patients [5].

After the introduction of VATS, the safety and effectiveness of carbon dioxide (CO₂) insufflation in the thoracic cavity (capnothorax) has been continuously controversial. Although studies have shown that

capnothorax helps to secure the vision of the surgeon and does not significantly affect the patient's hemodynamic stability during anesthesia [6–8], other studies have also reported that capnothorax should be used only at low pressure, as it significantly affects the patient's hemodynamic and pulmonary stability [9, 10].

In our hospital, we have been performing capnothorax and one-lung ventilation (OLV) at the request of a thoracic surgeon since 2016 when bilateral VATS extended thymectomy (BVET) was introduced. However, we found out that OLV makes maintenance of anesthesia very difficult, so we decided to switch to two-lung ventilation (TLV) using a single lumen tube after discussing with the surgeon.

We observed that there were differences in pulmonary function according to the two anesthetic methods. Thus, this study aimed to compare the differences between the two anesthetic methods and to determine the appropriate anesthetic method.

The primary end point of our study was arterial oxygen (O_2) index (partial pressure of arterial oxygen [PaO_2]/fraction of inspired oxygen [FiO_2]) for the evaluation of patient safety. The secondary end point was the duration of anesthesia for the effectiveness of the surgery.

Methods

This retrospective study was approved by the Research Board of the National Medical Center (Institutional Review Board number: H-1806-091-003). We retrospectively investigated the medical records of MG patients who underwent BVET between August 2016 and January 2018.

The inclusion criteria were as follows: age 18–65 years, American Society of Anesthesiologists (ASA) physical status I–III, preoperative vital capacity (VC) > 2 L, no history of sternotomy, and no cardiothoracic disease. Patients who underwent conversion from OLV to TLV or changed VATS to sternotomy were excluded. We divided patients into two groups: group D (the double-lumen tube [DLT] group), including patients who underwent ventilation for one lung, and group S (the single-lumen tube [SLT] group), including those who underwent ventilation for two lungs during surgery. Finally, 83 patients were enrolled in the present study.

We set nine anesthesia time points (T0–T8) and collected the data. The time points were set as follows: T0 was immediately after tracheal intubation, T1 was the time of incision on the right side, T2 was set as 10 min after the CO_2 gas insufflation of the right lung, T3 was set as 30 min from the right lung CO_2 gas insufflation, T4 referred to the transition period from the right to the left side (in group D, TLV), T5 was the time of incision on the left side, T6 was set as 10 min after the CO_2 gas insufflation of the left lung, T7 was set as 30 min after the left lung CO_2 gas insufflation, and T8 referred to the end of the left side operation (in group D, TLV).

The basic characteristics of the patients, such as age, sex, body mass index (BMI), ASA physical status, Myasthenia Gravis Foundation of America (MGFA) class, operation, and anesthesia time were recorded.

The end-tidal CO₂ (EtCO₂), peak inspiratory pressure (PIP), respiratory rate (RR), peripheral capillary oxygen saturation (SpO₂), PaO₂, FiO₂, arterial oxygen index (PaO₂/FiO₂), mean blood pressure (MBP), heart rate (HR), and cardiac index (CI) were recorded at T0–T8. Postoperative complications, intensive care unit stay time, and hospitalization day (HD) were also recorded.

None of the patients received premedication. Intraoperative monitoring included noninvasive blood pressure measurement, invasive arterial blood pressure monitoring, electrocardiography, pulse oximetry, capnography, bispectral index (BIS) monitoring, and neuromuscular function assessment (TOF Watch SX monitor®, Organon, Ireland). General anesthesia was induced using total intravenous anesthesia. Propofol and remifentanyl were administered to the end organ concentrations of 4–5 and 3–4 ng/mL, respectively, using a target-controlled infusion pump (Orchestra®, Fresenius Vial, France). Rocuronium (0.6 mg/kg) was administered to facilitate intubation. In group D, a 35-F or 37-F left-sided DLT was inserted using videolaryngoscopy, and its correct position was confirmed by auscultation and eventually by bronchoscopy. In group S, a 7.0 mm or 8.0 mm I.D single-lumen tube was inserted using videolaryngoscopy. Mechanical ventilation with O₂ and air (FiO₂, 0.5) was started with tidal volumes (TVs) of 8–10 ml/kg and an initial RR of 9–10 breath/min. In group D, passive lung collapse and contralateral OLV were started just before the first trocar insertion. During OLV, the FiO₂ was adjusted to 0.5–1.0, the TV was reduced to 6–8 ml/kg to maintain a PIP of < 35 cm H₂O, and the RR was increased to avoid respiratory acidosis. In group S, the TV was reduced to 6–8 ml/kg. Propofol and remifentanyl infusions were titrated to maintain an MBP within 20% of the baseline during anesthesia and to maintain BIS < 50. Rocuronium was continuously injected to maintain a TOF count of 1 or 2. A radial arterial pressure line was placed, and a central venous catheter was inserted via the right internal jugular vein. CI was monitored using a minimally invasive hemodynamic monitor (FloTrac System®, Edwards Lifesciences, USA).

The BVET was performed with patients in the supine position with 15° reverse Trendelenburg position. Both arms were placed at the 90° forearm abduction external rotation position without any pressure on the brachial plexus nerve. The right-side approach was always performed first. First, a 5-mm trocar was placed along the upper edge of the fifth intercostal space in the midaxillary line. After inspecting the right thoracic cavity to evaluate the adhesions and pathology, CO₂ insufflation was installed using a pressure limit of 8–14 mmHg and a flow of 4 L/min. Under thoracoscopic guidance, a second 5-mm trocar was inserted near the anterior axillary line of the sixth intercostal space, and a third 5-mm trocar was placed in the sixth or seventh intercostal space near the sternum without injury of the internal mammary vessel. The procedure on the left side was performed in the same manner.

At the end of the surgery, fentanyl (25 mcg) was injected intravenously, and intravascular patient-controlled analgesia was connected for postoperative pain control. Additionally, neuromuscular relaxation was reversed with sugammadex (2 mg/kg). After a TOF ratio > 0.9 was achieved, the tracheal tube was removed, and all patients were transferred to the intensive care unit (ICU).

Statistical Analyses

The Statistical Package for the Social Sciences program was used for the statistical analysis. Variables with a normal distribution are indicated by the mean value (standard deviation), and variables with a non-normal distribution are indicated by the median (25–75% interquartile ranges). The Student's unpaired t-test and Mann-Whitney U test were used for the continuous variables, and the chi-squared test was used for the categorical variables. A P value < 0.05 was considered statistically significant.

Results

A total of 29 out of the 83 patients were excluded from the analysis due to incomplete data. Therefore, the data of 54 patients were analyzed with 26 and 28 patients in groups D and S, respectively.

Age, sex, weight, height, BMI, MGFA class, and ASA physical status were not significantly different between the two groups (Table 1). However, the duration of surgery and anesthesia was longer in group D than that in group S. The durations of ICU and HD were not significantly different between the two groups.

Table 1
Characteristics of patients. Values are presented as median (range)

	Group D (n = 26)	Group S (n = 28)	P
Age (yr)	34.0 (23–38)	36 (25.7–43.0)	ns
Sex (M/F)	6/20	9/19	ns
ASA	2.0 (1, 2)	2.0 (2, 2)	ns
MGFA (I/IIa/IIb/IIIa)	12/12/2/0	15/8/4/1	ns
Pyridostigmine (mg/day)	360 (225–480)	360 (195–465)	ns
Height (cm)	163.5 (159.0–168.4)	164.7 (159.6–170)	ns
Weight (kg)	57.5 (50.4–72.1)	62.4 (53.4–71.1)	ns
BMI	21.2 (20.2–23.5)	22.3 (19.7–25.2)	ns
Operation time (min)	243.0 (200–300)	210.0 (176.2–238.8)	0.012
Anesthesia time (min)	308.5 (268.5–359.7)	272.0 (234–303.8)	0.03
ICU stay (days)	2.0 (1–2)	2.0 (2–2)	ns
Hospital stay (days)	8.0 (6.7–11)	8.5 (6–14.5)	ns
Bleeding (mL)	100.0 (37.5–100)	0.00 (0–175)	ns
Input (L)	1.8 (1.4–2.3)	1.8 (1.4–2.2)	ns
Urine (mL)	302.5 (200–393.7)	317.5 (172.5–447.5)	ns

Abbreviations: ns not significant, ASA American society of anesthesiologists physical status, MGFA myasthenia gravis foundation of America, BMI body mass index, ICU intensive care unit

The respiratory variables are shown in Table 2. The EtCO₂ values at T0 were not significantly different between the two groups, but were maintained at a higher level during surgery in group D, although statistical significance was only shown in T1–T3 and T7. The SpO₂ at T1–T3 and T8 were significantly lower in group D than those in group S. The FiO₂ was lower in group S than that in group D at all-time points. PIP and RR were not significantly different between the two groups at all-time points. The number of PaO₂/FiO₂ ≤ 300 and PaO₂/FiO₂ ≤ 200 were significantly higher in group D than those in group S (Table 4).

Table 2
Respiratory variables. Values are presented as medians (25–75% interquartile ranges) or medians (minimum).

	T0	T1	T2	T3	T4	T5	T6	T7	T8
EtCO ₂									
D	33.0 (32–35)	34.0* (31–34)	38.0* (35–40)	39.0* (37–43)	38.0* (33–46)	40.0 (36–45)	42.0 (35–44)	42.0* (40–47)	35.0 (32–41)
S	33.5 (31–37)	31.0* (30–34)	35.0* (33–37)	36.0* (34–38)	37.0 (34–40)	39.5 (36–45)	38.0 (36–42)	36.5* (34–41)	37.0 (33–38)
SpO ₂									
D	100 (99)	100* (96)	100* (91)	100* (96)	100 (96)	100 (94)	100 (95)	100 (96)	100* (97)
S	100 (99)	100* (99)	100* (98)	100* (99)	100 (99)	100 (99)	100 (99)	100 (98)	100* (100)
FiO ₂									
D	0.5 (0.5–0.6)	0.6* (0.5–1.0)	0.6* (0.5–1.0)	0.7* (0.5–1.0)	0.7* (0.5–1.0)	0.7* (0.5–1.0)	0.8* (0.6–1.0)	0.8* (0.6–1.0)	0.6* (0.5–1.0)
S	0.5 (0.6–0.6)	0.5* (0.5–0.6)	0.5* (0.5–0.7)	0.5* (0.5–0.7)	0.5* (0.5–0.7)	0.5* (0.5–0.6)	0.5* (0.5–0.6)	0.5* (0.5–0.6)	0.5* (0.5–0.5)
PIP									
D	18.5 (14–22)	20.5 (17–26)	21.0 (18–28)	26.0 (21–30)	27.0 (21–30)	26.0 (22–30)	26.0 (25–30)	30.0 (25–31)	23.0 (19–26)

Abbreviations: T0 immediately after tracheal intubation, T1 right-side incision time, T2 10 min after right lung CO₂ insufflation, T3 30 min from right lung CO₂ insufflation, T4 the transition period from the right to the left side (in group D, two-lung ventilation), T5–T8 T1–T4 on the left side. EtCO₂ end tidal CO₂, SpO₂ peripheral capillary oxygen saturation, PIP peak inspiratory pressure, RR respiratory rate, D group D, S group S, *p < 0.05.

	T0	T1	T2	T3	T4	T5	T6	T7	T8
S	16.5 (14–18)	20.0 (17–25)	25.0 (21–27)	28.0 (25–29)	28.0 (25–29)	28.0 (26–30)	29.5 (26–30)	29.0 (25–31)	26.0 (19–30)
RR									
D	12.0 (10–12)	12.0 (10–12)	13.0 (10–14)	14.0 (13–15)	14.0 (13–15)	15.0 (14.5–16)	15.0 (14–16)	15.0 (14–16)	12.0 (12–15)
S	11.5 (10–12)	12.0 (10–13)	13.0 (11–13)	14.0 (13–16)	14.0 (13–16)	15.0 (13–16)	15.5 (14–16)	15.0 (13–16)	15.0 (13–16)
<i>Abbreviations:</i> T0 immediately after tracheal intubation, T1 right-side incision time, T2 10 min after right lung CO ₂ insufflation, T3 30 min from right lung CO ₂ insufflation, T4 the transition period from the right to the left side (in group D, two-lung ventilation), T5–T8 T1–T4 on the left side. EtCO ₂ end tidal CO ₂ , SpO ₂ peripheral capillary oxygen saturation, PIP peak inspiratory pressure, RR respiratory rate, D group D, S group S, *p < 0.05.									

The hemodynamic variables are shown in Table 3. MBP, HR, and CI were not significantly different between the two groups at all-time points.

Table 3
Arterial oxygen index (partial pressure of arterial oxygen/fraction of inspired oxygen)

	Group D (n = 26)	Group S (n = 28)	P
Number of ABGA	41	46	
PaO ₂ /FiO ₂ ≤ 300 n (%)	24 (58.5)	6 (13.0)	< 0.001
PaO ₂ /FiO ₂ ≤ 200 n (%)	18 (44)	0 (0)	< 0.001
<i>Abbreviation:</i> ABGA arterial blood gas analysis, PaO ₂ partial pressure of arterial oxygen, FiO ₂ fraction of inspired oxygen			

Table 4
Hemodynamic variables. Values are presented as medians (25–75% interquartile ranges)

	T0	T1	T2	T3	T4	T5	T6	T7	T8
CI									
D	NS	2.8 (2.4–3.3)	2.8 (2.4–3.3)	2.5 (2.1–3.1)	2.7 (2.3–3.2)	3.1 (2.4–3.9)	3.4 (2.5–3.9)	3.2 (2.4–3.8)	3.3 (2.9–4.2)
S	NS	2.6 (1.9–3.6)	2.8 (2.1–3.5)	2.6 (2.1–3.0)	2.6 (2.1–3.1)	2.8 (1.9–3.3)	2.7 (2.3–3.1)	3.0 (2.3–3.4)	3.1 (2.8–3.9)
MBP									
D	93.0 (82–111)	89.0 (81–94)	87 (81–95)	81.5 (75–92.3)	87.0 (80.2–94.7)	81.5 (76.7–87.2)	84.0 (74.0–94.0)	84.5 (70.3–86.0)	84.0 (77–91)
S	90.5 (74.5–104.5)	87.0 (82.0–98.3)	88.0 (80.2–94.5)	83.0 (77.0–93.0)	85.5 (77.0–91.0)	86.0 (77.5–97.3)	85.5 (78.5–91.0)	82.5 (75.0–92.5)	88.0 (81.5–95.8)
HR									
D	76.0 (63.0–85.0)	67.5 (63.3–72.3)	74.0 (66.5–87.8)	77.0 (65.5–87.8)	78.5 (67.0–89.5)	83.5 (67.0–89.5)	82.0 (72.0–95.0)	84.5 (74.0–90.3)	75.0 (66.5–85.5)
S	76.5 (64.5–86.5)	66.5 (59.3–76.0)	73.0 (65.8–79.0)	73.0 (64.0–76.0)	70.5 (64.0–79.0)	75.0 (66.3–87.3)	71.5 (65.0–87.3)	73.0 (63.3–84.3)	70.5 (57.2–75.0)
Abbreviations: T0; immediately after tracheal intubation, T1; right-side incision time, T2; 10 min after right lung CO ₂ insufflation, T3; 30 min from right lung CO ₂ insufflation, T4; the transition period from the right to the left side (in group D, two-lung ventilation), T5–T8; the same as T1–T4 of the left side. D; group D, S; group S									

The postoperative complication rate was significantly higher in group D than that in group S (Table 5). There were no complications that were presumed to be related to the myasthenic crisis.

Table 5
Postoperative complications up to 24 h. Complications within 24 hours after the operation. Myasthenic crisis was not observed.

	Group D (n = 26)	Group S (n = 28)	P
Total (n)	10	5	0.007
Sore throat	1		
Right arm numbness	1	1	
Atelectasis	1		
Anxiety/palpitation	1		
Diarrhea	1		
Nausea/vomiting	5	3	
Dyspnea		1	
<i>Abbreviation: ns not significant</i>			

Discussion

As a result of the study, the duration of the operation and anesthesia in group S was short, and $\text{SpO}_2 > 90\%$ was maintained even when the FiO_2 level was lower in group D than that in group S. The number of $\text{PaO}_2/\text{FiO}_2$, which was 300 or less, was also significantly lower in group S than that in group D. Hemodynamic variables were not significantly different between the two groups. In conclusion, the present study showed that TLV was a safer and more effective method during BVET with capnothorax than OLV.

EtCO_2 was higher in group D than that in group S from T1 to T3. The difference between the two groups was no longer observed after T4, which can be estimated as the residual CO_2 effect after the operation on the right side. In the case of SpO_2 , the median value between the two groups was not different; however, due to the difference in the minimum values, the SpO_2 from T1 to T3 in group D was lower than that in group S. After T4, the difference between the two groups was no longer observed, which can be interpreted as a result of the increase in the FiO_2 value of group D over time.

The effectiveness and side effects of CO_2 insufflation in VATS are controversial. Ohtsuka et al. reported that low-flow CO_2 insufflation does not compromise the human heart with normal to moderately depressed function and can be an efficacious adjunct in specific thoracoscopic procedures [6]. On the contrary, Brock et al. investigated the hemodynamic and respiratory effects of OLV and CO_2 insufflation in 13 adult patients undergoing VATS [10]. They suggested that the combined use of OLV and CO_2

insufflation increases the hazards as both hypoxia and low CI are expected. In our study, although the O_2 index < 300 was higher in group D than that in group S, hypoxia ($SpO_2 < 90\%$) and hemodynamic exacerbation were not observed. Hence, the results were different from those of Brock et al.'s expectation.

After Brock's research, the researchers attempted to avoid OLV in the presence of capnothorax. No active clinical studies have been found since this study was published. However, it was difficult to prevent the introduction of capnothorax with OLV in the field where minimally invasive surgery was developed and actively introduced into the clinic. It is notable that OLV was safely used with capnothorax in BVET in hospitals that actively utilized BVET before our hospital did [11]. Nevertheless, ventilation during CO_2 insufflation should be titrated to maintain adequate oxygenation and a normal PCO_2 and pH.

Anesthesiologists must be aware that damage to the contralateral pleura may occur, resulting in CO_2 flow to the contralateral chest, making ventilation difficult and resulting in tension pneumothorax or severe subcutaneous emphysema, which subsequently produces a hemodynamic compromise [2].

Recently, SLT and CO_2 insufflation have been considered safe alternative treatments to OLV because they reduce the side effects caused by DLT, shorten the duration of surgery and anesthesia, and allow anesthesia to be performed by inexpert anesthesiologists [12–16]. However, in their studies, TLV in the presence of capnothorax and OLV in the absence of capnothorax were compared. In the present study, OLV and TLV were compared with various variables in the presence of capnothorax, which can be considered as different from other studies. Although the results of our study showed that TLV in the presence of capnothorax is a better anesthetic method, it should be remembered that there are various risks of CO_2 insufflation, such as venous gas embolism, compromised venous return, severe bradycardia, and progressive arterial desaturation [17].

Upon clarification with the operator, the only thoracic surgeon in our hospital, it was noted that he was satisfied with both anesthetic methods. However, the majority of anesthesiologists and anesthesiology residents preferred TLV. Failure to investigate the satisfaction score is one of the limitations of this study.

Thymectomy for MG is the most frequently performed surgery in our hospital in Korea. This is possibly because the diagnoses and treatment consultations of MG patients are active between the MG specialty center and our hospital. If a neurologist at the MG specialty center refers patients to our hospital, subsequently, a neurologist, thoracic surgeon, and anesthesiologist at our hospital discuss patient surgery. After the operation, we refer the patient to the MG specialty center again. The indications for surgical treatment of MG patients are not yet clearly established. The American Academy of Neurology published international consensus guidelines for the management of MG [18]. In non-thymomatous MG, thymectomy is performed as an option to potentially avoid or minimize the dose or duration of immunotherapy, or if patients fail to respond to an initial trial of immunotherapy or have intolerable side effects from that therapy. In our center, the occurrence of clinical symptoms with an ACh receptor antibody positive within 5 years of onset of symptoms and patients aged 18–65 years are considered indications for surgery.

MG patients may experience two crises: cholinergic crisis and myasthenic crisis. A cholinergic crisis is usually caused by an excess of cholinesterase inhibitors. Hypersalivation, sweating, abdominal cramps, bradycardia, and muscle weakness may occur. A myasthenic crisis can be triggered by emotional and physical stress, such as infections, certain medications, and surgery, which refers to a life-threatening condition that is defined as the worsening of myasthenic weakness requiring intubation or noninvasive ventilation [19]. Postoperative myasthenic crisis with respiratory muscle paralysis can be a severe complication and reportedly occurs in 12–18% of patients. Kanai et al. reported that the significant preoperative clinical predictive factors for postoperative myasthenic crises were percentage VC < 80% (3 points), duration of MG before thymectomy < 3 months (2 points), and bulbar symptoms immediately before thymectomy (1 point), yielding scores ranging from 0 to 6 [20]. Myasthenic crises were observed in 0.9% of patients with scores < 3 versus 25.9% of patients with scores ≥ 3 . There were no cases related to post-thymectomy myasthenic crisis in our study. Limitations were observed in the present study as the investigations were conducted only up to 24 hours postoperatively; however, the patients included in this study were able to determine that no postoperative myasthenic crisis occurred because the VC was normal and patients with low MGFA grades accounted for the majority.

This study has some limitations. As with all retrospective studies, there were several missing data; hence, the number of patients was smaller than planned. Additionally, it was impossible to compare the O_2 index at each time point because arterial blood gas analysis was not performed at a fixed time.

Conclusions

This retrospective study suggests that anesthesia using TLV during BVET with capnothorax is a safe and effective method to improve the oxygenation of the lungs and reduce the duration of the operation and anesthesia.

List Of Abbreviations

MG

Myasthenia Gravis; VATS:video-assisted thoracic surgery; OLV:one lung ventilation; TLV:two lung ventilation; BVET:bilateral ASA:American society of anesthesiologists; MGFA:myasthenia gravis foundation of America; BMI:body mass index; ICU:intensive care unit; HD:hospitalization days; $EtCO_2$:The end-tidal CO_2 ; PIP:peak inspiratory pressure; RR:respiratory rate; SpO_2 :peripheral capillary oxygen saturation; PaO_2 :partial pressure of arterial oxygen FiO_2 :fraction of inspired oxygen; MBP:mean blood pressure; HR:heart rate; CI:cardiac index

Declarations

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Authors' contributions

The authors have read and approved the manuscript. The detailed contribution of each author were listed below. MJ: design the study and interpret data. GK: design the study, analyze data. SK: collect data, prepare the manuscript. WK: search the literature, interpret data.

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Availability of data and materials

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

Ethics approval and consent to participate

This study was approved by the Research Board of the National Medical Center (Institutional Review Board (IRB) number: H-1806-091-003). All methods were performed in accordance with the relevant guidelines and regulations. Our study was a retrospective study that investigated medical record, so informed consent was waived according to the policy of IRB. The full name of the ethics committee who passed the waiver for the informed consent were listed below: Miyeon Park, Jongyoon Lee, Sukjoong Kim, Joonwon Lee, Kyungmi Lee, Jong Kyung Choi, Jong Hyun Yoon, Beoumsik Jin, Seong Hyun Cha, Hak Soo Kyung, Haeryeun Lee, and Seunghee Seo.

Consent for publication

Not applicable.

Competing interests

Nothing to declare.

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