Spine

SPINE Volume 46, Number 16, pp E852–E858

RANDOMIZED TRIAL

OPEN

Equal Ratio Ventilation Reduces Blood Loss During Posterior Lumbar Interbody Fusion Surgery

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Study Design. A prospective randomized double-blinded study.

Objective. The aim of this study was to compare the effect of two different ventilator modes (inspiratory to expiratory ratio [I:E ratio] of 1:1 and 1:2) on intraoperative surgical bleeding in patients undergoing posterior lumbar interbody fusion (PLIF) surgery.

Summary of Background Data. During PLIF surgery, a considerable amount of blood loss is anticipated. In the prone position, engorgement of the vertebral vein increases surgical bleeding. We hypothesized that equal ratio ventilation (ERV) with I:E ratio of 1:1 would lower peak inspiratory pressure (PIP) in the prone position and consequentially decrease surgical bleeding.

Methods. Twenty-eight patients were randomly assigned to receive either ERV (ERV group, n = 14) or conventional ventilation with I:E ratio of 1:2 (control group, n = 14). Hemodynamic and respiratory parameters were measured at 5 minutes after anesthesia induction, at 5 minutes after the prone position, at the time of skin closure, and at 5 minutes after turning to the supine position.

Results. The amount of intraoperative surgical bleeding in the ERV group was significantly less than that in the control group (975.7 ± 349.9 mL *vs.* 1757.1 ± 1172.7 mL, $P = 0.030$). Among other hemodynamic and respiratory parameters, PIP and plateau inspiratory pressure (P_{plat}) were significantly lower and dynamic lung compliance (C_{dyn}) was significantly higher in the ERV group than those of the control group throughout the study period, respectively (all $P < 0.05$).

Conclusion. Compared to conventional ratio ventilation, ERV provided lower PIP and reduced intraoperative surgical blood loss in patients undergoing PLIF surgery.

Key words: dynamic lung compliance, equal ratio ventilation, mechanical ventilation, peak airway pressure, plateau airway pressure, posterior lumbar interbody fusion surgery, prone position, randomized controlled study, surgical blood loss, transfusion requirement.

Level of Evidence: 2

Spine 2021;46:E852–E858

Previous studies of chronic back pain report that the treatment of spinal diseases through the posterior lumbar interbody fusion (PLIF) surgery helps to improve patient satisfaction and physical activity.[1–3] Recently, several other surgical approaches for the interbody fusion have been used, but the PLIF is still widely used due to its effective access. The prone position is associated with inferior vena cava (IVC) compression and an increase in intra-abdominal pressure (IAP), which results in a decrease in venous return and cardiac output (CO).[4–8] Also, peak inspiratory pressure (PIP) increases and dynamic compliance (C_{dyn}) decreases in the prone position.[9–11] All of these hemodynamic and respiratory changes in the prone position may cause engorgement of the vertebral veins and increase in surgical bleeding.[8]

To reduce intraoperative surgical bleeding in the prone position, maneuvers to reduce IVC compression, IAP and/or PIP have been used.[8,9,12–16] Among various mechanical ventilation modes, pressure-controlled ventilation (PCV) mode provided lower PIP compared with volume-controlled ventilation (VCV) mode.[9,12,13] It was suspected that the lower PIP during PCV mode resulted in less IAP and IVC compression, which in turn prevented venous engorgement of the surgical field.[13] Similarly, there are some reports that equal-ratio ventilation (ERV), which sets inspiratory to expiratory ratio (I:E ratio) to 1:1, reduces PIP and plateau airway pressure (P_{plat}) and improves C_{dyn}.[14,15] However,

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Acknowledgment date: June 11, 2020. First revision date: July 29, 2020. Second revision date: December 7, 2020. Acceptance date: December 8, 2020.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work.

No relevant financial activities outside the submitted work.

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DOI: 10.1097/BRS.0000000000003957

there is no report on the effect of ERV on pulmonary mechanics in the prone position during PLIF surgery.

We hypothesized that ERV would lower PIP in the prone position and decrease surgical bleeding. The aim of this study was to compare the effect of two different I:E ratio (1:1 and 1:2) on intraoperative surgical bleeding in patients undergoing PLIF surgery in the prone position.

MATERIALS AND METHODS

Study Design, Settings, and Patients

This prospective, double-blinded, randomized, parallel study (allocation ratio = 1:1) was conducted at Gangnam Severance Hospital after obtaining approval of our institutional review board (3-2016-0241), along with informed consent from patients before the study. This study was registered at ClinicalTrials.gov (NCT03030963), and adhered to the CONSORT statement.[17] A total of 36 patients belonging to American Society of Anesthesiologists' (ASA) physical status of 1–3 aged between 20 and 75 years scheduled for elective PLIF surgery (2/3 levels) were enrolled. This study was carried out between March 2017 and March 2018. Exclusion criteria were as follows: emergency cases, prior instrumentation of the spine, concurrent surgery of the spine and other organs, body mass index >30 kg/m^2, myocardial infarction within 3 months, left ventricle ejection fraction <40%, maintaining anticoagulants on the day of surgery, history of heart failure, dysrhythmia, respiratory disease, chronic kidney disease more than stage 3, or severe hepatic disease. For participant allocation, sealed envelope technique was used with computer-generated random numbering system. Surgeons and anesthesiologists involved in patient care were aware of the study being conducted but blind to participant allocation and details of the study protocol. The patients were followed up during hospitalization period.

Study Protocol

The anesthesia was induced and maintained by the attending anesthesiologist, using standard anesthesia regimen in the study protocol. In the operating room, noninvasive patient monitoring, including electrocardiography, pulse oximetry, noninvasive blood pressure, bispectral index (BIS, Aspect Medical System Inc., Newton, MA) measurement was established. Propofol 1.0 to 2.0 mg/kg was intravenously administered to induce anesthesia, and remifentanil 0.05 to 0.2 μg/kg/min was continuously infused during the surgery. After loss of consciousness, rocuronium 0.6 mg/kg was administered under neuromuscular transmission monitoring and routine invasive systemic blood pressure monitoring was established at the radial artery. Cardiac index (CI) and stroke volume variation (SVV) were monitored using FloTrac system (Flotrac, Edwards Lifesciences, Irvine CA). Tracheal intubation was performed at a train-of-four (TOF) of 0. Sevoflurane was controlled to maintain BIS values between 40 and 60 with fraction of inspired oxygen (FiO_2) of 0.5. All patients were ventilated with VCV mode, using tidal volume (TV) of (50 [female 45.5] + 0.91 × [height-152.4]) × 8 mL, which was calculated using ideal body weight. Respiratory rate was adjusted to maintain end-expiratory carbon dioxide ($ETCO_2$) between 35 and 38 mmHg. Positive end-expiratory pressure (PEEP) was not used. I:E ratio was adjusted to 1:2 in the control group and 1:1 in the ERV group. I:E ratio on the ventilator was covered with multiple sheets of paper, and the attending anesthesiologist was not aware of the patient allocation. A central venous catheter insertion for central venous pressure (CVP) monitoring and fluid or drug administration was established through the internal jugular vein. The patients' position was changed from the supine to prone position using the Jackson frame. Fluid administration was maintained at a dose of 4 mL/kg/h using plasmalyte (Plasma solution-A injection, CJ Pharma, Seoul, Korea). An additional fluid was administered according to goal-directed fluid therapy, which aimed at CI >2.4 L/min/m^2 and SVV <13%. In cases of acute surgical bleeding, colloid solution (Volulyte, Fresenius Kabi, Seoul, Korea) was administered if hematocrit (Hct) was >30% and packed red blood cells (pRBCs) were transfused if Hct was <30%. Additional laboratory tests or other allogeneic blood product transfusion was done at the attending anesthesiologist's discretion. When mean arterial pressure (MAP) fell below 60 mmHg, phenylephrine 30 μg was given if heart rate (HR) was >45 beats/min and ephedrine 4 mg was administered if HR was <45 beats/min. Atropine 0.5 mg was injected when HR was <40 beats/min. Extubation was performed when the recovery was confirmed as follows: a TOF >4/4, 90%; BIS >80; patients' ability to obey the attending anesthesiologist's verbal commands. Then, the patient was shifted to the postanesthesia care unit. Patients were transferred to the general ward after confirmation of the anesthesia recovery. In the general ward, the patients were managed by the neurosurgical surgeons with institutional protocol throughout the postoperative period.

The primary outcome was the intraoperative surgical bleeding. The secondary outcomes were intraoperative transfusion requirement, postoperative blood loss and transfusion requirement during 72 hours.

Measurement Values

The measured values were as follows: MAP (mmHg) and HR (beats/min) derived from the invasive systemic arterial pressure monitoring device; CI (L/min/m^2) and SVV (%) derived from Flotrac system; CVP (mmHg) derived from the central venous catheter; PIP (cmH_2O), mean inspiratory pressure (P_{mean}, cmH_2O), and plateau inspiratory pressure (P_{plat}, cmH_2O) derived from mechanical ventilator; arterial partial pressure of oxygen (PaO_2, mmHg), arterial partial pressure of carbon dioxide ($PaCO_2$, mmHg), hemoglobin (g/dL) measured by arterial blood gas analysis. Static lung compliance (C_{stat}, mL/cmH_2O) and dynamic lung compliance (C_{dyn}, mL/cmH_2O) were calculated using P_{plat} and PIP, respectively. The PaO_2/FiO_2 ratio was also calculated. The above values were measured at 5 minutes after anesthesia

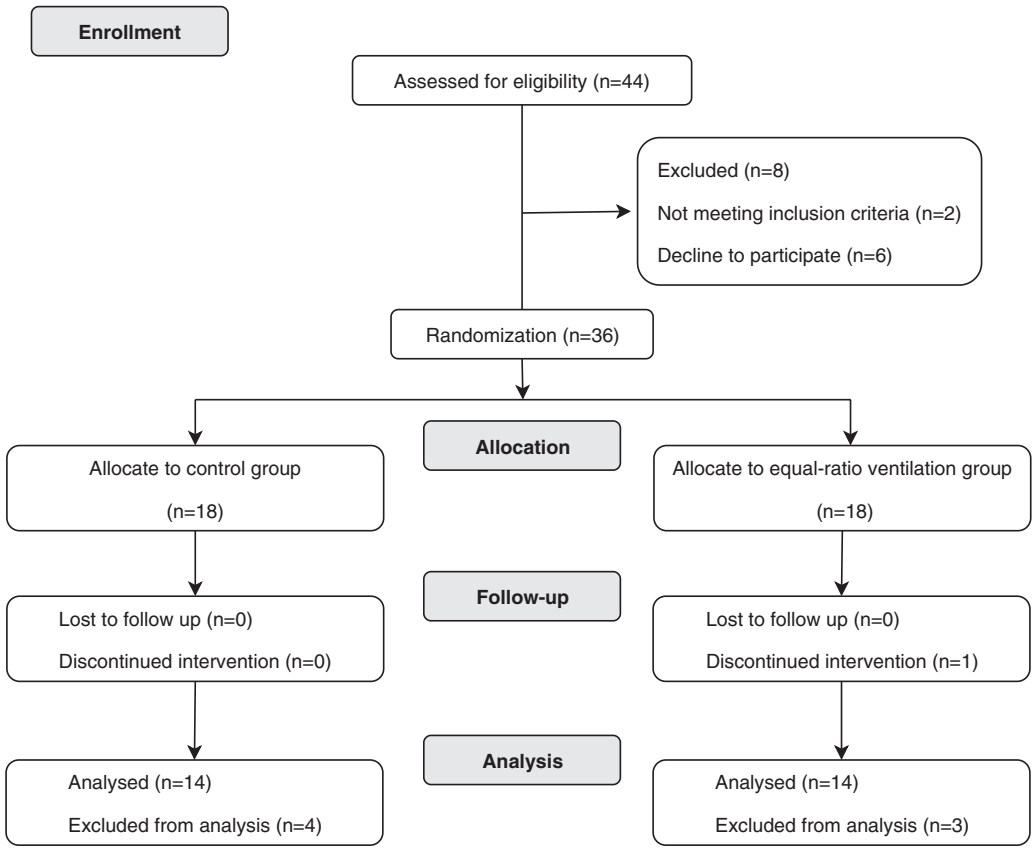

Figure 1. Flow diagram of the study.

induction in the supine position (T0), at 5 minutes after position change from the supine to prone position (T1), at the time of skin closure in the prone position (T2), and at 5 minutes after position change from the prone to supine position (T3). At the end of the surgery, intraoperative surgical bleeding (mL), transfusion of allogeneic blood products (mL), fluid administration (mL), urine output (mL), the dose of drugs used were checked. Postoperative surgical bleeding (mL) and transfusion (mL) were recorded for 72 hour. Prothrombin time (PT, s), activated partial thromboplastin time (aPTT, s), hemoglobin (g/dL), platelet counts (10^3 cells/μL) were recorded every 24 hours for 72 hours.

Statistical Analyses

Statistical analyses were conducted using software SAS version 9.3 (SAS Inc., Cary, NC). Sample size was based on the previous study.[13] On the assumption of an average intraoperative bleeding difference being 150.5 mL (standard deviation [SD] = 116.8 mL) between two groups, at an α error of 0.05 and power of 90%, sample size was calculated to be 14 in each group. To confirm the normality of the data, Kolmogorov-Smirnov test was performed. Continuous variables were analyzed using Student *t* test or Mann-Whitney *U* test or linear mixed model with *post hoc* analysis where appropriate. Categorical variables were analyzed using Pearson χ^2 test. Data were expressed as the number of patients with percentages, mean ± SD, or median (25%–75% interquartile range). A P value <0.05 was considered statistically significant.

RESULTS

A total of 44 patients undergoing PLIF surgery were screened. Eight patients were excluded: six due to refusal; one due to change of surgical plan; one due to history of spinal instrumentation on the spine level to be operated. After allocation, eight patients were dropped out: 1 due to change of surgical plan during the surgery; seven due to incomplete data regarding PaO_2, $PaCO_2$, and hemoglobin (Figure 1). Finally, a total of 14 patients in each group were analyzed, and no harm or unintended effect occurred.

The demographic and subject characteristics in two groups were similar (Table 1). The amount of intraoperative surgical bleeding and transfusion requirement in the ERV group was significantly less (975.7 ± 349.9 mL *vs.* 1757.1 ± 1172.7 mL, $P = 0.030$; 0 [0–0] mL *vs.* 200 [0–600] mL, $P = 0.012$, respectively, Table 2). The amount of postsurgical bleeding for 72 hours were comparable (Table 2). There were no differences in PT, aPTT, hemoglobin, and platelet count between the groups.

Among intraoperative parameters, total fluid volume administered was significantly lower in the ERV group compared to that in the control group ($P = 0.037$, Table 3), whereas others were not different.

Intraoperative hemodynamic and respiratory parameters are listed in Table 4. PIP, P_{plat} values in the ERV group were

TABLE 1. Demographic and Clinical Characteristics

	Control Group (n = 14)	ERV Group (n = 14)	*P*
Age, y	65.4 ± 6.0	64.8 ± 5.6	0.773
Sex (male/female)	3 / 11	7 / 7	0.115
Height, cm	152.5 (150.0–161.3)	158.1 (155.0–163.3)	0.232
Weight, kg	63.5 (58.0–67.0)	60.2 (55.5–63.8)	0.323
Surgical procedure 2 level/3 level	9 / 5	13 / 1	0.165
Spine BMD (z score)	1.3 ± 0.9	1.2 ± 0.9	0.806
PT, s	11.4 ± 0.8	11.8 ± 0.5	0.227
aPTT, s	25.1 ± 2.0	25.6 ± 1.7	0.545

Data are expressed as number, mean ± standard deviation or median (interquartile range).
aPTT indicates activated partial thromboplastin time; BMD, bone mineral density; ERV, equal ratio ventilation; PT, prothrombin time.

TABLE 2. Perioperative Blood Loss and Transfusion Requirements

		Control Group (n = 14)	ERV Group (n = 14)	*P*
Bleeding, mL	Intraoperative	1757.1 ± 1172.7	975.7 ± 349.9	0.030*
	Postoperative 72 h	826.2 ± 329.6	993.2 ± 442.4	0.268
Transfusion, mL	Intraoperative	200 (0–600)	0 (0–0)	0.012*
	Postoperative 72 h	0 (0–0)	0 (0–200)	0.387

Data are expressed as mean ± standard deviation or median (interquartile range). ERV indicates equal ratio ventilation.
**P < 0.05 compared with control group.*

significantly lower than those in the control group throughout the study period (all $P < 0.05$). C_{dyn} values in the ERV group were significantly higher than those in the control group at all time points and C_{stat} values were also higher at all measurement points except T2. Hemoglobin levels were not different between the groups. CVP values at all time points except T0 in the ERV group were significantly lower (all $P < 0.05$). There were no differences in MAP, HR, and CI values between the groups. The PaO_2/FiO_2 ratio was higher in the ERV group than that in the control group at T0 and T1.

DISCUSSION

In this study, the application of ERV reduced intraoperative surgical bleeding and transfusion requirement in patients undergoing PLIF surgery. PIP, P_{plat} in the ERV group were significantly lower and C_{dyn} in the ERV group was significantly higher than those of the control group throughout the study period. There were no significant differences in hemoglobin levels between the groups. Postoperative bleeding during 72 hours was similar between the groups.

There are many factors affecting the blood loss during PLIF surgery. Maintaining low IAP and intrathoracic pressure (ITP) decreases engorgement of the vertebral vein, which reduces surgical bleeding. In this study, Jackson table was used to support the thoracic area in the prone position because free hanging abdomen relieves the effect of the abdominal pressure on the IVC and ITP. Since the chest wall is supported by the frame in the prone position, restriction on the chest wall movement cannot be changed.

TABLE 3. Intraoperative Parameters

	Control Group (n = 14)	ERV Group (n = 14)	*P* Valu
Fluid administration, mL	3275 (2200–4900)	2350 (2000–2600)	0.037*
Crystalloid	3025 (1900–3900)	1950 (1550–2150)	0.050
Colloid	500 (500–1000)	500 (0–500)	0.222
Urine output, mL	775 (550–1300)	725 (350–1100)	0.435
Phenylephrine dose, μg	3500 (1600–10000)	3800 (1400–6000)	0.613
Operation time, min	260.6 ± 86.1	226.3 ± 38.9	0.191
Anesthesia time, min	337.9 ± 92.3	298.2 ± 48.2	0.170

Data are expressed as mean ± standard deviation or median (interquartile range).
**P < 0.05 compared with control group. ERV indicates equal ratio ventilation.*

TABLE 4. Intraoperative Hemodynamic and Respiratory Parameters

	Control Group (n = 14)				ERV Group (n = 14)			
	T0[a]	T1[b]	T2[c]	T3[d]	T0[a]	T1[b]	T2[c]	T3[d]
MAP, mmHg	77.2 ± 11.2	73.8 ± 8.8	73.5 ± 8.3	76.1 ± 10.5	84.1 ± 9.2	76.5 ± 10.7*	75.7 ± 8.1*	77.6 ± 7.3
HR, beats/min	72.0 ± 13.2	66.8 ± 12.3*	68.9 ± 13.6	68.4 ± 13.8	70.6 ± 12.9	68.9 ± 10.1	66.4 ± 9.5	66.6 ± 11.5
CVP, mmHg	6.3 ± 2.4	5.4 ± 2.6	7.1 ± 3.3†	8.2 ± 3.5*,†	4.9 ± 2.2	3.6 ± 1.7*,‡	4.5 ± 2.2‡	5.7 ± 2.8†,‡
CI, L/min/m^2	2.9 ± 0.7	2.7 ± 0.7	2.9 ± 0.8	3.1 ± 0.9†	2.6 ± 0.5	2.4 ± 0.3	2.7 ± 0.4	2.7 ± 0.6
SVV (%)	6.9 ± 2.3	8.2 ± 2.3	8.1 ± 2.6	7.9 ± 3.7	7.0 ± 2.5	9.9 ± 2.5*	10.6 ± 3.3*,‡	8.1 ± 3.6§
RR, times/min	11.3 ± 1.1	11.4 ± 1.2	12.3 ± 1.8*,†	12.1 ± 1.6†	10.9 ± 1.5	11.2 ± 1.4	11.9 ± 1.6*,†	12.0 ± 1.8*,†
PIP, cmH_2O	17.3 ± 7.0	16.1 ± 1.7	17.4 ± 2.6†	16.4 ± 2.6§	12.1 ± 1.3‡	13.5 ± 1.3‡	14.9 ± 1.4†,‡	13.3 ± 3.0§,‡
P_{mean}, cmH_2O	5.8 ± 1.4	5.9 ± 1.5	6.3 ± 1.7*,†	6.1 ± 1.5	5.4 ± 0.8	5.8 ± 0.8*	6.1 ± 1.0*	6.3 ± 1.5*
P_{plat}, cmH_2O	13.4 ± 1.1	14.1 ± 1.2*	15.3 ± 2.6*,†	14.6 ± 2.6*	10.6 ± 1.4‡	12.0 ± 1.5*,‡	13.6 ± 1.7*,†,‡	11.8 ± 3.2*,§,‡
C_{dyn}, mL/cmH_2O	26.3 ± 6.6	26.4 ± 4.2	24.7 ± 4.6†	26.3 ± 5.2	36.5 ± 7.4‡	32.7 ± 6.9*,‡	29.6 ± 5.8*,†,‡	34.0 ± 7.9§,‡
C_{stat}, mL/cmH_2O	31.8 ± 6.8	30.2 ± 6.1	28.2 ± 6.0*	29.8 ± 6.5	41.8 ± 10.3‡	37.1 ± 9.3*,‡	32.5 ± 7.4*,†	39.0 ± 10.7*,§,‡
PaO_2/FiO_2 ratio, mmHg	312 ± 86	424 ± 78*	451 ± 68*,†	409 ± 130*	424 ± 64‡	478 ± 36*,‡	482 ± 25*	484 ± 75*
P_aCO_2, mmHg	37 ± 4	38 ± 4*	39 ± 4*	39 ± 4*	35 ± 3	37 ± 3*	37 ± 4	37 ± 4
Hemoglobin, g/dL	11.8 ± 0.9	11.7 ± 1.0	9.8 ± 1.2*,†	10.0 ± 0.9*,†	12.2 ± 1.2	12.1 ± 1.2	10.8 ± 1.5*,†	10.5 ± 1.3*,†

Data are expressed as mean ± standard deviation. C_{dyn} indicates dynamic lung compliance; CI, cardiac index; C_{stat}, static lung compliance; CVP, central venous pressure; ERV, equal ratio ventilation; FiO_2, fraction of inspired oxygen; HR, heart rate; MAP, mean arterial pressure; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, arterial partial pressure of oxygen; PIP, peak inspiratory pressure; P_{mean}, mean inspiratory pressure; P_{plat}, plateau inspiratory pressure; RR, respiratory rate; SVV, stroke volume variation.

[a]*T0 indicates 5 minutes after anesthesia induction in the supine position.*

[b]*T1, 5 minutes after position change from the supine to the prone position.*

[c]*T2, at the time of skin closure after main surgical procedure in the prone position.*

[d]*T3, 5 minutes after position change from the prone to the supine position.*

**$P < 0.05$ compared with T0.*

†$P < 0.05$ compared with T1.

§$P < 0.05$ compared with T2.

‡$P < 0.05$ compared with control group at each measure point.

However, there are several ventilator modes that affect the ITP through PIP and P_{plat}, which are determined by the airway resistance and the lung compliance, respectively. In this study, PIP, P_{plat} values in the ERV group were significantly lower and C_{dyn} values were significantly higher than those of the control group throughout the study period. Previous studies on ERV during surgeries affecting airway resistance and lung compliance also reported that prolongation of the I:E ratio reduced PIP and/or P_{plat}.[14,15] In some reports, the prone position was reported to increase PIP and decrease respiratory compliance due to restrictive movement of the chest wall and abdominal compression.[18,19] However, the change in PIP and P_{plat} was not significant when patients were turned to the prone position in both groups in this study. This is likely because the Jackson table was reported to reduce the effect of the prone position on pulmonary mechanics.[11] Hemoglobin level was similar between two groups at all measuring points. Postoperative bleeding for 72 hours, during which all patients in both groups were spontaneously breathing, was also similar. This also supports the effect of decreased airway pressure on intraoperative surgical bleeding during PLIF.

In this study, there were no differences in MAP, HR, and CI between the groups. In critically ill patients, deleterious effects of ERV on the hemodynamic profile have been reported.[14,20] In 1993, Mercat *et al*[20] reported that prolongation of the inspiratory time increased P_{mean}, which in turn decreased the CI in patients with adult respiratory distress syndrome (ARDS). Another study on patients undergoing lung surgery reported that central venous oxygen saturation ($S_{CV}O_2$) was decreased in patients ventilated with ERV during one-lung ventilation.[14] However, Kim *et al*[15] reported that the cardiac output (CO) was similar between patient groups ventilated with I:E ratio of 1:1 or 1:2 during laparoscopic surgery under Trendelenburg position. Another study in patients undergoing laparoscopic surgery under head down position also reported similar $S_{CV}O_2$ between the two groups.[21] Therefore, the effect of ERV on CO in patients without respiratory compromise needs further investigation.

The oxygenation ratio (PaO_2/FiO_2) was higher in the ERV group than that in the control group only at the beginning of the surgery (T0/T1) in this study. Theoretically, the prolongation of the I:E ratio should improve the oxygenation by increasing P_{mean}, which recruits alveoli by preventing their collapse.[22] However, studies in healthy patients reported similar oxygenation between the ERV and conventional ventilation groups during general anesthesia.[14,15,21] In this study, the statistical difference in oxygenation at the beginning of the surgery has disappeared maybe due to the combined effect of the prone position and prolonged ventilation time. Within each group, the

oxygenation ratio was increased from the baseline (T0) in both groups. When IAP was relieved by proper positioning, the prone position during general anesthesia was reported to improve lung volume and oxygenation.[23,24] The mechanism underlying improvement of oxygenation in the prone position can be explained mainly with improved ventilation/perfusion matching, which is the rationale underlying prone positioning of ARDS patients.[25] Further study is warranted to clarify the effect of ERV on lung oxygenation in the prone position.

There are limitations in this study. First, the surgeon factor was not considered. It would have been better to have the same surgeon to perform all the surgeries because hemostasis style may be different. However, since patients were randomized and the amount of intraoperative bleeding passed the normality test, the effect must have been negligible. Second, the measurement of intraoperative blood loss might have been inaccurate due to fair amount of irrigation solution and imprecise estimation by anesthesiologists or surgeons. In addition, the small sample size may also have exacerbated the difference in blood loss in this study. However, the effect must have been little since the difference in intraoperative blood loss between the groups was a mean value of 800 mL, which was a clinically significant amount. Third, only patients undergoing PLIF surgery of two to three levels were included in this study because expected blood loss was high. As a result, intraoperative blood loss was quite high and the difference between the groups exceeded 150.5 mL, which was the average intraoperative bleeding used to calculate the sample size. This is why the results of this study were statistically significant despite limited sample size. Therefore, the intervention in this study might be less effective in cases where intraoperative blood loss is expected to be lower, such as minimally invasive surgery or transforaminal lumbar interbody fusion. Fourth, the possibility of autoPEEP during ERV was not considered. However, the occurrence of autoPEEP would have had positive effect on the calculation of the lung compliance. This means both C_{dyn} and C_{stat} values will increase with autoPEEP of 1 or 2 cmH_2O during ERV. Since C_{dyn} and C_{stat} were higher in the ERV group throughout the study, recording the occurrence of autoPEEP would not have affected the result of this study. Last, this study was limited to healthy patients, which limits generalizability of the findings. Further study with larger sample size is warranted.

In conclusion, ERV provided lower PIP and reduced intraoperative surgical bleeding compare to conventional ventilation in patients undergoing PLIF surgery. However, its efficacy will be low in cases of minimal blood loss.

➢ Key Points

- ❑ Bleeding is anticipated during PLIF surgery.
- ❑ In the prone position, engorgement of the vertebral vein increases surgical bleeding.
- ❑ ERV reduced airway pressure and improved dynamic lung compliance.
- ❑ ERV reduced CVP, which may be associated with the pressure of the vertebral veins.
- ❑ ERV reduced intraoperative surgical bleeding and transfusion requirements.

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