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Original Article

Comparison of systemic vascular resistance index-guided versus conventional fluid management on airway pressure, oxygenation and postoperative recovery in patients undergoing one-lung ventilation for thoracic surgery

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Abstract: Objective: To compare the effects of systemic vascular resistance index (SVRI)-guided goal-directed fluid therapy (GDFT) versus conventional fluid management on perioperative airway pressure, oxygenation, and postoperative recovery in thoracic surgery patients with one-lung ventilation (OLV), and to identify independent risk factors for postoperative pulmonary complications (PPCs). Methods: A total of 386 patients were retrospectively enrolled and randomly split into a training set (n=270) and a validation set (n=116) at a 7:3 ratio. The training set was divided into SVRI group (n=155) and control group (n=115). Baseline data, airway pressure, oxygenation, recovery indicators, and 7-day PPCs were collected. Independent risk factors were screened by logistic regression; a nomogram was constructed and evaluated by ROC and calibration curves. Results: Baseline characteristics were comparable between the groups (P>0.05). The SVRI group had lower airway pressure, fluid volume, infusion rate, recovery time, and PPCs incidence, as well as better oxygenation and urine output (all P<0.05). Ppeak ≥26.845 cmH_2O, Pplat ≥21 cmH_2O, ΔP ≥14.945 cmH_2O, and PaO_2/FiO_2 <303.815 mmHg were independent risk factors for PPCs. The combined four-index model showed better predictive efficiency. Conclusion: SVRI-guided GDFT improves perioperative outcomes and reduces PPCs in OLV patients. The four indicators effectively predict PPCs, and their combined detection enhances risk stratification accuracy.

Keywords: One-lung ventilation, systemic vascular resistance index, goal-directed fluid therapy, oxygenation, retrospective study

Introduction

One-lung ventilation (OLV) represents a standard respiratory management technique in thoracic surgery. By selectively isolating the operative lung, OLV creates adequate surgical space and clear visualization for procedures, making it the most widely applied ventilation strategy in this setting [1, 2]. Nonetheless, OLV frequently triggers ventilation-perfusion mismatch, pulmonary tissue compression, and aberrant fluid overload, which collectively impair oxygenation and elevate airway pressure. These pathophysiological changes raise the risk of postoperative pulmonary complications (PPCs) and impede postoperative recovery [3, 4]. For patients receiving OLV during thoracic surgery, maintaining hemodynamic stability and optimizing tissue perfusion demands rigorous perioperative anesthetic management. Conventional fluid management relies heavily on clinical experience and lacks individualized, hemodynamically guided adjustment, which often leads to fluid imbalance and fails to satisfy the physiological and intraoperative requirements of OLV patients [5]. Accordingly, developing a fluid management approach informed by accurate hemodynamic indicators is crucial for minimiz-

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ing PPCs and improving postoperative outcomes in this patient population.

As a key hemodynamic marker reflecting vascular tone and peripheral circulatory resistance, the systemic vascular resistance index (SVRI) reliably characterizes the patient's circulatory volume status and offers a quantitative reference for individualized fluid management [6]. Emerging evidence indicates that SVRI-based target-directed fluid therapy enables adaptive adjustment of fluid infusion rate and total volume in response to real-time hemodynamic fluctuations, thereby achieving personalized fluid optimization [7, 8]. However, whether SVRI guidance can improve airway pressure, oxygenation, and postoperative recovery during fluid management for patients undergoing OLV has not been clinically validated.

Using a retrospective cohort design, this study compared the efficacy of SVRI-guided fluid management versus conventional fluid management in patients undergoing one-lung ventilation (OLV) for thoracic surgery. We assessed the impacts of these two strategies on perioperative airway pressure, oxygenation, and postoperative recovery, and identified key risk factors associated with postoperative outcomes. This study aims to inform the optimization of evidence-based perioperative fluid management protocols for clinical practice.

Methods

Study population

A total of 386 patients who underwent thoracic surgery with one-lung ventilation (OLV) at the General Hospital of Ningxia Medical University between February 2021 and February 2025 were retrospectively enrolled in this cohort study. All patients were randomly split into a training cohort (n=270) and a validation cohort (n=116) at a 7:3 ratio. The training cohort was further divided into an SVRI-guided fluid management group (SVRI group, n=155) and a conventional fluid management group (control group, n=115) according to the intraoperative fluid management strategy applied. The validation cohort was grouped using identical criteria (SVRI group, n=65; control group, n=50). This study was approved by the Medical Ethics Committee of the General Hospital of Ningxia Medical University. Written informed consent was waived due to the retrospective design of the study.

Inclusion criteria: age ≥18 years; undergoing lobectomy, radical esophagectomy, or mediastinal tumor resection; duration of continuous OLV ≥60 minutes; and complete available clinical data. Exclusion criteria: preoperative pulmonary infection or acute respiratory distress syndrome (ARDS), severe cardiac, hepatic and renal dysfunction, emergency surgery and missing key clinical variables.

Data collection

Baseline data, surgical and anesthetic records, postoperative laboratory test results, and imaging findings were collected from the hospital's electronic medical record system. Data were independently extracted by two trained researchers, verified for consistency and entered into an Excel database. Discrepancies were adjudicated by a senior physician as the third party.

Fluid management

The SVRI group received SVRI-guided goal-directed fluid therapy. SVRI was continuously monitored via pulse contour cardiac output monitoring and recorded every 15 minutes during the operation. The intervention threshold was set as 1200-2000 $dyn{\cdot}s{\cdot}cm^{-5}{\cdot}m^{-2}$; crystalloid fluid was infused at 3-5 $ml{\cdot}kg^{-1}{\cdot}h^{-1}$ when SVRI<1200 $dyn{\cdot}s{\cdot}cm^{-5}{\cdot}m^{-2}$; maintained at 1-2 $ml{\cdot}kg^{-1}{\cdot}h^{-1}$ when SVRI was within 1200-2000 $dyn{\cdot}s{\cdot}cm^{-5}{\cdot}m^{-2}$; and infusion rate was reduced with low-dose vasoactive drugs if needed when SVRI>2000 $dyn{\cdot}s{\cdot}cm^{-5}{\cdot}m^{-2}$. The control group received conventional empirical fluid management, with crystalloid infusion at 4-6 $ml{\cdot}kg^{-1}{\cdot}h^{-1}$ adjusted according to blood pressure, heart rate and urine output, without SVRI monitoring or targeted intervention.

Outcome measures

Baseline clinical data: Demographic characteristics: age, gender, body mass index (BMI), comorbidities (hypertension, diabetes mellitus), smoking history, surgical type (lobectomy, radical resection of esophageal cancer, mediastinal tumor resection), intraoperative ventilation parameters (tidal volume, positive end-expiratory pressure [PEEP]), use of vasoactive drugs, intraoperative blood loss volume and intraoperative blood transfusion volume were collected.

Airway pressure parameters: Peak airway pressure (Ppeak), plateau pressure (Pplat) and driving pressure (ΔP=Pplat - PEEP) were monitored and recorded using an anesthetic ventilator before and at the end of OLV.

Oxygenation function indicators: Arterial partial pressure of oxygen (PaO_2) and fraction of inspired oxygen (FiO_2) were measured via arterial blood gas analysis before and at the end of OLV and the oxygenation index (PaO_2/FiO_2) was calculated.

Postoperative recovery indicators: Time to recovery of spontaneous breathing, time to tracheal extubation, intensive care unit (ICU) length of stay, postoperative hospital stay, total fluid infusion volume, infusion rate, urine output and intraoperative mean SVRI of SVRI group were documented.

Incidence of postoperative pulmonary complications (PPCs): The occurrence of PPCs within 7 days after surgery was recorded, including atelectasis, pneumonia, hypoxemia, respiratory failure, bronchospasm and pneumothorax/pleural effusion.

Statistical analysis

Statistical analyses were performed using SPSS 26.0 software. Measurement data were presented as mean ± standard deviation (SD) and compared between groups using the independent-samples t-test. Count data were expressed as cases (percentage) and analyzed via the χ^2 test. Bonferroni correction was applied for multiple comparisons of airway pressure and oxygenation parameters to control the Type I error rate. For the predictive model, 32 events of PPCs occurred in the training set, with 4 independent variables included in the final model, yielding an events-per-variable (EPV) ratio of 8 (close to the recommended threshold of 10). To mitigate model overfitting, the cohort was randomly split into training and validation sets at a 7:3 ratio, supplemented by stepwise multivariate logistic regression, internal calibration curves and external validation. Before multivariate logistic regression, multicollinearity was assessed using the variance inflation factor (VIF), with VIF<10 indicating no severe collinearity. The Hosmer-Lemeshow (H-L) test was used to evaluate model goodness-of-fit, and P>0.05 indicated satisfactory fitting. Univariate logistic regression was conducted to screen potential risk factors for PPCs. Variables with P<0.10 were included in multivariate logistic regression, and stepwise selection was used to identify independent risk factors. A nomogram model was constructed based on the independent risk factors. Receiver operating characteristic (ROC) curves were plotted and the area under the curve (AUC), sensitivity and specificity were calculated to assess the model's predictive performance. A two-sided P<0.05 was considered statistically significant.

Results

Baseline characteristics of the training and validation sets

No statistically significant differences were observed in baseline characteristics between the training set and validation set, including age, gender, history of hypertension, history of diabetes mellitus, smoking history, surgical type, intraoperative tidal volume, PEEP, use of vasoactive drugs, blood loss volume and blood transfusion volume (all P>0.05, **Table 1**).

Baseline characteristics between the SVRI and control groups

There were no significant between-group differences in baseline data, including age, gender, comorbidities (hypertension, diabetes mellitus), smoking history, surgical type, intraoperative tidal volume, PEEP, use of vasoactive drugs, blood loss volume and blood transfusion volume (all P>0.05, **Table 2**), indicating good comparability between the SVRI group and the control group.

Comparison of airway pressure and oxygenation parameters before and after OLV between the two groups

As shown in **Table 3**, no significant differences in baseline airway pressure and oxygenation parameters were detected between the two groups before OLV (all P>0.05). At the end of OLV, airway pressure parameters were significantly elevated and oxygenation function was markedly decreased in both groups relative to pre-OLV levels. After Bonferroni correction for multiple comparisons, the SVRI group had significantly lower Ppeak, Pplat and ΔP, as well as a significantly higher PaO_2/FiO_2 ratio, than the control group (all P<0.05).

Table 1. Baseline data of the training set and the validation set [n (%), $\bar{x}\pm$sd]

	Training set (n=270)	Validation set (n=116)	t/χ^2	*P*
Age (yr)	56.85±2.63	56.82±2.71	0.102	0.919
Gender			0.730	0.392
Male	157 (58.1)	62 (53.4)		
Female	113 (41.9)	54 (46.6)		
BMI (kg/m^2)	22.60±2.62	22.59±2.58	0.035	0.973
Diabetes			0.026	0.872
Yes	156 (57.8)	66 (56.9)		
No	114 (42.2)	50 (43.1)		
Hypertension			0.398	0.528
Yes	188 (69.6)	77 (66.4)		
No	82 (30.4)	39 (33.6)		
Smoking history			0.114	0.736
Yes	165 (61.1)	73 (62.9)		
No	105 (38.9)	43 (37.1)		
Surgical type			0.148	0.929
Lobectomy	96 (35.6)	39 (33.6)		
Esophageal cancer radical resection	85 (31.5)	37 (31.9)		
Mediastinal tumor resection	89 (33.0)	40 (34.5)		
Intraoperative tidal volume (ml/kg)	8.09±0.66	8.11±0.64	0.275	0.783
Intraoperative PEEP (cmH_2O)	5.04±0.46	5.06±0.41	0.404	0.686
Use of vasoactive drugs			0.100	0.751
Yes	55 (20.4)	22 (19.0)		
No	215 (79.6)	94 (81.0)		
Intraoperative blood loss volume (ml)	125.47±16.24	125.11±16.87	0.197	0.844
Intraoperative blood transfusion volume (ml)	52.40±4.65	52.68±4.77	0.538	0.591

Notes: BMI: body mass index; PEEP: positive end-expiratory pressure.

Comparison of postoperative recovery indicators between the two groups

As shown in **Table 4**, the SVRI group had significantly shorter time to recovery of spontaneous breathing, time to tracheal extubation, ICU length of stay, postoperative hospital stay and lower total fluid infusion volume and infusion rate compared with the control group, while intraoperative urine output was significantly higher (all P<0.05). The mean intraoperative SVRI value in the SVRI group was maintained within the target range (1200-2000 dyn·s·cm^{-5}·m^{-2}).

Comparison of the incidence of PPCs between the two groups

As presented in **Table 5**, the incidence of PPCs in the SVRI group was 7.7% (12/155), which was significantly lower than the 17.4% (20/115) observed in the control group (P<0.05). Subgroup analysis classified by complication type showed that the incidences of hypoxemia and pneumothorax/pleural effusion in the SVRI group were significantly lower than those in the control group (all P<0.05). There were no significant differences in the incidences of atelectasis, pneumonia, respiratory failure and bronchospasm between the two groups (all P>0.05).

Comparison of clinical parameters between patients with and without PPCs

No significant differences were found in age, gender, history of hypertension, history of diabetes mellitus, smoking history, surgical type, intraoperative tidal volume, PEEP, use of vasoactive drugs, blood loss volume and blood transfusion volume, time to recovery of spontaneous breathing, time to tracheal extubation, ICU length of stay, or postoperative hospital stay between the PPCs group and the non-PPCs group (all P>0.05). Patients who developed

Table 2. Baseline data of the SVRI group and the control group [n (%), $\bar{x}\pm$sd]

	SVRI group (n=155)	Control group (n=115)	t/χ^2	*P*
Age (yr)	56.90±2.81	56.77±2.38	0.401	0.689
Gender			0.047	0.828
Male	91 (58.7)	66 (57.4)		
Female	64 (41.3)	49 (42.6)		
BMI (kg/m^2)	22.66±2.80	22.52±2.37	0.307	0.759
Diabetes			0.150	0.698
Yes	88 (56.8)	68 (59.1)		
No	67 (43.2)	47 (40.9)		
Hypertension			0.266	0.606
Yes	106 (68.4)	82 (71.3)		
No	49 (31.6)	33 (28.7)		
Smoking history			0.883	0.347
Yes	91 (58.7)	74 (64.3)		
No	64 (41.3)	41 (35.7)		
Surgical type			1.121	0.571
Lobectomy	51 (32.9)	45 (39.1)		
Esophageal cancer radical resection	51 (32.9)	34 (29.6)		
Mediastinal tumor resection	53 (34.2)	36 (31.3)		
Intraoperative tidal volume (ml/kg)	8.11±0.70	8.07±0.59	0.496	0.620
Intraoperative PEEP (cmH_2O)	5.05±0.49	5.02±0.41	0.533	0.595
Use of vasoactive drugs			1.954	0.162
Yes	27 (17.4)	28 (24.3)		
No	128 (82.6)	87 (75.7)		
Intraoperative blood loss volume (ml)	125.82±17.30	124.99±14.76	0.415	0.679
Intraoperative blood transfusion volume (ml)	52.51±4.97	52.25±4.20	0.454	0.651

Notes: SVRI: systemic vascular resistance index; BMI: body mass index; PEEP: positive end-expiratory pressure.

PPCs had significantly higher Ppeak, Pplat and ΔP, along with significantly lower PaO_2/FiO_2, than those without PPCs (all P<0.05, **Table 6**).

Univariate and multivariate logistic regression analyses of risk factors for PPCs

Assignment of variables with significant between-group differences in **Table 6** is shown in **Table 7**. Multicollinearity test results showed that the VIF values of the four independent variables ranged from 1.23 to 2.15 (all<10), indicating no significant multicollinearity. The Hosmer-Lemeshow test yielded χ^2=6.328, P=0.610, suggesting a favorable goodness-of-fit of the model. Univariate logistic regression analysis (**Table 8**) and multivariate logistic regression analysis (**Table 9**) identified Ppeak ≥26.845 cmH_2O, Pplat ≥21 cmH_2O, ΔP ≥14.945 cmH_2O and PaO_2/FiO_2 <303.815 mmHg as independent risk factors for the development of PPCs in patients undergoing OLV.

Nomogram model for predicting the risk of PPCs

The nomogram for the training set revealed that PaO_2/FiO_2 was the strongest predictor of PPCs, with the most prominent contribution to risk prediction, while Ppeak, Pplat and ΔP had relatively weaker effects (**Figure 1A**). In the validation set, all four indicators (Ppeak, Pplat, ΔP, and PaO_2/FiO_2) were strong predictors of PPCs (**Figure 1B**). Calibration curves demonstrated that the model incorporating these four parameters had favorable predictive performance for PPCs in both the training set (**Figure 1C**) and the validation set (**Figure 1D**). The combined validation strategies effectively eliminated the risk of model overfitting and ensured the stability and generalizability of the nomogram.

ROC curve analysis of the prediction model

The results of ROC curve analysis are summarized in **Table 10** and **Figure 2**. In the training

Table 3. Comparison of airway pressure indexes and oxygenation function indexes before and after OLV between the two groups ($\bar{x}$±sd)

Group	n	Ppeak (cmH_2O)		Pplat (cmH_2O)		ΔP (cmH_2O)		PaO_2/FiO_2 (mmHg)	
		Before OLV	At the end of OLV	Before OLV	At the end of OLV	Before OLV	At the end of OLV	Before OLV	At the end of OLV
SVRI group	155	18.37±1.03	25.56±1.16*	13.97±1.13	19.58±1.07*	9.87±0.73	13.98±0.82*	406.32±13.73	310.18±8.34*
Control group	115	18.49±1.17	26.57±1.24*	14.02±1.25	20.71±1.17*	9.79±0.86	14.74±0.75*	408.83±12.76	303.22±11.57*
t		0.893	6.869	0.344	8.245	0.825	7.807	1.530	5.745
P		0.373	<0.001	0.732	<0.001	0.410	<0.001	0.127	<0.001

Notes: SVRI: systemic vascular resistance index; Ppeak: Peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen. *P < 0.05 compared with baseline.

Table 4. Comparison of postoperative rehabilitation indexes between the two groups

Group	n	Recovery time of spontaneous breathing (min)	Tracheal extubation time (h)	ICU stay time (h)	Hospital stay (d)
SVRI group	155	23.06±1.49	4.89±0.54	22.43±1.24	8.86±0.61
Control group	115	24.51±1.21	5.60±0.49	23.72±1.12	9.70±0.64
t		8.551	11.109	8.805	10.956
P		<0.001	<0.001	<0.001	<0.001

Intraoperative mean SVRI ($dyn{\cdot}s{\cdot}cm^{-5}{\cdot}m^{-2}$)	Total fluid infusion volume (ml)	Fluid infusion rate ($ml{\cdot}kg^{-1}{\cdot}h^{-1}$)	Intraoperative urine output (ml)
1628.35±185.62	925.57±76.11	2.23±0.25	238.33±23.87
-	1061.82±71.44	2.63±0.20	193.60±23.41
-	14.928	14.127	15.351
-	<0.001	<0.001	<0.001

Notes: SVRI: systemic vascular resistance index.

Table 5. Comparison of PPCs occurrence between the two groups [n (%)]

Group	n	Atelectasis	Pneumonia	Hypoxemia	Respiratory failure	Bronchospasm	Pneumothorax/ Pleural effusion	PPCs incidence
SVRI group	155	3 (1.9)	2 (1.3)	0 (0.00)	4 (2.6)	3 (1.9)	0 (0.00)	12 (7.7)
Control group	115	4 (3.5)	5 (4.3)	3 (2.6)	0 (0.00)	3 (2.6)	5 (4.3)	20 (17.4)
χ^2		0.622	2.444	4.089	3.012	0.138	6.866	5.884
P		0.430	0.117	0.043	0.083	0.711	0.009	0.015

Notes: SVRI: systemic vascular resistance index; PPCs: postoperative pulmonary complications.

set, each individual indicator (Ppeak, Pplat, ΔP, and PaO_2/FiO_2) exhibited favorable diagnostic performance for PPCs, with the combined model achieving significantly better diagnostic efficacy than any single marker (**Figure 2A**). Consistent results were observed in the validation set, where the combined model also outperformed individual indicators in the diagnostic prediction of PPCs (**Figure 2B**).

Discussion

OLV is a staple respiratory support strategy in thoracic surgery. While it optimizes surgical exposure and maintains operative ventilation, it often disrupts fluid homeostasis, exacerbates pulmonary injury, and elevates the risk of PPCs [9, 10]. Conventional fluid administration relies heavily on clinician's experience rather than individualized hemodynamic monitoring, which frequently results in either fluid overload or inadequate tissue perfusion - two major pitfalls that compromise perioperative outcomes [11, 12]. Against this clinical gap, the present retrospective cohort study investigated the impacts of SVRI-guided goal-directed fluid therapy on perioperative airway pressure, oxygenation and postoperative recovery in patients undergoing OLV for thoracic surgery and identified independent risk factors for PPCs. To our knowledge, this study is the first to validate the clinical utility of SVRI for targeted fluid management in this

Table 6. Baseline data of the training set and the validation set [n (%), $\bar{x}\pm sd$]

	PPCs group (n=32)	Non-PPCs group (n=238)	t/χ^2	*P*
Age (yr)	56.97±2.73	56.83±2.62	0.282	0.897
Gender			0.376	0.540
Male	17 (53.1)	140 (58.8)		
Female	15 (46.9)	98 (41.2)		
BMI (kg/m^2)	22.64±2.58	22.59±2.63	0.101	0.920
Diabetes			0.035	0.852
Yes	18 (56.3)	138 (58.0)		
No	14 (43.7)	100 (42.0)		
Hypertension			0.118	0.732
Yes	21 (65.6)	167 (70.2)		
No	11 (34.4)	71 (29.8)		
Smoking history			0.974	0.324
Yes	17 (53.1)	148 (62.2)		
No	15 (46.9)	90 (37.8)		
Surgical type			0.393	0.822
Lobectomy	12 (37.5)	84 (35.3)		
Esophageal cancer radical resection	11 (34.4)	74 (31.1)		
Mediastinal tumor resection	9 (28.1)	80 (33.6)		
Intraoperative tidal volume (ml/kg)	8.11±0.56	8.09±0.67	0.161	0.872
Intraoperative PEEP (cmH_2O)	5.02±0.45	5.04±0.46	0.231	0.817
Use of vasoactive drugs			0.059	0.808
Yes	6 (18.8)	49 (20.6)		
No	26 (81.3)	189 (79.4)		
Intraoperative blood loss volume (ml)	124.98±17.66	125.54±16.08	0.183	0.855
Intraoperative blood transfusion volume (ml)	52.18±4.55	52.43±4.67	0.285	0.776
Recovery time of spontaneous breathing (min)	23.35±1.36	23.72±1.57	1.270	0.205
Tracheal extubation time (h)	5.36±0.67	5.17±0.62	1.612	0.108
ICU stay time (h)	22.67±1.49	23.02±1.33	1.377	0.170
Hospital stay (d)	9.16±0.72	9.23±0.75	0.498	0.619
Total fluid infusion volume (ml)	985.62±97.55	983.33±100.72	0.121	0.904
Fluid infusion rate ($ml{\cdot}kg^{-1}{\cdot}h^{-1}$)	2.48±0.23	2.39±0.31	1.584	0.115
Intraoperative urine output (ml)	216.35±31.66	219.67±32.54	0.544	0.587
Ppeak (cmH_2O)	27.47±1.28	25.79±1.16	7.597	<0.001
Pplat (cmH_2O)	21.47±1.18	19.87±1.13	7.481	<0.001
ΔP (cmH_2O)	15.29±0.89	14.17±0.78	7.496	<0.001
PaO_2/FiO_2 (mmHg)	295.00±8.94	308.86±9.48	7.815	<0.001

Notes: PPCs: postoperative pulmonary complications; BMI: body mass index; PEEP: positive end-expiratory pressure; Ppeak: Peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen.

specific patient population. Below, we discuss our key findings in depth with reference to existing literature.

Our results demonstrated that postoperative Ppeak, Pplat, and ΔP were significantly lower, while PaO_2/FiO_2 was markedly higher in the SVRI group than those in the control group. These findings are consistent with those reported by Wang et al. [13] and Xing et al. [14], indicating that SVRI-guided goal-directed fluid therapy (GDFT) yields better outcomes in perioperative airway pressure and oxygenation relative to conventional fluid management. The underlying mechanism may be attributed to the critical role of SVRI. As a key hemodynamic

Table 7. Assignment of influencing factors

Influencing factors	Assignment
Ppeak	0: <26.845 cmH_2O
	1: ≥26.845 cmH_2O
Pplat	0: <21 cmH_2O
	1: ≥21 cmH_2O
ΔP	0: <14.945 cmH_2O
	1: ≥14.945 cmH_2O
PaO_2/FiO_2	0: ≥303.815 mmHg
	1: <303.815 mmHg

Notes: Ppeak: peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen.

marker reflecting systemic vascular tone and peripheral circulatory resistance, SVRI precisely delineates the patient's circulatory volume status; its real-time fluctuations directly mirror the balance between fluid infusion and physiological demand [15]. By dynamically monitoring SVRI, this strategy enables adaptive titration of fluid infusion rate and total volume, thereby realizing individualized and precise fluid optimization and alleviating pulmonary injury caused by fluid overload [16, 17]. Concurrently, the SVRI group presented significantly shorter spontaneous breathing recovery time, tracheal extubation time, ICU length of stay, and postoperative hospital stay, suggesting that SVRI-guided GDFT effectively promotes postoperative rehabilitation. This benefit is likely ascribed to the attenuation of OLV-related pulmonary tissue damage, which accelerates the recovery of spontaneous respiration and the overall rehabilitation process, ultimately improving postoperative recovery outcomes [18, 19].

PPCs are critical adverse events that impair postoperative recovery and long-term prognosis in patients undergoing OLV for thoracic surgery and their incidence serves as a key indicator for evaluating the quality of perioperative anesthetic management [20]. Our results demonstrated that the incidence of PPCs was significantly lower in the SVRI-guided group than that in the conventional control group, which is consistent with the findings reported by Zhu et al. [21] and Yang et al. [22]. These data confirm the clinical advantages of SVRI-guided fluid therapy in reducing the risk of PPCs relative to conventional management. Subgroup analysis further revealed that SVRI-guided fluid management primarily lowered the incidence of hypoxemia and pneumothorax/pleural effusion, two complications tightly associated with fluid overload and impaired oxygenation. This finding identifies targeted clinical indications for SVRI application in preventing specific PPCs, thereby enhancing the translational value of our study results.

Univariate and multivariate logistic regression analyses identified elevated airway pressure-related parameters and reduced PaO_2/FiO_2 as independent risk factors for PPCs, with PaO_2/FiO_2 showing the most pronounced predictive impact. Elevated Ppeak and Pplat induce excessive alveolar distension and exacerbate secondary lung injury [23, 24]. As a core marker of pulmonary mechanical stress, sustained increases in ΔP damage alveolar and vascular endothelia, disrupt ventilation-perfusion matching and establish the pathological basis for PPCs [25]. PaO_2/FiO_2 is a standard clinical index for assessing systemic oxygenation; its reduction directly reflects impaired alveolar gas exchange and increased intrapulmonary shunting in OLV patients, which significantly elevates the risk of PPCs [26].

The nomogram prediction model incorporating Ppeak, Pplat, ΔP, and PaO_2/FiO_2 showed satisfactory calibration in both the training and validation sets. The AUC for the combined four-indicator panel was markedly higher than that for any single indicator, with AUC values of 0.903 in the training set and 0.953 in the validation set. These results confirm that combined detection of these parameters can comprehensively reflect pulmonary function in OLV patients and substantially improve the accuracy of PPCs risk stratification. Each indicator provides unique complementary information: PaO_2/FiO_2 directly quantifies pulmonary gas exchange function; Ppeak reflects peak airway resistance during ventilation; Pplat indicates static lung compliance; and ΔP serves as a core marker for ventilator-induced lung injury. Together, these indices characterize OLV-related pulmonary damage from both functional and structural perspectives [27, 28]. Combined detection captures concurrent functional abnormalities and structural alterations in pulmonary injury, offsets the limitations of insufficient specificity or sensitivity of single indicators and significantly enhances the identification of high-risk patients for PPCs.

Table 8. Univariate Logistic regression analysis of factors influencing PPCs occurrence

Factors	β	StdError	Wald x^2	P	OR	95% CI	
						Lower	Upper
Ppeak ≥26.845 cmH_2O	2.508	0.429	34.172	<0.001	12.279	5.296	28.467
Pplat ≥21 cmH_2O	2.580	0.424	37.034	<0.001	13.200	5.750	30.302
ΔP ≥14.945 cmH_2O	2.582	0.417	37.117	<0.001	13.105	5.652	30.281
PaO_2/FiO_2 <303.815 mmHg	2.728	0.444	37.723	<0.001	15.308	6.409	36.562

Notes: OR: Odds Ratio; Ppeak: peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen.

Table 9. Multivariate logistic regression analysis of factors influencing PPCs occurrence

Factors	β	StdError	Wald x^2	P	OR	95% CI	
						Lower	Upper
Ppeak ≥26.845 cmH_2O	1.142	0.535	4.555	0.033	3.132	1.098	8.937
Pplat ≥21 cmH_2O	1.190	0.551	4.667	0.031	3.289	1.117	9.684
ΔP ≥14.945 cmH_2O	1.262	0.544	5.392	0.020	3.534	1.218	10.257
PaO_2/FiO_2 <303.815 mmHg	2.010	0.502	16.033	<0.001	7.461	2.790	19.955

Notes: OR: Odds Ratio; Ppeak: peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen.

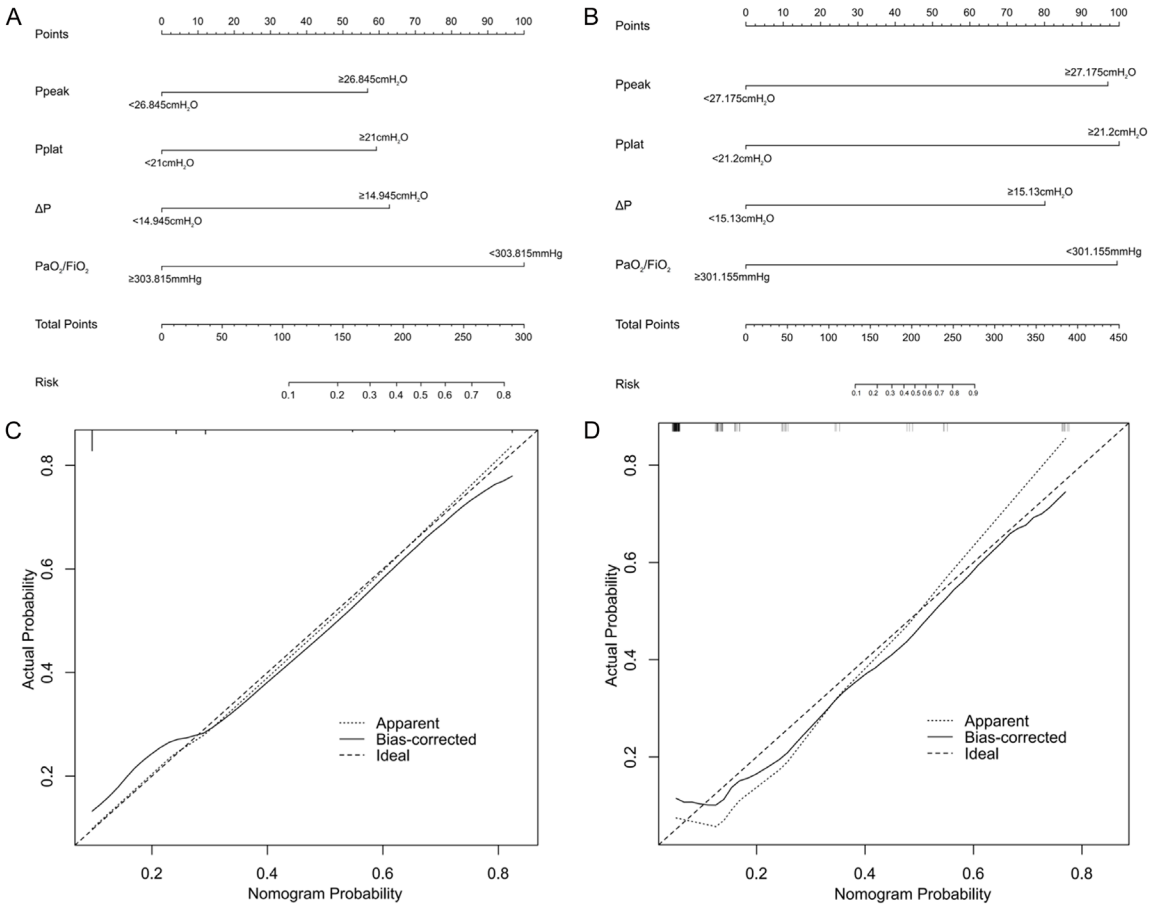

Figure 1. Construction and diagnostic performance evaluation of the Nomogram model. A. Nomogram for training set; B. Nomogram for validation set; C. Calibration curve for validating the Nomogram of training set; D. Calibration curve for validating the Nomogram of validation set. Notes: Ppeak: peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen.

Table 10. ROC curve analysis of each risk factor for predicting PPCs occurrence

Group	Factor	AUC	P	95% CI	Sensitivity	Specificity	Youden index	Cut-off value
Training set	Ppeak	0.847	<0.001	0.773-0.921	0.719	0.828	0.547	26.845 cmH_2O
	Pplat	0.849	<0.001	0.776-0.921	0.688	0.857	0.545	21 cmH_2O
	ΔP	0.841	<0.001	0.765-0.917	0.688	0.857	0.545	14.945 cmH_2O
	PaO_2/FiO_2	0.860	<0.001	0.793-0.926	0.689	0.875	0.564	303.815 mmHg
	Combine	0.903	<0.001	0.853-0.957	0.781	0.878	0.659	-
Validation set	Ppeak	0.848	<0.001	0.725-0.970	0.750	0.930	0.680	27.175 cmH_2O
	Pplat	0.847	<0.001	0.725-0.968	0.750	0.930	0.680	21.2 cmH_2O
	ΔP	0.844	<0.001	0.724-0.964	0.750	0.910	0.660	15.13 cmH_2O
	PaO_2/FiO_2	0.858	<0.001	0.765-0.951	0.778	0.846	0.624	301.155 mmHg
	Combine	0.953	<0.001	0.868-1.000	0.938	0.950	0.888	-

Notes: ROC: Receiver Operating Characteristic; AUC: Area Under the Curve; 95% CI: 95% Confidence Interval; Ppeak: peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen.

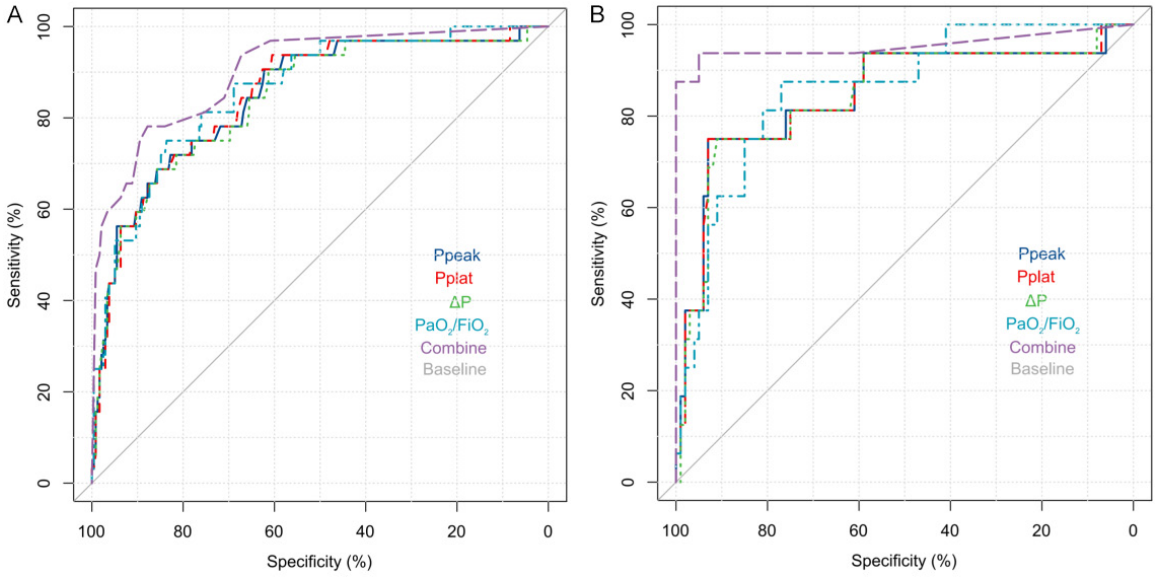

Figure 2. ROC curves predicting PPCs occurrence. A. Training set; B. Validation set. Notes: Ppeak: peak airway pressure; Pplat: plateau pressure; ΔP: driving pressure; PaO_2: arterial partial pressure of oxygen; FiO_2: fraction of inspired oxygen.

There are still some limitations in this study. First, this was a single-center retrospective cohort design, which may introduce selection bias during patient enrollment. Second, the study had a moderate sample size, which precluded subgroup analyses to evaluate the efficacy of SVRI-guided fluid therapy across different surgical procedures, thereby limiting the external generalizability of our findings. Third, follow-up was restricted to PPCs occurring within 7 days postoperatively, which prevented assessment of the long-term clinical benefits of SVRI-guided fluid management. Future investigations should adopt a multicenter, prospective, randomized controlled design to define the optimal SVRI target range during OLV for various thoracic surgeries. Prolonged follow-up is also recommended to evaluate long-term improvements in pulmonary function, quality of life, and survival, to fully elucidate the long-term clinical value of SVRI-guided fluid therapy.

Conclusion

SVRI-guided goal-directed fluid therapy represents an optimized perioperative fluid management strategy for patients undergoing OLV during thoracic surgery. This approach effectively

reduces perioperative airway pressure, improves oxygenation, accelerates postoperative recovery and significantly lowers the incidence of PPCs. Ppeak, Pplat, ΔP, and PaO_2/FiO_2 are reliable quantitative markers for predicting PPCs in OLV patients, and combined detection of these four indicators markedly enhances predictive accuracy.

Disclosure of conflict of interest

None.

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