Am J Transl Res 2022;14(12):8621-8631
www.ajtr.org /ISSN:1943-8141/AJTR0145114

Original Article

The predictive value of lung ultrasound combined with central venous oxygen saturation variations in the outcome of ventilator weaning in patients after thoracic surgery

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Received July 4, 2022; Accepted November 2, 2022; Epub December 15, 2022; Published December 30, 2022

Abstract: Objective: To evaluate the predictive value of lung ultrasound score (LUS) combined with central venous oxygen saturation variations ($\Delta ScvO_2$) in the outcome of ventilator weaning in patients after thoracic surgery. Methods: The clinical data of 60 patients who received tracheal intubation ventilator-assisted breathing after thoracic surgery were retrospectively analyzed, and they were divided into successful (n = 35) and failed (n = 25) groups according to the postoperative weaning outcomes. The factors influencing the failure of weaning in patients after thoracic surgery were compared and analyzed, and the values of LUS, $\Delta ScvO_2$ as well as the combination of both were calculated to predict the failure of weaning in patients after thoracic surgery. Results: The results of logistic regression analysis showed that LUS, $\Delta ScvO_2$, and partial pressure of carbon dioxide ($PaCO_2$) may be risk factors influencing weaning failure in patients after thoracic surgery (*OR* = 1.844, 4.006, 1.271, *P* < 0.001 for all), while diaphragm thickening fraction (DTF) and partial pressure of oxygen (PaO_2) may be protective factors (*OR* = 0.852, 0.674, *P* = 0.002 for all). Receiver operator characteristic (ROC) curve showed that area under the curves (AUCs) of LUS, $\Delta ScvO_2$, and the combination of the two was 0.865 (95% CI: 0.766-0.964), 0.874 (95% CI: 0.781-0.967), and 0.925 (95% CI: 0.860-0.990), respectively, in predicting failure of weaning in patients after thoracic surgery. Conclusion: LUS and $\Delta ScvO_2$ were closely related to chest ultrasound index and arterial blood gas index in patients after thoracic surgery, both of which may be risk factors for weaning failure in patients after thoracic surgery, and their combination can effectively predict the occurrence of weaning failure.

Keywords: Thoracic surgery, weaning, lung ultrasound score, central venous oxygen saturation variations

Introduction

Due to long operation time, mechanical injury, large amount of intraoperative blood loss, and the persistent effects of anesthetics, thoracic surgery often damages the periodic respiratory function and respiratory system of patients, and if this condition persists, it will aggravate complications such as pulmonary atelectasis, respiratory tract infection, and pulmonary edema, and delay the postoperative recovery [1, 2]. Therefore, ventilator-assisted respiratory support is often given to postoperative patients after thoracic surgery, but prolonged use of ventilator increases adverse outcomes such as pneumonia, weaning failure, and diaphragm dysfunction [3]. Data show that the weaning failure rate of mechanically ventilated patients is up to 30%, and weaning failure is associated with prolonged intensive care unit (ICU) stay and increased risk of death [4]. The spontaneous breathing trial (SBT) is traditionally used to assess the process of weaning, but about 3-30% of patients who pass the SBT have difficulty in maintaining spontaneous breathing due to cardiac, pulmonary, and diaphragmatic dysfunction, resulting in reintubation within 48 h of weaning [5, 6]. Therefore, it is crucial to actively explore a reliable and convenient tool or marker during the weaning process to determine the oxygen supply and demand changes and pulmonary ventilation status. Lung ultrasound score (LUS) can quantitatively assess the respiratory dead space and effectively reflect the degree of pulmonary ventilation variations and pulmonary conditions [7, 8]. Central venous oxygen saturation ($ScvO_2$) is a key parameter for hemodynamic monitoring, which can provide the balance data between oxygen consumption and delivery and reflect tissue perfusion and cardiac function [9]. It has been confirmed [10, 11] that both LUS and respiratory dead space can be used to assess the success rate of weaning, but they have shortcomings such as low sensitivity and low specificity. However, there are few clinical studies on the combination of the two to predict the success rate of weaning from ventilator, especially in patients undergoing thoracic surgery. The purpose of this study was to evaluate the predictive value of LUS combined with $\Delta ScvO_2$ in the outcome of weaning in patients after thoracic surgery, aiming to further guide the clinical selection of the appropriate timing of weaning.

Materials and methods

General data

The clinical data of 60 patients who received ventilator-assisted breathing after thoracic surgery in the Department of Critical Care Medicine of the First Affiliated Hospital of Gannan Medical University from July 2020 to May 2022 were retrospectively analyzed. The patients included 32 males and 28 females; aged from 23 to 67 with an average age of 43.6±5.8 years; body mass index of 20.54-26.87 kg/m^2; surgery mode: 21 cases of median open chest and 39 cases of lateral open chest; disease type: 19 cases of complex heart disease, 27 cases of intrathoracic disease, 8 cases of esophageal cancer, 3 cases of cardia cancer, and 3 cases of mediastinal tumor.

Inclusion criteria: Patients who had tracheal intubation after thoracic surgery with an duration of mechanical ventilation > 24 h; Patients with an age ≥ 18 years; Patients who met SBT criteria: according to the Practical Guidelines for Mechanical Ventilation (2006 edition) [12], weaning screening test was carried out, and patients met the following four requirements: (I) the cause of mechanical ventilation was improved or removed; (II) oxygenation index: partial pressure of oxygen (PaO_2)/inspired oxygen concentration (FiO_2) > 150-200 mmHg; positive end-expiratory pressure (PEEP) ≤ 5-8 cmH_2O; FiO_2 ≤ 0.4-0.5; pH ≥ 7.25; COPD patients: pH > 7.30, PaO_2 > 50 mmHg, FiO_2 < 0.35; (III) stable hemodynamics, no active myocardial ischemia, no clinically significant hypotension [no need for vasoactive therapy or only low doses of vasoactive drugs such as dopamine or dobutamine, < 5-10 μg/(kg·min)]; (IV) if the weaning screening test was passed, the spontaneous breathing test was carried out; if patient could pass T-tube test in 3 min and continued spontaneous breathing for 30-120 min, the weaning was considered; and Patients with complete clinical data.

Exclusion criteria: Patients with the following criteria were excluded: previous history of pleural surgery, cardiac surgery, tracheotomy; neuromuscular pathology (myasthenia gravis, Grimballi, etc.), diaphragmatic palsy, massive pleural effusion, pneumothorax, thoracic deformity; administration of inotropes, vasoactive drugs within 48 h before enrollment; combined with severe chronic obstructive pulmonary disease or severe arrhythmias such as ventricular tachycardia, frequent ventricular premature, atrial fibrillation, atrial flutter; previous SBT failure; death during mechanical ventilation or accidental extubation during ventilator therapy; shackle chest or rib fracture; pregnancy or lactation.

This study was approved by the Ethics Committee of the First Affiliated Hospital of Gannan Medical University. The subjects and their families were informed and signed a fully-informed consent form before the start of the treatment.

Methods

Anesthesia

All patients underwent thoracic surgery. After entering the operation room, routine electrocardiogram monitoring was performed, and peripheral and central venous access was opened. Anesthesia induction: 0.04 mg/kg midazolam (Jiangsu Nhwa Pharmaceutical Co., Ltd., No. 20180514), 0.4 μg/kg sufentanil (Yichang Humanwell Pharmaceutical Co., Ltd., No. 200503312), and 1 mg/kg rocuronium (Jiangsu Nhwa Pharmaceutical Co., Ltd., No. 20170622) were given intravenously, 3 μg/mL

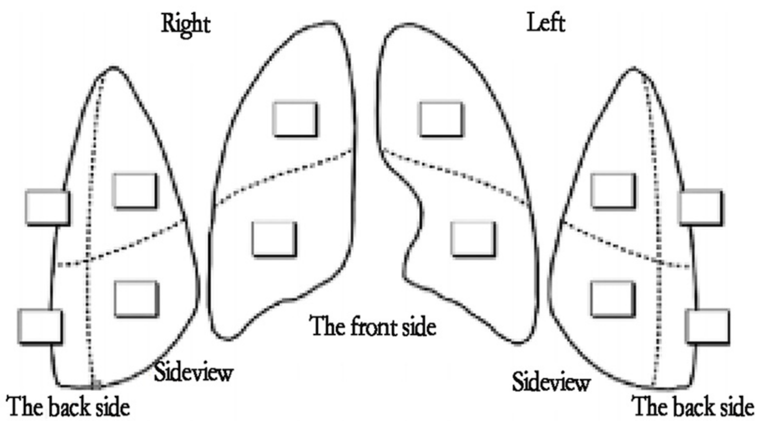

Figure 1. 12 lung-zones in lung ultrasound.

propofol (Guangdong Jiabo Pharmaceutical Co., Ltd., No. 081110) was given by target-controlled infusion, and assisted breathing was performed. Mechanical ventilation was performed in volume control mode, with tidal volume during 1-lung ventilation of 8 mL/kg, respiratory rate of 12-14 min/time, inhalation and inhalation ratio of 1:1.5, inhalation of pure oxygen 2 L/min, and the end-expiratory partial pressure of carbon dioxide (PCO_2) was continuously monitored. Anesthesia maintenance: 10-20 μg/(kg·h) remifentanil (Yichang Humanwell Pharmaceutical Co., Ltd., No. 190401) and 5 μg/(kg·min) cis-atracurium (Jiangsu Hengrui Medicine Co., Ltd., No. 16051713) were infused at a constant rate, and 1-1.3 MAC sevoflurane (Maruishi Pharmaceutical Co., Ltd., No. 7619) was inhaled for maintenance. The effect compartment concentration of propofol was set at 3 μg/mL according to the body mass and age of patients. All patients used a restrictive fluid infusion strategy, and in the absence of absolute fluid deficiency in hypotension and definite hypertension, vasoactive drugs were used to maintain circulatory stability. In case of intraoperative bleeding, an equal amount of colloid was supplemented accordingly.

Grouping

The weaning was considered successful if the following conditions were met within 48 h of weaning: (1) clear consciousness, no sweating, no discomfort, no auxiliary respiratory muscle activation; (2) $PaO_2 \geq$ 50-60 mmHg, oxygen saturation (SpO_2) ≥ 85%-90%, increase in partial pressure of carbon dioxide ($PaCO_2$) ≤ 10 mmHg, pH ≥ 7.32; (3) respiratory rate (RR) ≤ 30-35 breaths/min or variations < 50%; (4) heart rate (HR) < 120-140 breaths/min or variations < 20%. If any one or multiple indices were not met, it was considered failed weaning.

General data

General data such as age, gender, body mass index (BMI), operation time, acute physiological and chronic health (APACHE II) score, duration of ventilator use, fluid balance 24 h before weaning, operation modes, and disease types were collected.

SBT procedures

According to the standard SBT procedure in the "Practical Guidelines for Mechanical Ventilation" [12], the pressure support ventilation (PSV) mode was selected and the ventilator parameters were adjusted: $FiO_2 \leq 40\%$, PEEP was 4-6 cmH_2O, and pressure support (PS) was 8-12 cmH_2O. All patients were supine with a supine angle of 30-45°, and the duration of the SBT was 30 min. The hemodynamics, respiratory status, consciousness status, and blood gas analysis of patients were closely monitored during the SBT.

LUS score and chest ultrasound

The instrument was a color Doppler ultrasound diagnostic instrument (Philips CX50) with a linear array probe at 9-13 MHz. Before SBT, the patient was placed in a supine position, and the anterior chest wall, posterior chest wall, and lateral chest wall were examined bilaterally according to 12-lung zones LUS protocol. The posterior and anterior axillary lines were used as dividing lines, and each lung was divided into three zones (anterior, posterior, and lateral), and each zone was further divided into two parts (superior and inferior) (**Figure 1**). The lower parts of the lung were also scanned bilaterally under the patient's rib cage, and the total score of the 12 zones was the final score, according to the Chinese Expert Consensus on Critical Care Ultrasound [13]: score 0: A-lines or maximum 2 B-lines are visualized; score 1: ≥ 3

B-lines (well-spaced or involving ≤ 50% of the pleura, depending on the approach); score 2: B-lines becoming coalescent or involving > 50% of the pleura; score 3: tissue-like pattern, with LUS ranging 0-36 points. The patient was placed in a 30° head-up position, the probe was placed at the junction of the mid-axillary line and the 7th-8th intercostal space, and the thickness of the diaphragm (the hypoechoic portion between the two hyperechoic lines of the mural pleura and peritoneum) was measured using B-mode. The end-expiratory diaphragm thickness (DTee) and end-inspiratory diaphragm thickness (DTei) were measured using the M-mode with the sampling line perpendicular to the diaphragm. Subsequently, the patient was adjusted to the supine position, the probe was changed to a convex array probe of 2-4 MHz, and the probe was placed at the junction of the right rib original and the right midclavicular line. With the liver as the detection window and the probe pointing to the top of the diaphragm, the diaphragm excursion (DE) was obtained, and the diaphragm thickening fraction (DTF) = (DTei - DTee)/DTee × 100%.

Blood gas analysis

A central vein access (internal jugular vein or subclavian vein) was established, and before SBT and 30 min after SBT, 3 mL of central venous blood was retained. The pre-SBT pH, PaO_2, $PaCO_2$, and oxygenation index (PaO_2/FiO_2) were measured using a blood gas analyzer (model: GEM Premier 3000) manufactured by Instrumentation Laboratory, Bedford, MA, US. $\Delta ScvO_2$ = ($ScvO_2$ before SBT - $ScvO_2$ at 30 min after SBT)/$ScvO_2$ before SBT × 100%.

Statistical methods

The Statistical Package for Social Science (SPSS) 24.0 was used for statistical analysis. The measurement data conforming to normal distribution were expressed as mean ± standard deviation, the independent samples t-test was performed for comparison between groups, and the paired samples t-test was performed for intra-group comparison. The counting data were expressed as (n)% and analyzed using χ^2 test. Logistic regression analysis model was used to analyze the influencing factors. ROC curve was drawn to analyze the value of LUS score, $\Delta ScvO_2$ and their combination in predicting weaning failure in patients after thoracic surgery. $P < 0.05$ indicated statistically significant difference.

Results

General information

There were no statistically significant differences in terms of general data including gender, age, BMI, duration of surgery, APACHE II score, duration of ventilator use, fluid balance at 24 h before weaning, and mode of surgery between the two groups ($P > 0.05$) (**Table 1**).

LUS and chest ultrasound indices

The LUS of the failed group was higher than that of the successful group, and the DTF was lower than that of the successful group ($P < 0.05$). The DE, DTei, and DTee showed no statistically significant difference between the two groups ($P > 0.05$) (**Figure 2**).

$ScvO_2$, $\Delta ScvO_2$, modified ventilator weaning index

The $ScvO_2$ at 30 min after SBT was lower in the failed group than that in the successful group, and $\Delta ScvO_2$ was higher than that in the successful group ($P < 0.05$). There was no significant difference in the modified ventilator weaning index between the two groups ($P > 0.05$) (**Figure 3**).

Arterial blood gas indices

The PaO_2 and PaO_2/FiO_2 in the failed group were lower than those in the successful group, while $PaCO_2$ was higher than that in the successful group ($P < 0.05$). There was no significant difference in pH between the two groups ($P > 0.05$) (**Figure 4**).

Correlation

Bivariate Pearson correlation showed that LUS and $\Delta ScvO_2$ were negatively correlated with DTF, PaO_2, and PaO_2/FiO_2 (r = -0.400, -0.527, -0.566, -0.445, -0.557, -0.585, P = 0.002, < 0.001, < 0.001, < 0.001, < 0.001, < 0.001) and positively correlated with $PaCO_2$ (r = 0.450, 0.318, $P < 0.001$, $P = 0.013$). LUS was positively correlated with $\Delta ScvO_2$ ($r = 0.558$, $P < 0.001$) (**Table 2**).

Table 1. Comparison of general information (n, mean ± SD)

Group	Number of cases	Male/female	Age (years)	Body mass index (kg/m²)	Operating time (min)	APACHE II score (points)	Duration of ventilator use (h)	24 h fluid balance before weaning (mL)	Surgical method	Types of diseases
									Median open chest/lateral open chest	A/B/C/D/E
Successful group	35	19/16	42.5±6.3	23.86±2.48	145.62±21.49	15.85±2.34	72.15±10.65	421.53±64.59	12/23	11/15/5/2/2
Failed group	25	13/12	43.9±5.8	23.49±2.19	148.95±20.18	16.18±2.46	74.96±11.38	425.39±66.84	9/16	8/12/3/1/1
χ^2/t	-	0.031	0.877	0.598	0.607	0.527	0.979	0.225	0.019	0.316
P	-	0.861	0.384	0.552	0.546	0.600	0.332	0.823	0.891	0.989

Note: APACHE: Acute Physiology and Chronic Health Evaluation. A: Complex heart disease, B: Intrathoracic disease, C: Esophageal cancer, D: Cardia cancer, E: Mediastinal tumor.

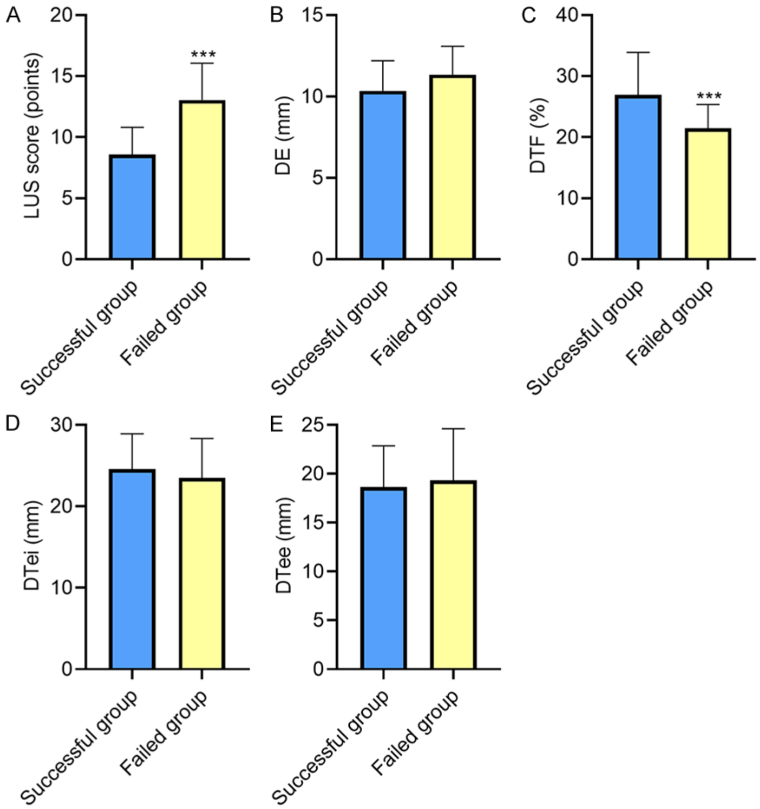

Figure 2. Comparison of LUS and chest ultrasound indices. The LUS in the failed group (A) was higher than that in the successful group, and DTF (C) was lower than that in the successful group. DE (B), DTei (D), and DTee (E) showed no significant difference between the two groups. Note: LUS: Lung Ultrasound Score; DE: Diaphragm Excursion; DTF: Diaphragm Thickening Fraction; DTei: End-Inspiratory Diaphragm Thickness; DTee: End-Expiratory Diaphragm Thickness. Compared with the successful group, $^{***}P < 0.001$.

Relevant factors

The logistic regression analysis showed that LUS, $\Delta ScvO_2$, and $PaCO_2$ may be risk factors affecting the failure of weaning in patients after thoracic surgery (*OR* = 1.844, 4.006, 1.271, *P* < 0.001 for all), while DTF and PaO_2 may be protective factors (*OR* = 0.852, 0.674, *P* = 0.002 for all) (**Table 3**).

Predictive value

The receiver operator characteristic (ROC) curves were plotted according to the weaning outcome of patients after thoracic surgery (0 for successful weaning and 1 for failed weaning), with LUS and $\Delta ScvO_2$ as test variables. The results showed that the area under the curves (AUCs) of LUS, $\Delta ScvO_2$, and the combination of both to predict failed weaning in patients after thoracic surgery were 0.865 (95% CI: 0.766-0.964), 0.874 (95% CI: 0.781-0.967), and 0.925 (95% CI: 0.860-0.990), respectively (**Table 4** and **Figure 5**).

Discussion

Mechanical ventilation controls, assists, or replaces the patient's spontaneous breathing movements with a ventilator, aiming to prevent respiratory muscle fatigue, maintain airway patency, expel carbon dioxide, and improve oxygenation status [14, 15]. The ventilator needs to be weaned when the patient's spontaneous breathing reaches normal standards, but there are still 20-30% of patients with ventilator dependence, and failure to wean the ventilator can increase the risk of death by 40-50% [16]. Therefore, it is particularly critical to accurately assess the ventilator weaning conditions and predict the outcome of early weaning.

With the advantages of non-invasive, immediate, reproducible, and easy operation, bedside ultrasound plays an important role in the diagnosis and condition monitoring of patients in ICU and during perioperative period. LUS enables a more direct and clear assessment of pulmonary ventilation by quantifying the extent of reduction in pulmonary ventilation and converting images to specific data [17, 18]. Soliman et al. [19] found that the LUS of patients in the weaning failure group after SBT was higher than that in the weaning success group, and the specificity and sensitivity of LUS ≥ 15.5 in predicting weaning failure were 70.0% and 82.5%, respectively. Li et al. [20] reported that LUS of patients with successful extubation was higher than that of patients with failed extubation, and the specificity and sensitivity of LUS < 11 in predicting successful extubation were 55.0% and 71.0%, respectively. The results of this study showed that the LUS was higher in

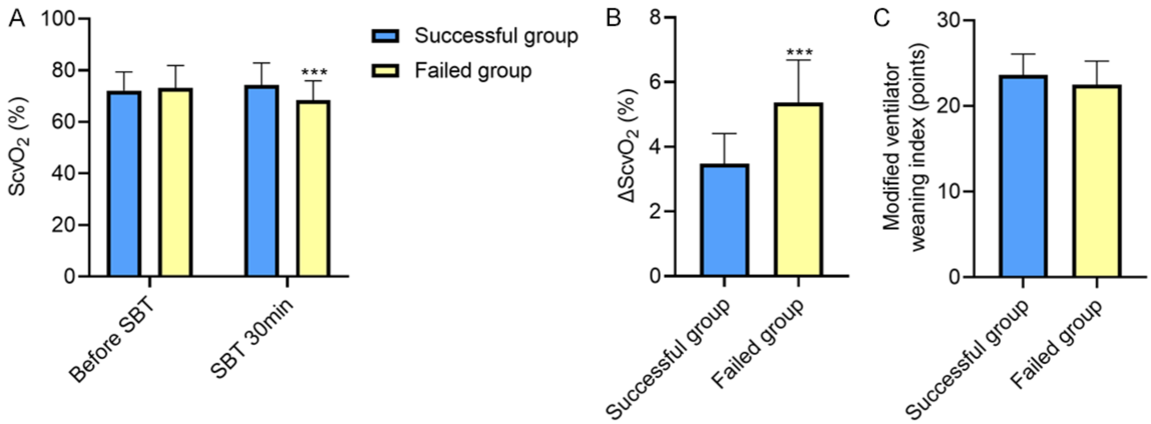

Figure 3. Comparison of $ScvO_2$ and $\Delta ScvO_2$. $ScvO_2$ (A) at 30 min of SBT in the failed group was lower than that in the successful group, while $\Delta ScvO_2$ (B) was higher than that in the successful group. There was no statistically significant difference between the two groups in terms of modified ventilator weaning index (C). Note: $ScvO_2$: Central Venous Oxygen Saturation; SBT: Spontaneous Breathing Trial. Compared with the successful group, $^{***}P < 0.001$.

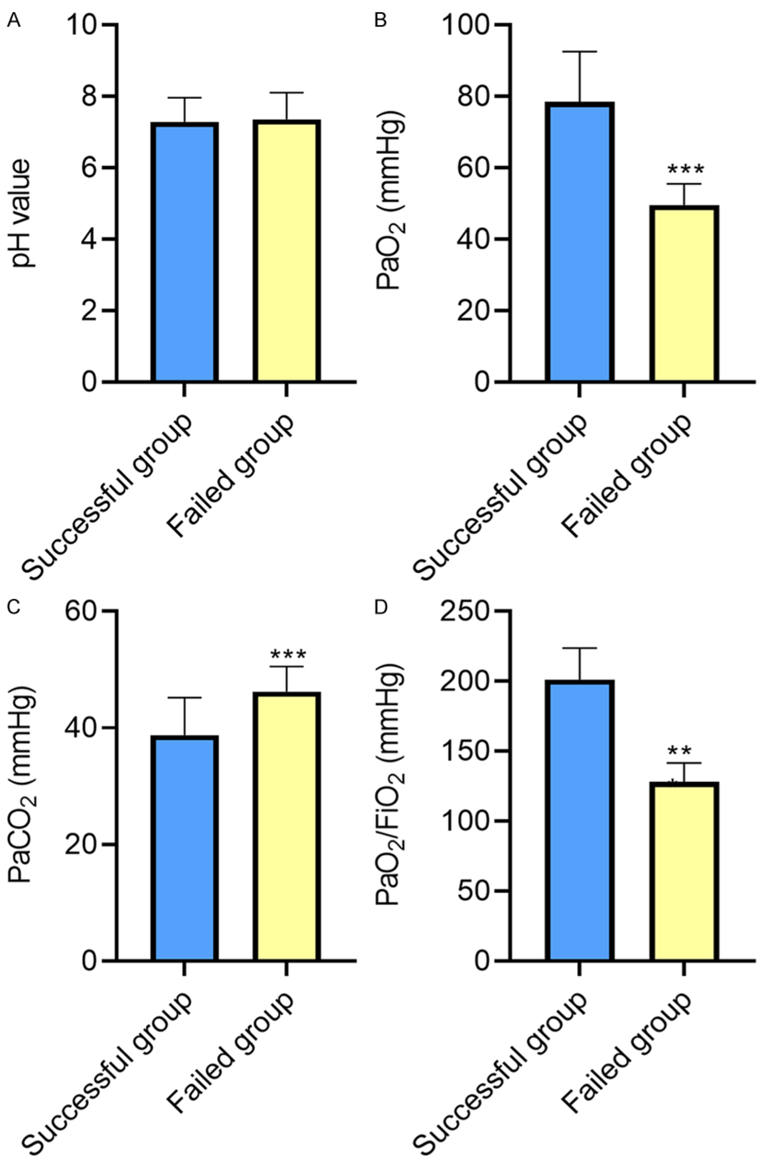

Figure 4. Comparison of arterial blood gas indices. There was no significant difference in pH (A) between the two groups ($P > 0.05$). PaO_2 (B) and PaO_2/FiO_2 (D) in the failed group were lower than those in the successful group, and $PaCO_2$ (C) was higher than that in the successful group ($P < 0.05$). Note: PaO_2: Partial Pressure of Oxygen; $PaCO_2$: Partial Pressure of Carbon Dioxide; FiO_2: Inspired Oxygen Concentration. Compared with the successful group, $^{***}P < 0.001$.

the failed group than that in the successful group, and the elevated LUS was a risk factor affecting the failure of weaning in patients after thoracic surgery, which was basically consistent with the conclusions reported by Soliman et al. and Li et al. The reason may be that patients with elevated LUS are prone to increased airway resistance and reduced pulmonary compliance, which may cause increased diaphragmatic load and reduced respiratory muscle capacity, resulting in weaning failure. In addition, hypoxemia caused by reduced pulmonary ventilation or alveolar collapse can increase the burden on other organs and

Table 2. Correlation analysis of LUS and $\Delta ScvO_2$ with chest ultrasound index and arterial blood gas index [r (P)]

Indicators	LUS	$\Delta ScvO_2$	DTF	PaO_2	$PaCO_2$	PaO_2/FiO_2
LUS score	-	0.558 (< 0.001)	-0.400 (0.002)	-0.527 (< 0.001)	0.450 (< 0.001)	-0.566 (< 0.001)
$\Delta ScvO_2$	0.558 (< 0.001)	-	-0.445 (< 0.001)	-0.557 (< 0.001)	0.318 (0.013)	-0.585 (< 0.001)

Note: LUS: Lung Ultrasound Score; $ScvO_2$: Central Venous Oxygen Saturation; DTF: Diaphragm Thickening Fraction; PaO_2: Partial Pressure of Oxygen; $PaCO_2$: Partial Pressure of Carbon Dioxide; FiO_2: Inspired Oxygen Concentration.

Table 3. Analysis of factors associated with failure of weaning in patients after thoracic surgery

Indicators	B	S.E	Wals	*P*-value	OR	95% CI	
						Lower limit	Upper limit
LUS	0.612	0.154	15.784	< 0.001	1.844	1.363	2.493
$\Delta ScvO_2$	1.388	0.355	15.287	< 0.001	4.006	1.998	8.034
DTF	-0.160	0.053	9.221	0.002	0.852	0.769	0.945
PaO_2	-0.394	0.130	9.152	0.002	0.674	0.523	0.871
$PaCO_2$	0.240	0.066	13.081	< 0.001	1.271	1.116	1.447
PaO_2/FiO_2	-2.164	194.423	0.000	0.991	0.115	0.000	0.354
Constant	-6.872	1.687	16.603	< 0.001	0.001	-	-

Note: LUS: Lung Ultrasound Score; $ScvO_2$: Central Venous Oxygen Saturation; DTF: Diaphragm Thickening Fraction; PaO_2: Partial Pressure of Oxygen; $PaCO_2$: Partial Pressure of Carbon Dioxide; FiO_2: Inspired Oxygen Concentration.

Table 4. Analysis of LUS, $\Delta ScvO_2$, and the combination of both in predicting failure of weaning in patients after thoracic surgery

Indicators	Best cut-off value	Sensitivity	Specificity	Standard error	*P*-value	AUC	95% CI	
							Lower limit	Upper limit
LUS	11	0.760	0.657	0.050	0.009	0.865	0.766	0.964
$\Delta ScvO_2$	4.540	0.800	0.724	0.048	0.011	0.874	0.781	0.967
Combination	-	0.880	0.771	0.033	0.003	0.925	0.860	0.990

Note: LUS: Lung Ultrasound Score; $ScvO_2$: Central Venous Oxygen Saturation; AUC: Area Under The Curve.

increase the risk of weaning failure. The ROC curve showed that the specificity and sensitivity of LUS < 11 in predicting successful weaning were 0.760 and 0.657, respectively, and the differences in the optimal threshold values of LUS reported in various literatures may be related to the different types of diseases and different timing of LUS detection. It is worth noting that the LUS still has limitations in the assessment of some specific patients during weaning, such as patients with diaphragmatic palsy with improved cardiac function and controlled pulmonary inflammation, who have difficulty in providing adequate tidal volume due to impaired diaphragmatic activity, resulting in the inability of a single LUS to reliably predict weaning outcomes [21].

$ScvO_2$ is the venous oxygen saturation obtained through central venous sampling, which can reflect the state of oxygen metabolism in human tissues and the balance between oxygen supply and oxygen consumption [22]. Zhang et al. [23] found that $ScvO_2$ was an early predictor of extubation failure in patients with difficult weaning, and a decrease of more than 5.4% at 30 min after SBT could be used as a predictive threshold. Qin et al. [24] found that $\Delta ScvO_2$ was an independent risk factor for predicting extubation failure in critically ill patients, and when $\Delta ScvO_2$ was set at 5.4, the sensitivity, specificity, and Youden index for predicting extubation failure were 0.829, 0.750, and 0.579, respectively. Teixeira et al. [25] reported that $ScvO_2$ reflected respiratory muscle oxygen consumption, and the decrease in $ScvO_2$ > 4.5% was a risk factor for reintubation [*OR* = 49.4 (95 CI%: 12.1-201.5)] with a sensitivity of 88% and specificity of 95%. This shows that $ScvO_2$ and $\Delta ScvO_2$ are closely relat-

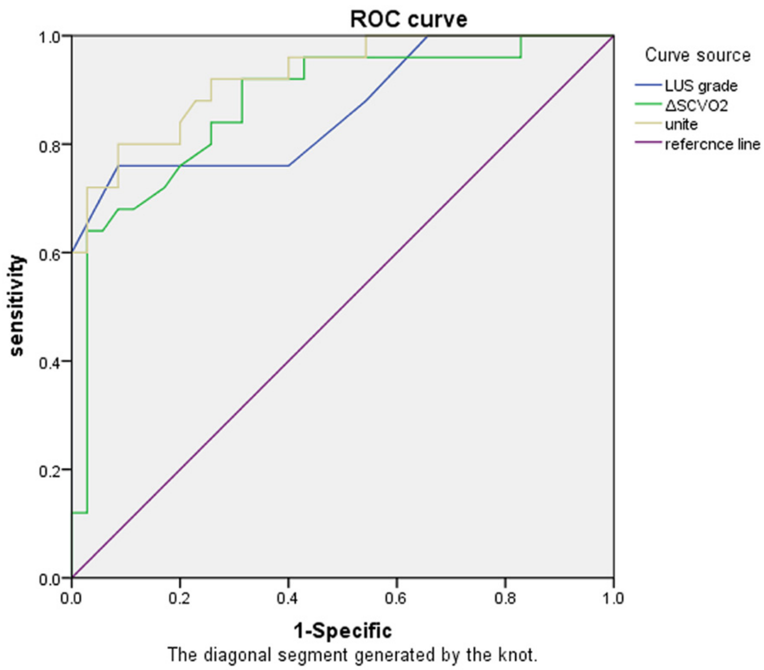

Figure 5. ROC curves of LUS, $\Delta ScvO_2$, and the combination of the two to predict failure of weaning in patients after thoracic surgery. Note: ROC: Receiver Operator Characteristic; LUS: Lung Ultrasound Score; $ScvO_2$: Central Venous Oxygen Saturation.

ed to the outcome of weaning. In this study, $\Delta ScvO_2$ in the failed group was higher than that in the successful group. $\Delta ScvO_2$ was a risk factor for weaning failure in patients after thoracic surgery [*OR* = 4.006 (95 CI%: 1.998-8.034)], and the AUC of $\Delta ScvO_2$ for predicting weaning failure was 0.874. When the prediction threshold was set to 4.540, the sensitivity and specificity were 0.800 and 0.724, respectively, which were similar to the above-mentioned studies. It was confirmed again that $\Delta ScvO_2$ has a certain predictive value for the outcome of weaning after thoracic surgery. Clinical attention should be paid to patients with $\Delta ScvO_2$ > 4.54% to determine the appropriate weaning time. In this study, the bivariate Pearson correlation was used to test the relationship between LUS and $\Delta ScvO_2$. The results showed that LUS and $\Delta ScvO_2$ had positive correlation, and the AUC of the combination of both to predict the failure of weaning in patients after thoracic surgery was 0.925, indicating that the combination of LUS and $\Delta ScvO_2$ can improve the predictive performance regarding weaning failure. $\Delta ScvO_2$ can improve the predictive performance regarding weaning failure. Fang et al. [26] have shown that a decrease of $ScvO_2$ < 5% in mechanically ventilated patients in ICU is a reliable predictor of successful extubation, and the change rate of $ScvO_2$ has a certain clinical value in judging the success rate of extubation in mechanically ventilated patients, which is similar to the results of this study. However, there is no report on the weaning outcome predicted by LUS combined with $ScvO_2$ change rate, which is an innovation of this study. The above research results showed that we should use LUS for semi-quantitative scoring while monitoring the change of $\Delta ScvO_2$ to accurately guide the weaning and avoid the impact of weaning failure on postoperative rehabilitation.

In conclusion, LUS and $\Delta ScvO_2$ are closely related to chest ultrasound index and arterial blood gas index in patients after thoracic surgery. Both of them may be risk factors for weaning failure in patients after thoracic surgery, and their combination can effectively predict the occurrence of weaning failure. However, this study has some shortcomings. The study is a retrospective analysis with a small sample size and single source, and different operators have different experience and judgment criteria, which may cause certain bias of results. Therefore, future prospective studies with more centers and larger samples are needed.

Acknowledgements

This study was funded by the Scientific and Technological Projects of the First Affiliated Hospital of Gannan Medical University (No. YJYB202046).

Disclosure of conflict of interest

None.

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