Open Journal of Preventive Medicine, 2020, 10, 267-275
https://www.scirp.org/journal/ojpm
ISSN Online: 2162-2485
ISSN Print: 2162-2477

# The Observation on Risk of Ventilator Failure Weaning by Ultrasound bedside Monitoring of Inferior Vena Cava and Lung B Line

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**How to cite this paper:** Shen, Z.S., Zhao, Q., Pan, H.M., Jia, Y.J. and Li, J.G. (2020) The Observation on Risk of Ventilator Failure Weaning by Ultrasound bedside Monitoring of Inferior Vena Cava and Lung B Line. *Open Journal of Preventive Medicine*, **10**, 267-275.
https://doi.org/10.4236/ojpm.2020.1010019

**Received:** October 10, 2020
**Accepted:** October 26, 2020
**Published:** October 29, 2020



## Abstract

**Objective:** This study was designed to investigate risk of ventilator weaning by ultrasound bedside monitoring of the width of inferior vena cava (IVC) and the number of lung B-lines (B-lines). **Methods:** This study was conducted on 106 patients from January 2019 to January 2020 who had mechanical ventilation for more than 48 hours in an emergency care unit. They were clinically stable and had the criteria for weaning from the ventilator. Before Spontaneous Breathing Test (SBT) and 30 min or 120 min after SBT, the width of IVC and the number of B-lines in patients were monitored via bedside ultrasound. There were 87 cases of successful weaning as a control group and 19 cases of ventilator failure weaning as a study group. Changes of the width of IVC and the number of B-lines were compared in the different stages of SBT. **Results:** A total of 106 patients were included in this study. There were 87 cases of ventilator successful weaning and 19 cases failure weaning. The weaning success rate was 82.08%. The width of IVC and the number of B-lines in the study group were higher than those in the control group in same stage of SBT, the difference was statistically significant ($P < 0.05$), and which increased significantly with time. There was no significant difference in the width of IVC and the number of B-lines on the different stage of SBT in the control group ($P > 0.05$), and significant difference in the study group. **Conclusion:** The width of IVC and the number of B-lines monitored by bedside ultrasound can assess the risk of ventilator weaning, it may be caused by cardiopulmonary interaction.

## Keywords

Ventilator Weaning, Cardiopulmonary Interaction, Bedside Ultrasound, IVC, The Lung B Line (B-Lines), SBT

# 1. Introduction

Mechanical ventilation is a means of respiratory support in the intensive care unit (ICU), most inpatients in ICU need mechanical ventilation. Ventilator weaning failure increases the length of hospital stay and mortality [1] [2]. SBT and Rapid Shallow Breathing Index (RSBI) are widely used to assess the risk of weaning failure because of its simplicity, noninvasive, no cooperation with patient and bedside measurement [3]. However, the phenomenon of shallow and fast breathing often occurs in respiratory failure and weaning failure due to imbalance between respiratory muscle strength and respiratory load, it has caused reinjury to patients, so it is lag for predicting weaning failure. It turned out that RSB has no advantage over other parameters, and may even prolong the weaning time [4] [5]. Another study showed that 15% - 30% of the patients who passed the SBT finally weaning failure [6]. To detect the possibility of weaning failure earlier is important. All possible causes of weaning failure should be thought over, especially those potential and reversible causes. However, there are many causes for weaning failure, which is often the result of the comprehensive influence of respiratory function, cardiac function, psychology, spirit, metabolic nutrition and other factors. How to detect the possibility of weaning failure earlier is worth studying. In this study, we measured the width of IVC and the number of B line of lung by ultrasound, and to explore the effect in ventilator weaning. This study was approved by the hospital ethics committee.

# 2. Materials and Methods

## 2.1. Study Object

### 2.1.1. General Information

In this study, 106 patients with weaning were selected as the study objects who were admitted to the emergency ICU of our hospital from January 2019 to January 2020. There were 64 males and 42 females. The average age was (71.4 ± 7.9) years. The primary diseases included 39 cases of severe pneumonia or acute respiratory distress syndrome (36.79%), 27 cases of central nervous system diseases (25.47%), 14 cases of severe sepsis (13.21%), 12 cases of accidental injury (11.32%), 9 cases of cardiovascular diseases (8.49%), and 5 cases (4.72%). The duration of mechanical ventilation (MV) was 25 - 152 hours (87.2 ± 76.9) hours before weaning. Main equipment: ventilator produced by Drager company of Germany.

### 2.1.2. Inclusion Criteria [6]

Before SBT, evaluate whether the patients meet the following criterion: 1) The pathogenic factors of mechanical ventilation were removed or corrected; meet the weaning screening criterion: oxygenation index ≥ 150 mmHg; 2) Peep ≤ 5 - 8 cm $H_2O$, $FiO_2 \le 0.4$; pH ≥ 7.25; for patients with COPD, pH ≥ 7.25, $FiO_2 \le 0.35$; $PaO_2 \ge 50$ mmHg; stable hemodynamics, no or only the use of small doses of vasoactive drugs, such as dopamine ≤ 5 ug/kg·min and no active myocardial ischemia; patients with stable spontaneous breathing, being conscious, powerful cough and expectoration. They also had enough airway protection ability; their nutritional status was improved, and there was no obvious abdominal distension.

#### 2.1.3. Exclusion Criteria

Patients who failed in SBT, those with acute coronary syndrome; delirium can not be corrected; electrolyte disorder or acid-base imbalance, severe malnutrition, and cerebrovascular hypertension.

### 2.2. Methods

Patients who meet the weaning parameters were tested by 30 minutes T-tube test. The standard of the SBT success [7]: RSBI < 105; Respiratory rate (RR) < 35 times/min; heart rate < 140 times/min or increase < 20%; no obvious dyspnea or auxiliary respiratory muscle were activated in breathing. After success in SBT, patients were given weaning, and those who failed in SBT were treated by mechanical ventilation again, and were not included in the study groups.

Weaning success parameters [8]: weaning time > 48 h; weaning failure parameters [7]: RR > 35 times/min or auxiliary respiratory muscle were activated; $SpO_2$ < 90%; heart rate > 130 times/min or increase > 20%; mental status changes. According to whether the weaning success or not within 48 hours, the study objects were divided into weaning success group (the control group) and weaning failure group (the study group).

### 2.3. Observation Indicators

Age, Acute Physiology and Chronic Health Evaluation II (APACHE II), body mass index (BMI), oxygenation index, hemoglobin and lactate levels before SBT were recorded. The width of IVC and the number of B-lines were monitored by bedside ultrasound before (SBT), 30 minutes and 120 minutes after the spontaneous breathing test. The average of the width of IVC and the number of B-lines at different time points in each group were calculated, and changes of them were compared in the different stages of SBT.

#### 2.3.1. The Width of IVC

The patient took the supine position, the width of IVC was measured by the convex array probe (2 - 5 MHz) from the lower xiphoid longitudinal section at 0.5 - 1 cm distal to the opening of the hepatic vein [9].

#### 2.3.2. The Number of Lung B Line

The patient took the supine position, numbers of B-lines were measured by the convex array probe (2 - 5 MHz) between 2 and 4 intercostals at points of sternal line, median clavicle line, axillary front line, axillary midline. The B-lines is a dynamic artifact, and moving or changing shape with the respiratory cycle. Numbers of which were judged by more than 2 experienced doctors with visual inspection [10].

### 2.4. Statistical Analysis

Spss21.0 statistical software was used for statistical analysis. The measurement data were expressed by mean ± standard deviation ( $\overline{X} \pm S$ ). T test was used for comparison between the two groups. The difference was statistically significant with $P < 0.05$.

## 3. Result

### 3.1. Comparison of the Fundamental State between the Two Groups

A total of 106 subjects were included in this study. There were 87 cases of ventilator successful weaning as a control group and 19 cases of ventilator failure weaning as a study group. The weaning success rate was 82.08%. There was no significant difference in age, APACHE II score at admission, BMI, oxygenation index, hemoglobin and lactate levels between the two groups ($P > 0.05$, **Table 1**).

### 3.2. The Width of IVC

The width of IVC before SBT in study group was higher than that in the control group, but no difference was statistically significant ($P > 0.05$). At 30 min and 120 min after SBT, the width of IVC in study group was higher than that in the control group, and the difference was statistically significant ($P < 0.05$). The width of IVC increased gradually in the study group with time, the change was statistically significant ($P < 0.05$) and no difference was statistically significant in the control group ($P > 0.05$) (**Table 2**).

### 3.3. The Number of B-Lines

The Number of B-lines before SBT in study group was higher than that in the control group, but no difference was statistically significant ($P > 0.05$). At 30 min and 120 min after SBT, the number of B-lines in study group was higher than that in the control group, and the difference was statistically significant ($P < 0.05$). The number of B-lines increased gradually in the study group with time, the change was statistically significant ($P < 0.05$) and no difference was statistically significant in the control group (**Table 3**).

## 4. Discussion

In this study, a total of 106 patients were included, and 19 cases of ventilator failure weaning. The weaning success rate was 82.08%. It was similar to previous reports [6]. Some data show that weaning failure is an independent risk factor for prolonged hospital stay and increased mortality in ICU patients [1] [2]. To detect the possibility of weaning failure earlier is important. However, there are many causes for weaning failure, clinicians often have some difficulties in subjective judgment of the causes of weaning failure. Another study such as

**Table 1.** Comparison of the fundamental state between the two groups ( $\bar{X} \pm S$ ).

| Item | Control group (n = 87) | Study group (n = 19) | P value |
|---|---|---|---|
| age (year) | 72.4 ± 7.8 | 72.8 ± 7.5 | P > 0.05 |
| males/females | 1.52 | 1.54 | P > 0.05 |
| BMI (kg/m$^2$) | 21.24 ± 4.78 | 20.88 ± 5.05 | P > 0.05 |
| oxygenation index (mmHg) | 185 ± 32 | 183 ± 35 | P > 0.05 |
| hemoglobin (g/L) | 91 ± 5.6 | 89 ± 6.1 | P > 0.05 |
| APACHE II | 18.7 ± 3.9 | 19.1 ± 4.3 | P > 0.05 |
| lactic acid (mmol/L) | 1.34 ± 0.43 | 1.28 ± 0.48 | P > 0.05 |

**Table 2.** Comparison of the width of IVC between the two groups in different stages ( $\bar{X} \pm S$ ).

| Groups | Before SBT | 30 min after SBT | 120 min after SBT |
|---|---|---|---|
| contral group (n = 87) | 14.07 ± 0.44° | 14.25 ± 0.61° | 14.96 ± 0.70° |
| study group (n = 19) | 14.62 ± 0.85▲ | 17.93 ± 1.32*▲ | 19.42 ± 2.10*▲ |

**P* < 0.05, compared with contral groups; ▲*P* < 0.05, compared with different stages in study group; °*P* > 0.05, compared with different stages in contral group.

**Table 3.** Comparison of B-lines of the lungs between the two groups in different stages ( $\bar{X} \pm S$ ).

| Groups | Before SBT | 30 min after SBT | 120 min after SBT |
|---|---|---|---|
| contral group (n = 87) | 1.0 ± 1.7° | 1.0 ± 1.8° | 1.2 ± 1.4° |
| study group (n = 19) | 1.1 ± 1.62▲ | 2.1 ± 2.0*▲ | 3.7 ± 2.6* |

**P* < 0.05, compared with contral groups; ▲*P* < 0.05, compared with different stages in study group; °*P* > 0.05, compared with different stages in contral group.

central venous oxygen saturation and brain natriuretic peptide (BNP) levels had been used to assess the risk of weaning failure [11] [12], but no most effective method was found.

Compared with them, bedside ultrasound is a rapidly developing diagnosis technology in critical illness, which is widely used in the fields of hemodynamics and respiratory monitoring [13] [14]. Evaluation of weaning failure has its unique advantages. Ultrasound monitoring width of IVC and B-lines has many advantages such as non-invasive, dynamic, real-time, simple and repeatable operation. At the same time, the dynamic contrast of width of IVC and number of B-lines of the patients themselves can better exclude the influence of other factors on weaning failure. In this study, these two indicators were taken as the breakthrough point, whether there were changes in cardiac function and volume state before the occurrence of rapid shallow breathing in weaning, and more strict assessment and adjustment were carried out in advance. Real-time monitoring of the width of IVC and the number of B-lines by bedside ultrasound can effectively guide the volume management, improve the rate of successful weaning, and has strong clinical value.

IVC is a volume vessel directly adjacent to the right atrium, and its inner diameter often changes with the change of body capacity. The width and variability of IVC can effectively evaluate volume status and volume responsiveness [15] [16] [17], which is widely used to guide fluid resuscitation in shock. In this study, at 30 min and 120 min after SBT, the width of IVC in study group was higher than that in the control group, and the difference was statistically significant ($P < 0.05$). The width of IVC increased gradually in the study group with time, the change was statistically significant ($P < 0.05$) and no statistically significant in the control group ($P > 0.05$) (**Table 2**).

Lung B-lines is a kind of reverberation artifact on ultrasonic images. It refers to the strong echo when ultrasound meets the strong reflection interface and the narrow strip echo with gradual attenuation and multiple reflection behind it. It is shaped like "comet tail" and a prompt for the level of extravascular lung water [18] [19], and which sensitivity is significantly better than that of chest X-ray film [20]. This study found that the number of B-lines at 30 min and 120 min after SBT in study group was higher than that in the control group, and the difference was statistically significant ($P < 0.05$). The number of B-lines increased gradually in the study group with time, the change was statistically significant ($P < 0.05$) and no statistically significant in the control group (**Table 3**).

This study found that there was a certain difference in the width of IVC and the number of B-lines between the two groups before weaning, and the difference continued to exist after SBT test and after weaning, and the difference increased significantly. It is speculated that the negative pressure of chest cavity increases significantly due to spontaneous breathing after weaning. The heart and lung of the human are in the chest cavity together, and have an anatomic proximity. In the process of respiratory physiology, ventilation and circulation interact by the changes of intrathoracic pressure and lung volume [21], it is called cardiopulmonary interaction, and in which the amount of return heart blood increased, and the left ventricular transmural pressure increased, leading to the cardiac preload and afterload. The cardiopulmonary interaction has already existed in healthy people, and this interaction will be amplified and even cause pathophysiological changes in patients with cardiopulmonary disease. If the patient's heart function reserve is insufficient and cannot be compensated, it will further lead to left heart failure, then produce pulmonary congestion or even pulmonary edema, and finally fail to wean.

In the process of mechanical ventilation, due to the continuous positive pressure of chest, the amount of return heart blood flowing from systemic circulation to right ventricle is reduced, and then the circulation blood volume from pulmonary circulation to left ventricle is significantly reduced, left ventricular filling pressure and preload are reduced. At the same time, left ventricular transmural pressure and left ventricular afterload are reduced due to the increase of chest pressure. At the same time, mechanical ventilation can reduce respiratory muscle work and improve cardiac function, which is the theoretical basis of mechanical ventilation in the treatment of left ventricular failure. The most obvious physiological change of patients with mechanical ventilation during spontaneous breathing after weaning is the change of intrathoracic pressure. During inhalation, the volume of blood returned to the heart increased significantly due to the suction of negative pressure in the chest, and the blood flow through the pulmonary circulation to the left ventricle increased. Studies have shown that the cardiac index of patients before and after weaning significantly increased [22]. After weaning, the decrease of chest pressure leads to the increase of left ventricular transmural pressure and the increase of left ventricular posterior negative pressure. The patients have obvious increase in the amount of return heart blood, and even have cardiac dysfunction or insufficient compensation of cardiac function. Clinically, we can see the phenomenon of shallow and fast breathing. The phenomenon of shallow and fast breathing is that the patients can not tolerate the pathophysiological changes after weaning, which leads to heart failure, extravascular lung water increase, and even pulmonary edema, which leads to weaning failure.

## 5. Conclusion

There was a greater possibility of weaning failure in patients with mechanical ventilation who passed the SBT. From the perspective of cardiopulmonary interaction, dynamic monitoring of width of IVC and the number of B-lines may be early predictors for weaning failure risk.

## Limitations

This study is clinical observation with a small sample, so it is not enough for predicting the weaning failure risk in the whole one, which is affected by many factors. Next, we will further expand the sample size and conduct a more in-depth prospective study, in order to provide strong clinical evidence for guiding evaluation of weaning failure risk.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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