# Application of Ultrasound Evaluation of Diaphragm Function in Guiding Ventilator Evacuation

Xinmeng Cui
Ri Zhang
Huan Lv
Li Li

**Objective.** To investigate the clinical effect of the application of ultrasound evaluation of diaphragm function in guiding ventilator evacuation. **Methods.** 100 patients with ventilator evacuation who were admitted to our hospital from March 2019 to June 2020 were selected as the study objects, and divided into the observation group and the control group, according to whether they succeeded in weaning. Among them, 50 patients succeeding in weaning were from the observation group; while 50 patients failing in weaning were from the control group. The Diaphragm Movement Degree (DMD) and Diaphragmatic Thickness at the End of Expiration (DTee), Diaphragmatic Thickness at the End of Inspiration (DTei) and Diaphragm Thickening Fraction (DTF), the right diaphragm displacement, diaphragm contraction velocity at 0 min, 5 min and 30 min of two groups as well as the ROC curve were all analyzed to predict weaning results of the ultrasound diaphragm index. **Results.** (1) There were no significant differences in Sequential Organ Failure Assessment (SOFA) score, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, ventilator ventilation time and oxygenation index before weaning between the two groups ( T=0.14,0.03, 0.04, 0.59, P=0.89, 0.97, 0.56). (2) Left DMD (18.59±2.96) mm, Right DMD (19.86±2.94) mm, Left DTei (2.69±0.16) mm, Right DTei (2.81±0.31) mm, Left DTee (1.93±0.11) mm, Right DTee (1.92±0.16) mm, Left DTF (0.40±0.11) mm and Right DTF (0.47±0.09) mm in the observation group were significantly higher than Left DMD (13.05±3.16) mm, Right DMD (13.13±3.63) mm, Left DTei (2.16±0.34) mm, Right DTei (2.18±0.39) mm, Left DTee (1.92±0.16) mm, Right DTee (1.68±0.24) mm, Left DTF (0.25±0.06) mm and right DTF (0.27±0.07) mm in the control group, T = 9.05, 10.19, 9.97, 8.94, 6.93, 5.88, 8.46, 12.40, P=0.00，0.00，0.00，0.00，0.00，0.00，0.00，0.00, with statistical significance. (3) The ROC curve showed that left and right DMD, left and right DTei, left and right DTee as well as left and right DTF can be used to predict the success of weaning. **Conclusion.** In the guidance of ventilator evacuation, the application of ultrasound evaluation of diaphragm function can effectively evaluate the timing of weaning, and played a positive role in improving the success rate of weaning.

**Keywords: Ultrasound evaluation; diaphragm function; guiding; ventilator evacuation; application**
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*Xinmeng Cui Department of Ultrasound, Gaomi People's Hospital, Weifang, 261500, Shandong Province, China, Ri Zhang Department of Equipment, Gaomi People's Hospital, Weifang, 261500, Shandong Province, China, Huan Lv Department of Equipment, Weifang People's Hospital, Binhai Branch, Weifang, 261500, Shandong Province, China, Li Li* Department of Ultrasound, Gaomi People's Hospital, Weifang, 261500, Shandong Province, China, *Corresponding author: Department of Ultrasound, Gaomi People's Hospital, No.77, Zhenfu Street, Weifang, 261500, Shandong Province, China (E-mail: 1156963401@qq.com)*

At present, Mechanical Ventilation (MV) is one of the effective means of respiratory therapy in the Critical Care Medicine. How to guide the ventilator evacuation at an appropriate time after the patient's smooth respiration is a hot topic in the study of MV [1-3]. Long-term MV brings patients not only the long hospitalization time in Intensive Care Unit (ICU) but also a large economic burden. What's worse, it also leads to diaphragmatic dysfunction, ventilator-related lung injury and other diseases, thus affecting the weaning of patients [4-6]. According to relevant studies, delayed weaning was associated with a higher incidence of diaphragmatic dysfunction than active weaning at the right time [7]. Patients with mechanical ventilation might suffer from diaphragmatic fatigue and respiratory overload during weaning, so the diaphragmatic function index of patients could be applied to judge the weaning time. In other words, respiratory load index and diaphragmatic contractile function could be the objective reference for weaning [8-10]. In this study, in order to investigate the clinical effect of the application of ultrasound evaluation of diaphragm function in guiding ventilator evacuation, in the purpose of providing important reference basis for guiding ventilator evacuation, 100 patients with the ventilator evacuation who were admitted to our hospital from March 2019 to June 2020 were selected as the study objects. The specific reports are as follows.

## MATERIALS AND METHODS

### General Information

100 patients with ventilator evacuation who were admitted to our hospital from March 2019 to June 2020 were selected as the study objects. There were no significant differences between the two groups in general clinical data such as gender, age, etc. ($P > 0.05$), as shown in Table 1.

Table 1
Analysis of general clinical data

| Factors | | Observation group(n=50) | Control group(n=50) | Statistical values | P |
|---|---|---|---|---|---|
| Gender | Male | 28 | 26 | 0.16 | 0.69 |
| | Female | 22 | 24 | | |
| Average age /year | | 55.32±5.78 | 55.41±5.74 | 0.08 | 0.94 |
| Average duration /year | | 2.22±0.68 | 2.25±0.65 | 0.23 | 0.82 |

### Inclusion/ Exclusion Criteria

#### Inclusion criteria.

(1) All study objects underwent tracheotomy or orotracheal intubation with ventilator in our hospital.
(2) The duration of MV was all more than or equal to 24 h.
(3) No large number of analgesic drugs was used during weaning.
(4) Qi-blood index ( PEEP < 5cm $H_2O$, $FiO_2$ < 5 cm $H_2O$, $PaO_2/FiO_2 \geq 150$).
(5) Pulmonary inflammation can be controlled.
(6) Patients with heart rate ( < 140 beats/min) and blood pressure (> 90/60 mmHg).
(7) This study has been approved by the Hospital Ethical Committee and the patients and their families were informed of the treatment and signed the informed consent.

#### Exclusion criteria.

(1) Patients' age ( < 18 years old).
(2) Patients suffered from end-stage tumors or were during pregnancy.
(3) Patients had pneumothorax, mediastinal emphysema and closed thoracic drainage.
(4) Patients underwent unplanned extubation including self-extubation and accidental extubation.
(5) Patients had severe pancreatitis.

### Methods

After admission, all patients weaned from ventilator after the Spontaneous Breathing Trial (SBT) was applied by clinicians according to patients' specific conditions. The spont mode was adopted. The Pressure Support (PS) with 6~8 cm $H_2O$ and $FiO_2$ of 40% was adjusted according to the type of tracheal intubation, and the positive end-respiratory pressure was 3 cm $H_2O$. If patients had oxygen saturation of blood ($SaO_2$) (< 90%), systolic blood pressure ( < 90 mmHg or >180 mmHg), respiratory rate ( > 35 beats/ min), pulse change rate ( ≥ 20%), pulse ( > 140 beats/ min), dyspnea, irritability as well as profuse sweating within 2 hours of SBT, the weaning of ventilator would fail. Thereafter, the SBT should be stopped in time, the respiratory parameters and mode should be restored to that before the SBT, and the respiratory support should also be given in time. However, the successful weaning was that the patient did not need MV again within 48 hours. After 30 minutes of SBT, ultrasound evaluation of diaphragm function was adopted by a non-weaning physician. Philips ClearVueCV650 color supersonic diagnostic was used and 2~5MHz convex probe was applied for detection. Detection mode was that with the head of the bed raised by 30 degrees, the patient was in supine position and then the probe was implanted at the junction of the lower edge of the costal arch and the anterior axillary line or the midclavicular line. The acoustic window of diaphragm was the spleen or liver, and the probe pointed at the dorsal or head side. The diaphragm would show a wide line-like hyperechoic band at 1/3 of the middle and posterior parts of the diaphragm. M-mode echocardiography was adopted to detect diaphragm movement on the basis of ideal two-dimensional images, and the sample line of M-mode echocardiography was pointed to DMD with clamp line from top of diaphragm to long axis less than 30 degrees. Thereafter, DTei and DTee were detected during one respiratory cycle. (DTF)=(DTei -DTee)/DTee. The operation should be repeated three times continuously, and the contraction speed of all patients in breathing according to the diaphragm displacement and inspiration time should be analyzed. In this study, the ultrasound operators were all doctors qualified for critical care ultrasound and passed the training qualifications of Chinese Critical Care Ultrasound Study Group.

1.4 Statistical treatment

The data software SPSS18.0 was adopted in this study to process and analyze the research data. The measurement data were expressed as ($\bar{x}$±s) and tested by t test. The enumeration data were expressed as [n(%)] and tested by $X^2$ test. Fisher was adopted to represent the enumeration data and predict the weaning results in order to construct ROC curve. The differences had statistical significance when P<0.05.

## RESULTS

### Analysis of The Critical Degree and Respiratory Parameters of The Two Groups

There were no significant differences in SOFA score, APACHE II score and oxygenation index between the two groups (T=0.14, 0.03, 0.04, 0.59, P=0.89, 0.97, 0.56), as shown in Table 2.

Table 2

| Factors | Observation group (n=50) | Control group (n=50) | T | P |
|---|---|---|---|---|
| **SOFA score /score** | 6.62±4.17 | 6.51±3.55 | 0.14 | 0.89 |
| **APACHEII score /score** | 18.16±9.03 | 18.10±9.08 | 0.03 | 0.97 |
| **Duration of ventilation /d** | 7.53±2.08 | 7.51±2.03 | 0.04 | 0.96 |
| **Oxygenation index /mmHg** | 230.45±130.95 | 246.82±145.36 | 0.59 | 0.56 |

### Analysis of Ultrasound Diaphragm Index of Two Groups

Left DMD (18.59±2.96) mm and Right DMD (19.86±2.94) mm in the observation group were significantly higher than Left DMD (13.05±3.16) mm and Right DMD (13.13±3.63) mm in the control group, with statistical significance ( T=9.05, 10.19, P=0.00, 0.00). Left DTei (2.69±0.16) mm, Left DTee (1.93±0.11) mm, Right DTei (2.81±0.31) mm and Right DTee (1.92±0.16) mm in the observation were significantly higher than Left DTei (2.16±0.34) mm, Left DTee (1.68±0.23) mm, Right DTei (2.18±0.39) mm and Right DTee (1.68±0.24) mm in the control group, with statistical significance (T=9.97, 6.93, 8.94, 5.88， P=0.00, 0.00, 0.00, 0.00). Left DTF (0.40±0.11) mm and Right DTF (0.47±0.09) mm in the observation group were significantly higher than Left DTF (0.25±0.06) mm and right DTF (0.27±0.07) mm in the control group, with statistical significance (T=8.46, 12.4, P=0.00, 0.00). The specific details are shown in Figs. 1~6.

**Figures.** 1~4

Figure 1 Analysis of DMD indicators of two groups

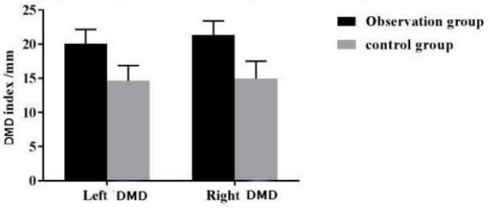



Figure 2 Analysis of DTei indicators of two groups

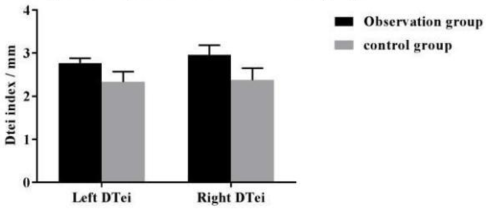



Figure 3 Analysis of DTee indicators of two groups

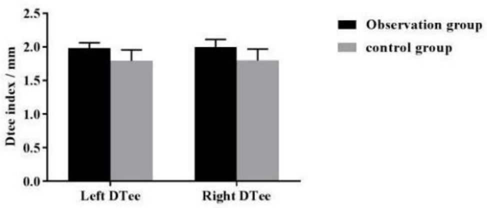
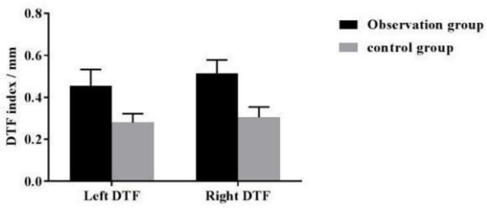



Figure 4 Analysis of DTF indicators of two groups




Note.

Figure 1 Analysis of DMD indicators of two groups. The abscissa from left to right represented Left DMD and Right DMD respectively; while the ordinate represented DMD index. The black represented the observation group and the gray represented the control group. Figure 1 showed that both Left DMD and Right DMD of the observation group were significantly higher than those of the control group, T=9.05, 10.19, P=0.00, 0.00, with statistical significance. The unit is mm.

Figure 2 Analysis of DTei indicators of two groups. The abscissa from left to right indicated Left DTei and Right DTei respectively; while the ordinate indicated the DTei index. The black represented the observation group and the gray represented the control group. Figure 2 showed that Left DTei and Right DTei of the observation group were significantly higher than those of the control group, T=9.97, 8.94, P=0.00, 0.00, with statistical significance. The unit is mm.

Figure 3 Analysis of DTee indicators of two groups. The abscissa from left to right indicated Left DTee and Right DTee respectively; while the ordinate represented DTee index. The black represented the observation group and the gray represented the control group. Figure 3 showed that Left DTee and Right DTee in the observation group were significantly higher than those in the control group, T=6.93, 5.88, P=0.00, 0.00, with statistical significance. The unit is mm.

Figure 4 Analysis of DTF indicators of two groups. The abscissa from left to right represented Left DTF and Right DTF respectively; while the ordinate represented DTF index. The black represented the observation group and the gray represented the control group. Figure 4 showed that Left DTF and Right DTF in the observation group were significantly higher than those of the control group, T=8.46, 12.40, P=0.00, 0.00, with statistical significance. The unit is mm.

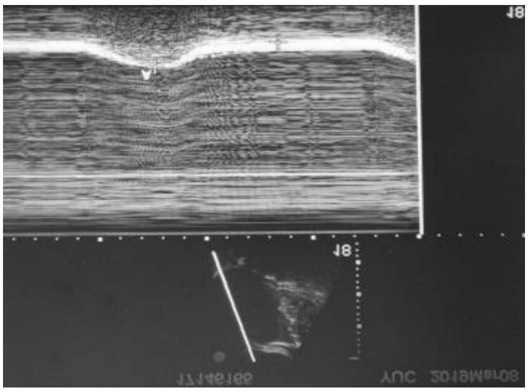


**Figure 5 Ultrasonic DMD**

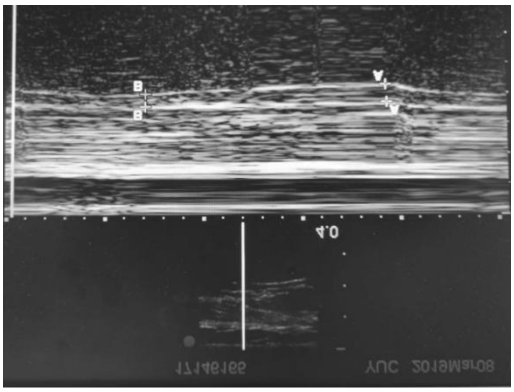
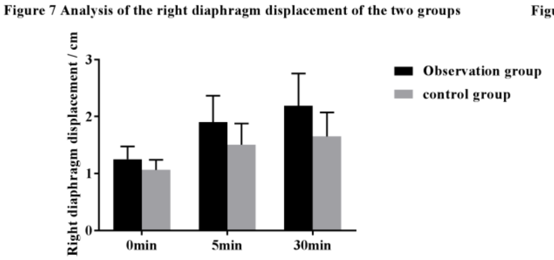


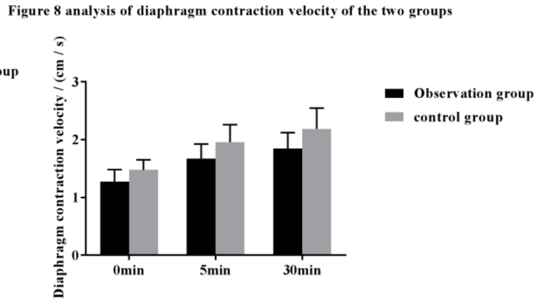
**Figure 6 Ultrasonic measurement of DTei and DTee**

### Analysis of The Right Diaphragm Displacement and The Diaphragm Contraction Velocity of The Two Groups During Spontaneous Breathing at Different Time.

The displacement of right diaphragm of (1.09±0.32) cm at 0 min, of (1.57±0.66) cm at 5 min, and of (1.79±0.80) cm at 30min in the observation group were significantly higher than the displacement of right diaphragm of (0.94±0.25) cm at 0 min, of (1.24±0.53) cm at 5 min and of (1.35±0.60) cm at 30 min in the control group, T=2.61,2.76, 3.11, P=0.00, 0.00, 0.00, with statistical significance. The diaphragm contraction velocity of (1.13±0.29) cm/s at 0 min, of (1.49±0.36) cm/s at 5 min and of (1.65±0.39) cm/s at 30 min in the observation group were significantly lower than the diaphragm contraction velocity of (1.35±0.25) cm/s at 0 min, (1.74±0.43) cm/s at 5 min and (1.93±0.51) cm/s at 30 min in the control group, T=4.06, 3.15, 3.08, P=0.00, 0.00, 0.00, with statistical significance. The specific details are shown in Figures 7~8.

**Figures 7~8.**




Note.

Figure 7 Analysis of the right diaphragm displacement of the two groups. The abscissa from left to right represented 0 min, 5 min, 30 min respectively; while the ordinate represented the right diaphragm displacement. The black represented the observation group and the gray represented the control group. Figure 7 showed that the right diaphragm displacement in the observation group at 0 min, 5 min, and 30 min were significantly higher than those in the control group, T=2.61, 2.76, 3.11, P=0.01, 0.00, 0.00, with statistical significance. The unit is cm.

Figure 8 Analysis the diaphragm contraction velocity of the two groups. The abscissa represented 0 min, 5 min and 30 min from left to right; while the ordinate represented diaphragm contraction velocity. The black represented the observation group and the gray represented the control group. Figure 8 showed that the diaphragm contraction velocity of the observation group at 0 min, 5 min and 30 min were significantly higher than those of the control group, T=4.06, 3.15, 3.08, P=0.00, 0.00, 0.00, with statistical significance. The unit is cm/s.

### Prediction of Weaning Results of Ultrasound Diaphragm Index by Roc Curve

ROC curve showed that the successful weaning could be predicted by the Left and Right DMD, the Left and Right DTei, the Left and Right DTee and the Left and Right DTF, as shown in Table 3 and Figures 9-10.

**Table 3**
**Prediction of weaning results of ultrasound diaphragm index by ROC curve**

| Index | Area under curve | Standard error | P |
|---|---|---|---|
| **Right DMD** | 0.94(0.83～1.00) | 0.06 | 0.00 |
| **Left DMD** | 0.95(0.86～1.00) | 0.05 | 0.00 |
| **Right DTei** | 0.94(0.83～1.00) | 0.06 | 0.00 |
| **Left DTei** | 0.95(0.85～1.00) | 0.05 | 0.01 |
| **Right DTee** | 0.79(0.58～1.00) | 0.11 | 0.02 |
| **Left DTee** | 0.81(0.60～1.00) | 0.12 | 0.02 |
| **Right DTF** | 0.96(0.92～1.00) | 0.03 | 0.00 |
| **Left DTF** | 0.85(0.66～1.00) | 0.09 | 0.00 |

**Figure 9**
**Prediction of weaning results of left diaphragm by ROC curve**

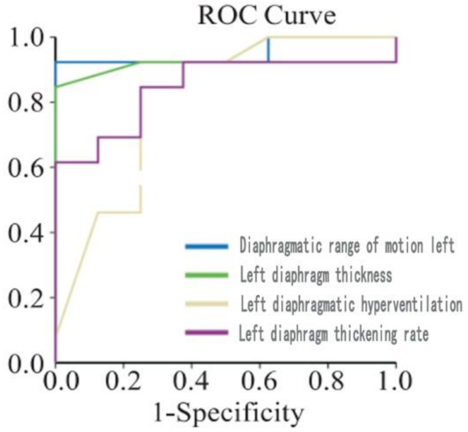
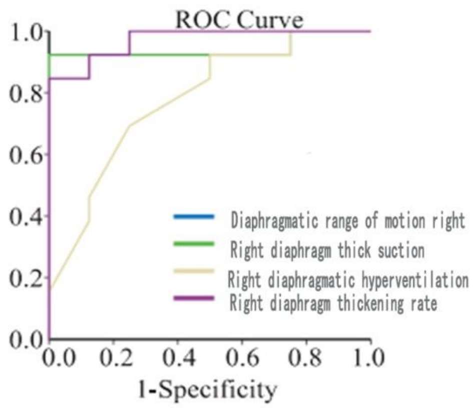



**Figure 10**
**Prediction of weaning results of right diaphragm by ROC curve**




## DISCUSSION

At present, ventilator ventilation is one of the early invasive treatment methods in clinical medicine, and it is mainly applied for the treatment of patients with emergency and severe cases [11-13]. With the increasing ventilation time, it is more and more difficult to wean from the ventilator, which will lead to serious economic and psychological burden of patients and their families. What's worse, the mortality rate of patients will gradually increase. Therefore, once the primary disease of patients with ventilator ventilation is controlled, ventilator ventilation evacuation should be implemented in time, which has a positive effect on improving the life quality of patients [14-16]. In this study, in order to investigate the clinical effect of the application of ultrasound evaluation of diaphragm function in guiding ventilator evacuation, 100 patients with ventilator evacuation who were admitted to our hospital from March 2019 to June 2020 were selected as the study objects, and divided into the observation group and the control group according to whether they had successful weaning. The related indicators of successful weaning were analyzed. In this study, it was found that ultrasound evaluation of diaphragm function was expected to become a new indicator to guide ventilator weaning, and combined with traditional weaning methods to improve the success rate of weaning.

A series of patient changes will lead to difficulty in weaning, such as respiratory muscle overload, respiratory depression, nutritional imbalance, imbalance of water-electrolyte and acid-base, insufficient blood supply, decreased compliance of thoracic and lung, endogenous positive end-expiratory pressure, imbalance between ventilator work and respiratory load, etc. [17-18]. According to Spiesshoefer Jens [19] and others, it could be seen that the diaphragm could effectively diagnose respiratory muscle strength, and had important significance in spontaneous breathing. Diaphragmatic dysfunction could prolong the ventilation time of patients with ventilator ventilation, increase the complication rate and further lead to damage of diaphragm function. Relevant investigation data showed that patients with ventilator ventilation for 12h to 18h would have obvious diaphragmatic atrophy and contraction dysfunction, which was called ventilator-associated diaphragmatic dysfunction in clinic. Therefore, one of the most common diseases in patients with ventilator ventilation was diaphragmatic dysfunction. The longer the ventilation time of ventilator was, the more severe the diaphragmatic dysfunction would be. The stronger the dependence of the patients was, the more difficult the weaning would be.

According to McCool F Dennis [20] and others, the most important factor of the failure of ventilator evacuation was the diaphragmatic dysfunction of the patient. Since the clinician only paid attention to the treatment of the patient's original disease in the course of ventilation and failed to fully understand the diaphragmatic dysfunction, thus further aggravating the diaphragmatic dysfunction of the patient, and ultimately leading to the failure of the patient's ventilator evacuation. Therefore, it was crucial to evaluate the diaphragmatic function. At present, common methods to evaluate diaphragmatic function include CT, Magnetic Resonance Imaging (MRI), diaphragmatic electromyographic activity, X-ray imaging, etc.. However, with complex detection, weak repetition and poor sensitivity, these methods might bring certain trauma to patients[21]. Ultrasound technology had the advantages of high speed, wide application, convenience, strong repeatability and noninvasiveness. In this study, ultrasound evaluation of diaphragm function was adopted in all patients and the results showed that the left and right DMD, left and right DTei, left and right DTee and left and right DTF of the patients in the observation group were higher than those of the control group, with statistically significant differences ($P < 0.05$). Moreover, the ROC curve showed that the left and right DMD, left and right DTei, left and right DTee and left and right DTF could predict the success of weaning, thus demonstrating that ultrasound evaluation of diaphragm function played an important role in guiding ventilator evacuation. In this study, by investigating the clinical value of the application of ultrasound evaluation of diaphragm function in guiding ventilator evacuation, it was found that ultrasound technology could evaluate diaphragm function more safely, conveniently, quickly, economically and intuitively. Additionally, by exploring the correlation between ultrasound technology and diaphragm function in guiding ventilator evacuation, ultrasound evaluation of diaphragm function had become a new guiding index, which had a positive effect on improving the success rate of weaning.

In conclusion, the application of ultrasound in evaluating diaphragm function in guiding ventilator evacuation could effectively evaluate the timing of patients' ventilator evacuation, and played a positive role in improving the success rate of weaning.

## REFERENCES

1. [1]ZhouYang,BuRongwei,GongJunhui, et al.Numerical investigation on the effectiveness of positive pressure ventilation technology in a multi-layer subway station[J].Indoor and Built Environment,2019,28(7):984-998.
2. [2]Mark Wesseling,Martin Schmidt,Dirk Müller.Numerical robustness analysis of natural and mechanical smoke extraction systems for buildings[J].International Journal of Ventilation,2019,18(2):79-95.
3. [3]Yamamoto, Kazuhiro,Sawaguchi, Yuusuke,Nishiki, Shinnosuke.Simulation of Tunnel Fire for Evacuation Safety Assessment[J].Safety,2018,4(2):12.
4. [4]Zhou, Yang,Bu, Rongwei,Gong, Junhui, et al.Numerical investigation on the effectiveness of positive pressure ventilation technology in a multi-layer subway station[J].Indoor and built environment: Journal of the International Society of the Built Environment,2019,28(7):984-998.
5. [5]Youssriah.Sabri,Sabah.Hussein,Ahmed.Baz, et al.Ultrasonographic evaluation of the diaphragm[J].Egyptian Journal of Bronchology,2019,13(5):690-698.
6. [6]Martin Dres,Bruno-Pierre Dubé,Ewan Goligher, et al.Usefulness of Parasternal Intercostal Muscle Ultrasound during Weaning from Mechanical Ventilati on[J].Anesthesiology,2020,132(5):1114-1125.
7. [7]Lisa D. Hobson - Webb,Zachary Simmons.ULTRASOUND IN THE DIAGNOSIS AND MONITORING OF AMYOTROPHIC LATERAL SCLEROSIS: A REVIEW[J].Muscle & Nerve,2019,60(2):114-123.
8. [8]Demiri, Suela,Dube, Bruno-Pierre,Demoule, Alexandre, et al.Ultrasound evaluation of diaphragm function in mechanically ventilated patients: comparison to phrenic stimulation and prognostic implications[J].Thorax: The Journal of the British Thoracic Society,2017,72(9):811-818.
9. [9]Priya.Ramachandran,Uma.Devaraj,Bhavna.Patrick, et al.Ultrasonographic assessment of skeletal muscle mass and diaphragm function in patients with chronic obstructive pulmonary disease: A case–control study[J].Lung India,2020,37(3):220-226.
10. [10]Sanket.Jain,Girija.Nair,Abhishek.Nuchin.Study of diaphragm in chronic obstructive pulmonary disease using ultrasonography[J].Lung India,2020,37(3):288-288.
11. [11]OtaHideki,MatsumotoHidekazu.Impact of the crural diaphragm thickness on pulmonary function after lobectomy[J].Asian Cardiovascular and Thoracic Annals,2019,27(5):388-393.
12. [12]Ashley J. Smuder,Aaron B. Morton,Stephanie E. Hall, et al.Effects of exercise preconditioning and HSP72 on diaphragm muscle function during mechanical ventilation[J].Journal of Cachexia, Sarcopenia and Muscle,2019,10(4):767-781.
13. [13]Elisabetta Cattoni,Claudio Tamagnini.Critical Accelerations for Propped Diaphragm Walls in Sand by Finite Element Limit Analysis[J].Journal of Earthquake Engineering,2020,24(3):403-420.
14. [14]Khurram, Obaid U.,Fogarty, Matthew J.,Vang, Pangdra, et al.Diaphragm muscle function following midcervical contusion injury in rats[J].Journal of applied physiology,2019,126(1):221-230.
15. [15]Hideki Ota,Hidekazu Matsumoto.Impact of the crural diaphragm thickness on pulmonary function after lobectomy[J].Asian cardiovascular & thoracic annals,2019,27(5):388-393.
16. [16]Malas, Fevziye Unsal,Koseoglu, Fusun,Kara, Murat, et al.Diaphragm ultrasonography and pulmonary function tests in patients with spinal cord injury[J].Spinal cord: the official journal of the International Medical Society of Paraplegia,2019,57(8):679-683.
17. [17]Uma.Devaraj,Kavitha.Venkatnarayan,Uma.Krishnaswamy.Assessing the flat diaphragm in chronic obstructive pulmonary disease: Deep-diving is a better approach[J].Lung India,2020,37(1):82-83.
18. [18]Kelsey Gudmundson,Harsimran K. Kalra,Michael M. Tymko, et al.Respiratory capacity is maintained despite Duchenne muscular dystrophy - related diaphragm weakness[J].The Journal of Physiology,2019,597(12):2973-2974.
19. [19]Spiesshoefer Jens,Herkenrath Simon,Henke Carolin et al. Evaluation of Respiratory Muscle Strength and Diaphragm Ultrasound: Normative Values, Theoretical

Considerations, and Practical Recommendations.[J] .Respiration, 2020, 99: 369-381.

20. [20]McCool F Dennis,Oyieng'o Dennis O,Koo Patrick,The Utility of Diaphragm Ultrasound in Reducing Time to Extubation.[J] .Lung, 2020, 198: 499-505.
21. Wang Gaihua, Zhang Tianlun, Dai Yingying, Lin Jinhe ng and Chen Lei. A Serial-Parallel Self-Attention Netwo rk Joint With Multi-Scale Dilated Convolution, IEEE A ccess, 9(5), 2021: 71909-7191.DOI: 10.1109/ACCESS. 2021.3079243