Annals of Clinical Medicine and Research

Case Report
Published: 15 Jul, 2024

Chest Wall Loading in Severe ARDS: A Case Report

Wei-Hung C[1], Chieh-Jen W[1]*, Yen-Siang T[1,2], Yu-Chung K[1,2] and Chang-Yi L[1,2]

[1]Department of Internal Medicine, Division of Pulmonary, MacKay Memorial Hospital, Taiwan

[2]Department of Critical Care Medicine, MacKay Memorial Hospital, Taiwan

Abstract

Chest Wall Loading (CWL) has emerged as a potential strategy to enhance oxygenation and lung compliance in patients with Acute Respiratory Distress Syndrome (ARDS). We present a case of a 58-year-old female, post-leukemia bone marrow transplant, who developed severe ARDS. Despite conventional protective ventilation, her oxygenation did not significantly improve. Following suboptimal response to prone ventilation, we implemented CWL. Placing a 5-kg sandbag on the upper back of the patient resulted in an immediate increase in lung compliance from 27.3 ml/cmH_2O to 34.4 ml/cmH_2O and a decrease in plateau pressure from 29 cmH_2O to 23 cmH_2O. Post-intervention, the patient's PaO_2/FiO_2 ratio improved dramatically from approximately 70 to 300, indicating substantial clinical improvement. This case highlights the potential benefits of CWL in selected ARDS patients and lays the groundwork for further research in this area.

Keywords: Local Chest Wall Compression; Severe ARDS; Prone Positioning; Belly Push

Abbreviations

ARDS: Acute Respiratory Distress Syndrome; ICU: Intensive Care Unit; NTUH: National Taiwan University Hospital; OPD: Outpatient Department; ER: Emergency Room; CRP: C-Reactive Protein; PaO_2: Partial Pressure of Oxygen; $PaCO_2$: Partial Pressure of Carbon Dioxide; HCO_3: Bicarbonate; FiO_2: Fraction of Inspired Oxygen; Crs: Respiratory System Compliance; PEEP: Positive End Expiratory Pressure; PJP: *Pneumocystis Jirovecii* Pneumonia; ECMO: Extracorporeal Membrane Oxygenation; IAP: Intra-Abdominal Pressure; BMI: Body Mass Index; PCR: Polymerase Chain Reaction

Introduction

Acute Respiratory Distress Syndrome (ARDS) remains a life-threatening condition, where conventional lung protective ventilation might not suffice to correct hypoxemia and prevent ventilator-induced lung injury [1]. Prone positioning is an alternative strategy that has been shown to improve oxygenation. However, Gattinoni and Marini pointed out that it might decrease thoracoabdominal compliance due to modified transpulmonary pressure and regional variations in lung and chest wall properties [2]. This suggests that while prone positioning can improve oxygenation, it may not be beneficial for all patients and can lead to complications related to compliance.

To address these limitations, the application of Chest Wall Loading (CWL) has been explored as a method to positively alter respiratory mechanics. CWL, involving external pressure applied to the chest wall, has shown promise in enhancing lung compliance and possibly reducing ventilator-induced lung injury. However, the exact patient profile that would benefit most from this maneuver and the details of its application remain to be fully determined.

In this case, we report on a pneumocystis pneumonia patient with severe ARDS, who was successfully managed through prone positioning complemented by chest wall loading, illustrating the potential of CWL in ARDS treatment.

Case Presentation

A 58-year-old female with a medical history of leukemia post-surgical bone marrow transplantation in December 2021 regularly received follow-up at the National Taiwan University Hospital (NTUH). She received Tixagevimab-Cilgavimab on September 14 at NTUH OPD. Then she had dizziness and fatigue starting on September 17. She presented at our Emergency Department (ER) due to progressive shortness of breath with a fever of up to 39° Celsius for 3 days. She had no history of heart failure or pulmonary disease and denied having chest pain, wheeze, swollen

OPEN ACCESS

***Correspondence:**
Wang Chieh-Jen, Department of Internal Medicine, Division of Pulmonary, MacKay Memorial Hospital, Tapei City, Taiwan, Tel: 0932026019;

Received Date: *20 Jun 2024*
Accepted Date: *09 Jul 2024*
Published Date: *15 Jul 2024*

Citation:
Wei-Hung C, Chieh-Jen W, Yen-Siang T, Yu-Chung K, Chang-Yi L. Chest Wall Loading in Severe ARDS: A Case Report. Ann Clin Med Res. 2024; 5(1): 1072.

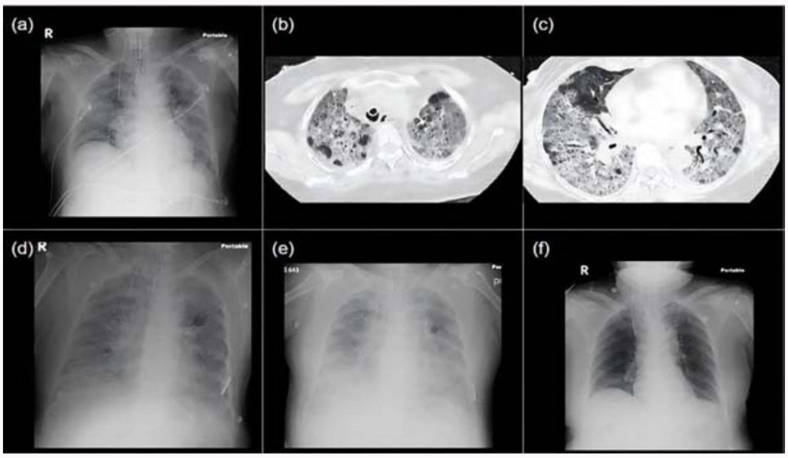

Figure 1: (a) First day of chest radiograph. (b) First day upper to middle region of chest CT. (c) First day middle to lower chest CT. (d) Second day of chest radiograph. (e) Fourth day of chest radiograph. (f) 10th day of chest radiograph.

Figure 2: (a) quasi-static pressure - volume curve was plotted, there is no significant recruitment potential present. (b) Prone position before chest wall loading.

Figure 3: (a) plateau pressure show 29 cmH_2O before chest wall loading. (b) Respiratory system compliance showed 27.3 ml/cm H_2O before chest wall loading.

leg, or hemoptysis. Physical examination revealed rales sound in bilateral lungs. Laboratory tests revealed a white blood cell count of 2,300/μL and an elevated C-Reactive Protein (CRP) level of 34.7 mg/dL. Arterial blood gas test revealed a pH of 7.27, partial Pressure of Oxygen (PaO_2) of 70, Partial Pressure of Carbon Dioxide ($PaCO_2$) of 28, Bicarbonate (HCO_3) of 12.9, and a PaO_2/FiO_2 ratio of 70 under mechanical ventilation.

The chest radiograph disclosed bilateral infiltration progress and pulmonary edema (Figure 1a). CT images showed diffuse mixed consolidation and ground glass opacity with interlobular septal thickening involving parenchyma of both lungs, consistent with a crazy paving pattern (Figure 1b, 1c). She was intubated at the ER for acute respiratory failure and then transferred to the ICU for further management.

Bronchoscopy was performed after admission for bronchoalveolar lavage fluid studies. The rapid multiplex PCR assay BioFire FilmArray Pneumonia Panel yielded no positive results in common bacterial/viral panels. Additional studies for atypical pathogens were arranged (*Pneumocystis jirovecii* was later confirmed as the prime culprit pathogen). She was ventilated with protective ventilation strategies with deep sedation and neuromuscular blockade (ventilator setting: Adaptive Pressure Ventilation mode, tidal volume of 7 ml/kg of predicted body weight, peak airway pressure of 27 cmH_2O, positive end-expiratory pressure of 12 cmH_2O). However, her PaO_2/FiO_2 ratio was 92.8 under FiO_2 70%, and the respiratory system Compliance (Crs) was only 21.7 ml/cm H_2O. She was placed in a prone position at the end of the first day in the ICU at a tidal volume of 350 ml, positive end-expiratory pressure of 10 cmH_2O, and PaO_2/FiO_2 ratio of 165.4 under FiO_2 55%.

On the morning of the second ICU Day, the PaO_2/FiO_2 ratio improved to 164 with Crs of 42.6 ml/cm H_2O. A supine trial was performed but failed at a tidal volume of 350 ml, positive end-expiratory pressure of 10 cmH_2O, and PaO_2/FiO_2 ratio of 46 under FiO_2 100% (Figure 1d). She was immediately returned to a prone position and stabilized at a tidal volume of 350 ml, positive end-

Figure 4: Prong position with Chest wall compression with a 5-kilogram sand bag placed on the upper back of the patient (Patient height: 150 cm, weight: 61.7 kg, BMI: 27.1).

expiratory pressure of 10 cmH_2O, and PaO_2/FiO_2 ratio of 152 under FiO_2 70%.

On the third ICU Day, lung mechanics measurement and quasi-static pressure-volume curve were plotted and found no further recruitment potential above PEEP of 10 cmH_2O (Figures 2a, 2b, 3a, 3b). Chest wall loading with a 5-kg sandbag placed on the upper back of the patient was performed. Crs improvement was recognized immediately (from 27.3 to 34.4), with plateau pressure reduction from 29 cmH_2O to 23 cmH_2O (Figures 4, 5a, 5b). The PaO_2/FiO_2 ratio one hour later was 169. The patient could tolerate ventilator settings with a volume of 7.5 ml/kg of predicted body weight and positive end-expiratory pressure of 12 cmH_2O. We kept the weight on her back for 1 day. She was returned to a supine posture the following day and stabilized with a tidal volume of 8.5 ml/kg of predicted body weight, positive end-expiratory pressure of 10 cmH_2O, and PaO_2/FiO_2 ratio of 300 (Figure 1e). The patient responded well to antibiotic treatment for PJP. She was extubated on the hospital's 10th day (Figure 1f) and discharged on the 13th day.

Discussion and Conclusion

The lungs are enclosed by the chest wall, which is a complex structure made up of the rib cage and abdomen. The diaphragmatic floor is normally the most pliable portion of the lung's thoracic enclosure. For patients admitted to the ICU under the support of mechanical ventilation, expansion of the rib cage by chest wall muscle and positive airway pressure during intermittent positive-pressure ventilation may provide enough lung compliance, although compressive effects of the abdominal organs on the lungs [3]. In comparison with moderate to severe ARDS, at very low and very high thoracic volumes approaching residual volume and total lung capacity, respectively, the pressure-volume relationship of the chest wall would flatten, at last decreasing lung compliance. Prone positioning, which has multiple mechanisms, may decrease the gravitational pressure of the heart and mediastinum on the lungs and compressive effects of the abdominal organs on the lungs. The most important is the non-physiological stress and strain associated with mechanical ventilation, thus decreasing the risk of ventilator-induced lung injury, which is known to adversely impact patient survival [1]. In the past few years, the consequent Coronavirus Disease 2019 (COVID-19), the most concerning complication, of which is acute hypoxemic respiratory failure, led to a surge in patients requiring mechanical ventilation and ICU admission [4]. Prone positioning is an established strategy to improve oxygenation in severe ARDS, and its application was associated with a reduction in mortality rate [5]. However, patients with spinal instability, unstable fractures, open wounds, shock, and pregnancy are contraindications to prone positioning. And ECMO was not enough for many patients during the global pandemic infection.

Figure 5: (a) Plateau pressure show 23 cmH_2O after chest wall loading. (b) Respiratory system compliance showed 34.5 ml/cm H_2O after chest wall loading.

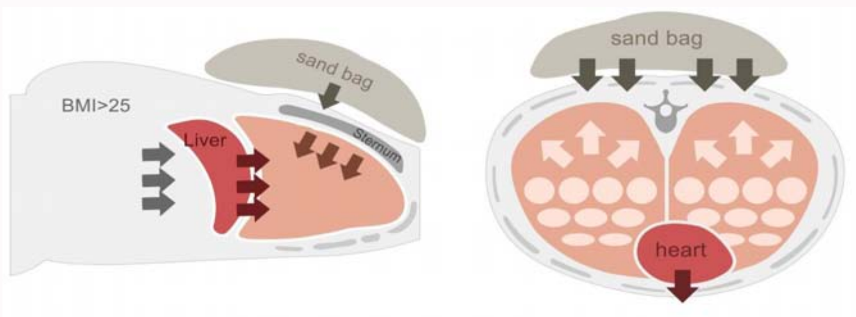

Figure 6: (a) Hypothetical effects of placing sand bag over sternum improves the tidal compliance of the lung by "Belly push" in overweight patient. (b) A reduction in hyperinflation in the dorsal lung region despite the already compressed anterior chest wall of prone positioning.

In these conditions, interventions that reduce resting lung volume, such as loading the chest wall through application of external weights or manual pressure, could unexpectedly improve tidal compliance of the lung and integrated respiratory system by reducing previously undetected end-tidal hyperinflation [6]. Five kilograms placed on the midabdomen of supine ventilated raised Intra-Abdominal Pressure (IAP) by ~ 6 cmH_2O to 7 cmH_2O and predictably increased plateau pressure. Intrapleural pressure and tidal respiratory system compliance change little until the IAP rises above ~ 6 cmH_2O, which is the upper limit of the normal range for non-morbidly obese humans (BMI>25: Overweight) [7]. Additional weights on the chest wall (hypothetical effects), "belly push" might prove to be more efficient in eliciting any benefits from reducing lung volume (Figure 6a).

A reduction in hyperinflation in the dorsal lung region, despite the already compressed anterior chest wall of prone positioning, which had additionally decreased the superimposed pressure and IAP of both the heart and the abdomen on the Dorso-caudal regions of the lungs (Figure 6b).

In Lassola et al. study, alveolar dead space decreased from supine position with no chest wall compression, supine position with chest wall compression, prone position with no chest wall compression to prone position with chest wall compression. However, the PaO_2/FiO_2 ratio increased from supine position with no chest wall compression, prone position with no chest wall compression, supine position with chest wall compression to prone position with chest wall compression [8]. This shows the chest wall compression had neither proportional effect in supine and prone position.

And the recent literature shows that the lower the respiratory system compliance was at enrollment (below 40), the greater the improvement may be, with a further 20% improvement in compliance found when chest wall loading was applied in patients in the prone position compared with no chest wall loading in the supine position; both improved by 10% with chest wall loading in the supine position and no chest wall loading in the prone position compared with no chest wall loading in the supine position [9]. In our case, a severe ARDS with high IAP, the prone positioning combined with chest wall loading (5 kg) successfully improved her condition almost immediately. As we tried the chest wall loading for more than 12 h with no decrease in Crs.

Our suggestion for chest wall loading is to perform it in severe ARDS in both supine and prone positions for hours, as it shows no harm to lung compliance. This may also result in a 10% improvement in lung compliance compared with no chest wall compression in the supine position for patients with spinal injuries or others who cannot perform prone positioning. Check lung compliance 1 min after chest wall compression with 5 kg is performed.

However, further studies will be required to identify which patients will benefit from this intervention and to determine the optimal timing, duration, and weight of chest wall loading.

References

1. Slutsky AS, Ranieri VM. Ventilator-induced lung injury. N Engl J Med. 2014;370(10):980.
2. Marini JJ, Gattinoni L. Improving lung compliance by external compression of the chest wall. Crit Care. 2021;25:264.
3. Venus K, Munshi L, Fralick M. Prone positioning for patients with hypoxic respiratory failure related to COVID-19. CMAJ. 2020;192:E1532-7.
4. Grasselli G, Zangrillo A, Zanella A, Antonelli M, Cabrini L, Castelli A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy Region, Italy. JAMA. 2020;323:1574-81.
5. Guérin C, Reignier J, Richard JC, Beuret P, Gacouin A, Boulain T, et al. Prone positioning in severe acute respiratory distress syndrome. N Engl J Med. 2013;368:2159-68.
6. Selickman J, Marini JJ. Chest wall loading in the ICU: Pushes, weights, and positions. Ann Intensive Care. 2022;12(1):103.
7. Regli A, De Keulenaer BL, Singh B, Hockings LE, Noffsinger B, van Heerden PV. The respiratory pressure-abdominal volume curve in a porcine model. Intensive Care Med Exp. 2017;5(1):11.
8. Miori S, Sanna A, Pace R, Magnoni S, Vetrugno L. Critical Care. Effect of chest wall loading during supine and prone position in a critically ill covid-19 patient: A new strategy for ARDS? Crit Care. 2021;25:442.
9. Bastia L, Rezoagli E, Guarnieri M, Engelberts D, Forlini C, Marrazzo F, et al. External chest-wall compression in prolonged COVID-19 ARDS with low-compliance: A physiological study. Ann Intensive Care. 2022;12(1):35.