Personalized ventilatory strategy for patients with acute respiratory distress syndrome

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Abstract

Acute respiratory distress syndrome (ARDS) is a biologically, physiologically, and morphologically heterogeneous disease with diverse etiologies. This heterogeneity has limited the success of standardized treatments, necessitating a shift toward personalized therapeutic approach.

Our research focuses on the mechanisms that exacerbate lung injury in ARDS patients from a pulmonary physiological perspective, identifying three key factors contributing to the heterogeneity: **(1) Recruitability**, **(2) Effort of breathing**, and **(3) Lung stress**. These factors play a pivotal role in worsening lung injury and outcomes. Categorizing the heterogeneous ARDS patients into more homogeneous subgroups based on these factors allows us to provide personalized ventilatory strategies. Additionally, we found that heterogeneity in the distribution of ventilation is associated with worse outcomes in postoperative patients. Based on these findings, personalized ventilatory strategies are being developed to improve patient outcomes.

Background & Results

The mortality of ARDS has remained high at approximately 40% over two decades. Despite numerous clinical trials, few therapies have successfully reduced mortality. One primary reason is the heterogeneity of ARDS, which obscures the efficacy of uniform treatment strategies. This underscores the urgent need for individualized therapeutic strategies.

Our research team has been investigating the factors that exacerbate lung injury and contribute to ARDS heterogeneity from a pulmonary physiological perspective. Using the insights from these studies, personalized ventilatory strategies for ARDS are being developed (***Figure 1***).

1. Recruitability

The Recruitment-to-Inflation (R/I) ratio, a bedside technique for assessing lung recruitability, has recently been developed. We found that there was significant interpatient variability in R/I ratio among patients with COVID-19-associated ARDS and personalized ventilatory strategy based on the R/I ratio might prevent ventilator-induced lung injury (Reference 1).

2. Effort of Breathing

Traditionally, the preservation of inspiratory effort has been considered beneficial in ARDS. However, we found that excessive inspiratory effort induces the shift of air within the lungs (pendelluft phenomenon), worsening lung injury. Our studies demonstrated that ventilatory strategies such as applying higher positive end-expiratory pressure or prone positioning can attenuate the inspiratory effort and protect the lungs. Additionally, we demonstrated that patient-ventilator asynchrony exacerbates lung and diaphragm injury in preclinical models of ARDS (Reference2). These findings provide a rationale for optimizing effort of breathing to improve outcomes in ARDS patients.

3. Lung Stress

Using esophageal manometry, we quantified lung stress (*i.e.*, trans-pulmonary pressure) and demonstrated its association with lung injury. Moreover, we have been developing a novel technique for visualizing and quantifying lung stress (the risk of lung injury) in whole lungs using the data from chest CT and esophageal pressure (***Figure 2***).

Beyond ARDS, heterogeneity in the distribution of ventilation measured by electrical impedance tomography (EIT) in postoperative patients was associated with poor outcomes (Reference3). These insights suggest the potential applicability of personalized ventilatory strategies in postoperative management.

Significance of the research and Future perspective

Personalized ventilatory strategies for ARDS patients, based on pulmonary physiology, is promising for improving outcomes. By developing a therapeutic framework based on personalized ventilatory strategies, we can provide high-quality care not only to ARDS patients but also to patients under mechanical ventilation.

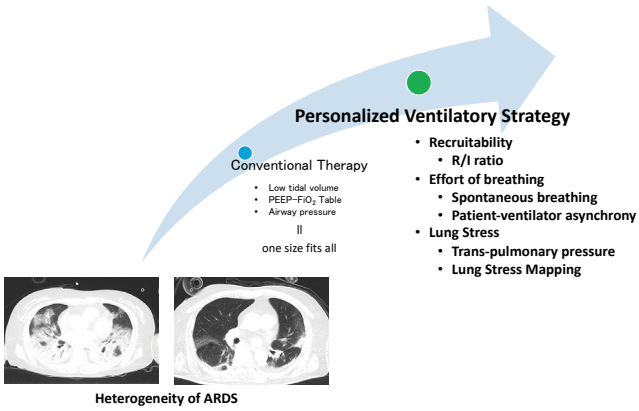

Figure 1. Personalized Ventilatory Strategy for ARDS

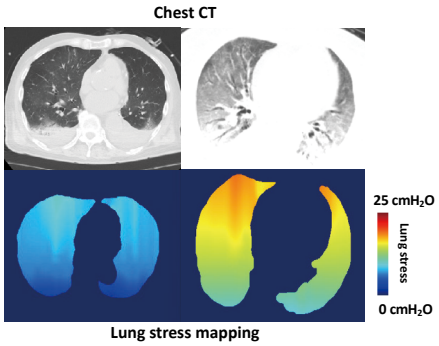

Figure 2. Lung stress mapping

Patent	Japanese Patent Application No. 2023-179486, US Patent Application No. 18/916815
Treatise	1)Taenaka, Hiroki; Yoshida, Takeshi; Hashimoto, Haruka et al. Personalized ventilatory strategy based on lung recruitablity in COVID-19-associated acute respiratory distress syndrome: a prospective clinical study. Critical Care. 2023, 27, 152. doi: 10.1186/s13054-023-04360-6 2)Hashimoto, Haruka; Yoshida, Takeshi; Firstiogusran, AMF et al. Asynchrony injures lung and diaphragm in acute respiratory distress syndrome. Critical care medicine. 2023, 51, e234-e242. doi: 10.1097/CCM.0000000000005988 3)Iwata, Hirofumi; Yoshida, Takeshi; Hoshino, Taiki et al. Electrical impedance tomography-based ventilation patterns in patients after major surgery. American journal of respiratory and critical care medicine. 2024, 209, 1328-1337. doi: 10.1164/rccm.202309-1658OC
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