EC CLINICAL AND MEDICAL CASE REPORTS
Case Report

Static Compliance of Respiratory System (CSTAT(RS)) and its Trend as an Objective Guide for Managing COVID-19 ARDS Across a Heterogeneous Patient Population. A Bedside Observation and Perspective

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Abstract

Background: Critical care physicians, although comfortable with invasive mechanical ventilation of acute respiratory distress syndrome (ARDS) after years of research on ARDS, are left wondering what the optimal ventilatory strategy for COVID ARDS is. We did not find any publication describing a precise method of utilization of Static Compliance of Respiratory System (CSTAT(RS)) in COVID ARDS patients to date. In our institution, we did observe both the phenotypes (L and H) and some patients behaving as hybrids (having both L and H features) intermittently.

Case Summary: 67-year-old obese black woman who presented to the ED with progressive dyspnea progressed into acute respiratory failure secondary to COVID-19 ARDS (P: F <100). Ventilator management was guided by her CSTAT(RS), which improved during the second week, and she was liberated from mechanical ventilation after three weeks.

Conclusion: Our ventilator strategy, with particular attention to the CSTAT(RS), may help prevent worsening and perhaps facilitate recovery. In addition, the trend in Static Compliance of the Respiratory System CSTAT(RS), may be a better predictor of disease progression than inflammatory markers.

Keywords: *Lung Compliance; COVID-19; ARDS; Respiratory Failure; Static Compliance*

Introduction

COVID-19 ARDS patients requiring mechanical ventilatory support in our COVID ICU had at least two different phenotypes (L and H), as described by Gattinoni. However, L-phenotype patients may evolve into H-phenotype, with a consequent poor outcome, giving us a window of opportunity to halt this transition. Our ventilator strategy, which is utilized with particular attention to the Static Compliance of Respiratory System ($C_{STAT(RS)}$) and determinants of oxygen delivery and consumption, may play a role in halting this transition and perhaps facilitating eventual recovery. Our novel algorithmic approach to managing heterogenous COVID ARDS based on the $C_{STAT(RS)}$ and its trend is described here.

Case Report

67-year-old obese black woman with a history of osteoarthritis, cerebral vascular accident, and cervical cancer who presented to the ED with progressive dyspnea and cough of five days duration and she was in acute respiratory failure. Nasopharyngeal swab revealed COVID-19 infection. Chest radiograph showed extensive bilateral airspace disease. She was diagnosed with COVID-19 ARDS (P: F < 100).

She had only mildly decreased $C_{STAT(RS)}$ (42 mL/cmH_2O), with high inflammatory markers that fluctuated during her ICU stay. Her $C_{STAT(RS)}$ improved to 57 mL/cmH_2O during the second week, and she was liberated from mechanical ventilation after three weeks.

Discussion

Like many institutions, we do not have the capability of measuring lung compliance. Our ventilation strategy guided by $C_{STAT(RS)}$ in heterogenous COVID ARDS patients as described in our case, did work in facilitating liberation of mechanical ventilation. At one end of this continuum, the H-Phenotype patients had consistently low $C_{STAT(RS)}$ and high inflammatory markers with slight fluctuation, requiring complex ventilator strategies to ensure oxygenation and ventilation. Consideration for ECMO in such cases may need to be considered.

ARDS is a heterogeneous disease characterized by hypoxemia. The most widely accepted definition of ARDS is the 'Berlin Definition,' introduced in 2012 [1] is broad, and most patients admitted to the ICU for acute respiratory failure with bilateral parenchymal lung disease will meet this definition. Over the past decade, several histologic, morphologic and physiologic phenotypic subtypes of ARDS have been proposed, with some arguing for different treatment approaches depending on the subtype [2,3]. Mortality rates and outcomes have differed between different parts of the world, which raises the question about the optimal approach to ventilation in these patients [4].

Gattinoni postulated that a subgroup of patients with COVID present with an atypical form of ARDS, having shunt physiology, characterized by low elastance, and high compliance (L-type), in contrast to the typical ARDS phenotype, which is characterized by high elastance, and low compliance (H-type). It was theorized that the L-type was a result of vascular insult, leading to increased V/Q mismatch. Based on these speculations, it was recommended that clinicians deviate from the ARDS Network lung-protective ventilation strategy when treating L-type patients, instead favoring larger tidal volumes (7 - 8 cc/kg PBW) and avoiding high PEEP (maximum PEEP 8 - 10 cm-H_2O) due to a lack of alveolar recruitability, desire to avoid stressing already injured pulmonary vasculature, and impairing CO_2 exchange. Gattinoni's observation has been challenged by some. These phenotypes are not mutually exclusive, as shown in one study [5]. Also, the idea that COVID-19 ARDS represents a unique disease that should be treated outside of established guidelines can be questioned in the context of a recent large cohort study that showed COVID-19 patients admitted to the ICU had respiratory system indices comparable to those seen in previous extensive studies of ARDS patients, with average static compliance of the respiratory system of 35 mL/cmH_2O at the time of intubation [6]. To complicate this further, another study from the Netherlands showed a weak correlation between respiratory system compliance and lung weight as estimated by CT scan [5].

Understanding pulmonary pathophysiology and lung mechanics remains pivotal to optimize individual ventilator strategies. Most ICUs like ours, are not capable of accurately measuring or monitoring lung compliance, and hence a quick and easily available bedside information from the ventilator, "Respiratory System Compliance", more specifically "static compliance" can be used as a surrogate for lung compliance.

We propose an algorithmic approach that incorporates respiratory system mechanics and its trend to guide bedside clinicians, prescribing ventilator settings while paying attention to the determinants of oxygenation as depicted in the following figure.

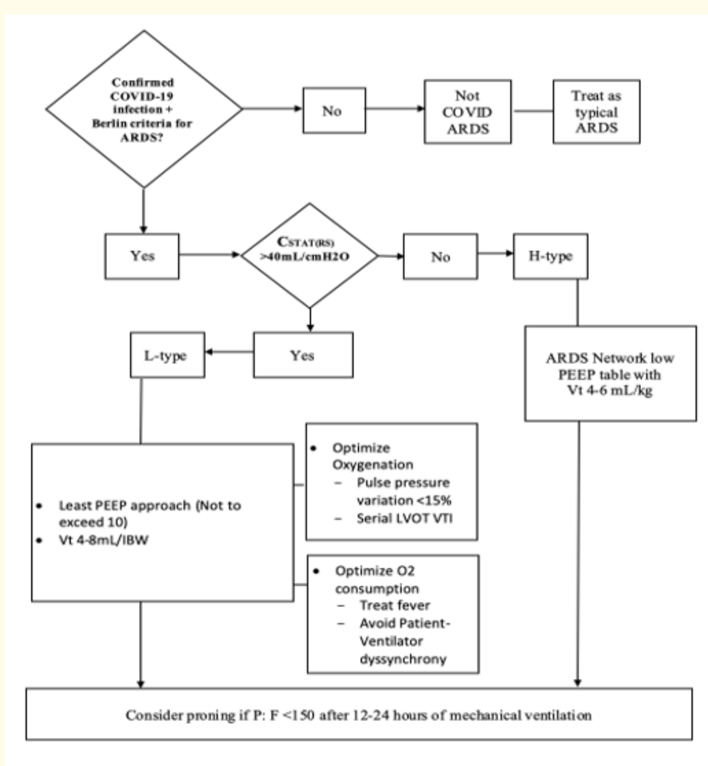

Figure : *Algorithmic approach to managing heterogenous COVID ARDS based on the CSTAT(RS).*

Patients with low $C_{STAT(RS)}$ (< 40 mL/cmH_2O) should be ventilated with traditional lung-protective ventilation strategies, aiming for a plateau pressure < 30 cmH_2O and a driving pressure < 15 cmH_2O. We believe that patients with high $C_{STAT(RS)}$ (> 40 mL/cmH_2O) may be ventilated with more liberal tidal volumes not exceeding 8 mL/kg PBW per the ARDS Network protocol. PEEP and FiO_2 should be determined individually. PEEP generally does not need to exceed 10 cm H_2O. As these "L-type" patients may be less recruitable than "H-type" patients, the overall adverse effects of PEEP on cardiac output and thus oxygen delivery may outweigh the benefits of improved V/Q matching gained with higher PEEP [7,8]. It was recently demonstrated that poor survival is associated with increasing dead space in COVID related ARDS soon after initiation of ventilator support. At the other end of this COVID ARDS continuum, the L-phenotype patients such as the one described here had $C_{STAT(RS)}$ consistently more than 40 mL/cm H_2O. This patient was managed with least PEEP approach, physiology-driven ventilator management; her tidal volumes were set at 6 - 8 mL/ideal body weight. PEEP was 5 - 10 cm H_2O. She had better oxygenation, ventilation, and hemodynamics with this approach. When higher PEEP was used (elevated beyond 10 cmH_2O) transiently, it led to increased shunt fraction compromising both oxygenation and hemodynamics.

We advocate that tissue O_2 delivery be optimized, so patients do not develop signs or symptoms of O_2 dept, such as rising lactic acid. Acute Cor Pulmonale in severe ARDS due to acute increase in right ventricular (RV) after load, is associated with increased mortality in ARDS [9]. RV protective ventilator strategies like limiting plateau and driving pressures, optimizing oxygenation, and ventilation, prone positioning and minimal PEEP to recruit lung without overdistension [10,11]. Monitoring certain hemodynamic parameters, if applied in the context of PEEP's effect on cardiac output, may be helpful. A pulse pressure variation of <15%, or serial left ventricular outflow tract velocity time integral (LVOT VTI) assessment to evaluate the effects of PEEP on cardiac output may be helpful [12,13]. End tidal carbon dioxide ($etCO_2$) can be followed as PEEP is increased. An increasing $etCO_2$ may indicate alveolar overdistension and an increase in the dead space fraction. The $etCO_2/PaCO_2$ relationship is a useful tool to quantify the efficiency of gas exchange. A ratio of 1 is ideal, and less than 1, could be due to elevated shunt or dead space. Prone positioning should be considered in patients with P: F < 150 after 12 - 24 hours of lung-protective mechanical ventilation.

Some L-phenotype patients such as in this case had fluctuating trend in $C_{STAT(RS)}$. Ventilator management was driven by physiology. We used the least PEEP approach and allowed higher tidal volumes of 6 - 8 mL/kg of ideal body weight while monitoring driving pressures, and trend in $C_{STAT(RS)}$. Tidal volumes were adjusted to maintain plateau pressures < 30 cm$H_2$0 and driving pressures < 15 cm H_2O. The trend in $C_{STAT(RS)}$ correlated with the patient's lung pathophysiology and disease progression. Prone positioning, in addition to physiology driven ventilation, seemed to help improve P: F ratios and $C_{STAT(RS)}$. Hence, we propose a physiology-based ventilation strategy as shown in the figure, that worked well for our heterogenous COVID-19 ARDS patients.

Conclusion

The trend in $C_{STAT(RS)}$ may be a better predictor of disease progression or respiratory failure than inflammatory markers.

Although inflammatory markers may indicate the severity of covid-19, they fluctuate with time and seem to poorly predict patient's trajectory in terms of worsening respiratory failure and other organ dysfunctions.

Prone positioning appears to be one of the key ventilation strategies, along with physiology driven settings, optimizing pulmonary blood flow, minimizing the risk of Ventilator induced lung injury; and eventually, leading to improved P: F ratios.

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