Oesophageal manometry and gas exchange in patients with COVID-19 acute respiratory distress syndrome

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Editor—Since the first description of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pneumonia, the associated coronavirus disease 2019 (COVID-19) has rapidly spread worldwide.[1] Up to 35% of patients with COVID-19 have required ICU admission as a result of hypoxaemic respiratory failure.[2] The majority of patients meet current criteria for acute respiratory distress syndrome (ARDS). Invasive mechanical ventilation has been applied in 29–91% of cases.[1]

In one of the largest studies of ICU patients, it was found that the median PEEP in mechanically ventilated patients was 14 cm H_2O.[3] The recent Surviving Sepsis Campaign guidelines for management of critically ill adults with COVID-19 suggest, as a weak recommendation with low quality of evidence, the use of a higher PEEP strategy compared with a lower PEEP strategy (>10 cm H_2O *vs* <10 cm H_2O, respectively).[4] Several strategies have been proposed to select optimal PEEP during ARDS, including PEEP/FiO_2 titration according to the ARDS Network protocol, use of electrical impedance tomography, the decremental PEEP test, the volume–pressure curve, and oesophageal manometry. Oesophageal manometry, by measuring oesophageal pressure swings during mechanical ventilation, allows measurement of the mechanical characteristics of the lung and chest wall and computation of transpulmonary pressure, the real distending force of the lung.[5] Lung and chest-wall mechanics in COVID-19 are still unknown. Reports have described the heterogeneity of the disease characterised by a dissociation between relatively well-preserved lung mechanics and severe hypoxaemia[6] with variable degrees of lung recruitability[7] and perfusion.[8–11]

We studied 23 consecutive mechanically ventilated Covid-19–ARDS (C-ARDS) patients admitted to the ICU of ASST Santi Paolo e Carlo Hospital in Milan, Italy from February 21, 2020 to May 1, 2020. All had positive RT–PCR testing for SARS-CoV-2 on nasal or pharyngeal swab with bilateral lung infiltrates on chest radiography. The institutional review board approved the study (# 9890/2017). All measurements were performed under rigorously controlled conditions. Patients were deeply sedated and paralysed, and then ventilated by volume-control ventilation with tidal volumes of 6–8 ml kg^{-1} of ideal body weight. An oesophageal balloon catheter (SmartCath, Bicore, Irvine, CA, USA) was inserted in the lower part of the oesophagus; its correct position was assessed by external compression during an end-expiratory hold.

A PEEP trial was performed within 48 h of ICU admission. With stable haemodynamic conditions, a recruitment manoeuvre was performed with pressure control ventilation to a plateau pressure of 45 cm H_2O with PEEP of 5 cm H_2O, *I*:*E* ratio of 1:1, and ventilatory frequency of 10 bpm for 2 min. Subsequently, PEEP was set to 5 cm H_2O, and airway and oesophageal pressures were recorded during both end-inspiratory and end-expiratory holds. Values of respiratory system, lung and chest-wall elastance and of end-inspiratory transpulmonary pressure were derived accordingly. Arterial and central venous blood gas analyses were also collected.

Table 1 Respiratory mechanics and gas exchange variables at different levels of PEEP. Continuous variables are expressed as median [inter-quartile range]; Mann–Whitney test was used for continuous variable comparison. Two-tailed *P*-values <0.05 were considered statistically significant.

Characteristic	5 cm H_2O	15 cm H_2O	P-value
Driving pressure (cm H_2O)	10 [8–12]	11 [10–13]	0.004
Respiratory system elastance (cm H_2O L^{-1})	18 [15–25]	20 [19–28]	0.007
Lung elastance (cm H_2O L^{-1})	13 [11–18]	17 [14–24]	0.001
Chest-wall elastance (cm H_2O L^{-1})	6 [4–7]	4 [3–6]	0.276
End-inspiratory airway pressure (cm H_2O)	17 [14–18]	27 [25–29]	<0.001
End-inspiratory transpulmonary pressure (cm H_2O)	11 [10–14]	22 [19–24]	<0.001
Pa_{co2} (kPa)	6.4 [5.9–6.8]	6.3 [5.7–7.3]	0.357
$Pa_{o2}/FiO_{2,}$ (mm Hg)	84 [67–102]	119 [107–144]	<0.001

After 15 min, PEEP was set to 15 cm H_2O, and these measurements were repeated.

Baseline characteristics were median age of 65 (56–69) yr, BMI 27 (25–30) kg m^{-2}, and Pa_{o2}/FiO_2 108 (82–141) mm Hg with a clinical PEEP of 10 (10–12) cm H_2O. Respiratory mechanics and gas exchange data at 5 and 15 cm H_2O of PEEP are reported in Table 1. At 15 cm H_2O of PEEP, the driving pressure, lung elastance, and end-inspiratory transpulmonary pressure significantly increased compared with 5 cm H_2O of PEEP. Arterial oxygenation also significantly increased without change in arterial carbon dioxide.

Our results show that increasing PEEP from a low (5 cm H_2O) to higher (15 cm H_2O) level led to significant deterioration in lung mechanics in critically ill COVID-19 patients. In addition, at 15 cm H_2O of PEEP, end-inspiratory transpulmonary pressure was dangerously close to the physiological limit of 20–25 cm H_2O. These data suggest that the lung in COVID-19 is particularly prone to over-distension and to ventilator-induced lung injury. In this regard, oesophageal manometry represents an invaluable tool in the ventilatory management of C-ARDS, allowing computation of the partitioned respiratory mechanics between lung and chest wall. Although standard ventilatory management would imply use of conventional PEEP/FiO_2 tables with resulting high PEEP levels caused by the severity of hypoxaemia in COVID-19 patients, our data support use of a PEEP trial and with oesophageal manometry to provide an individualised ventilatory strategy.

Declarations of interest

The authors declare that they have no conflicts of interest.

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A low-cost off-the-shelf pressure-controlled mechanical ventilator for a mass respiratory failure scenario

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