The Pressure Paradox: Abdominal Compression to Detect Lung Hyperinflation in COVID-19 Acute Respiratory Distress Syndrome

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A 57-year-old male with respiratory failure secondary to coronavirus disease (COVID-19) pneumonia was intubated for worsening hypoxemia 22 days after onset of symptoms. Past medical history was significant for type 2 diabetes mellitus, hypertension, mild asthma, distal pancreatectomy in the context of severe necrotizing pancreatitis (2003), small hiatal hernia, and 20-pack-year smoking. His body mass index was 20.7 kg/m^2. He was ventilated with ultraprotective volume-control ventilation (V_T of 4.5 ml/kg predicted body weight) and, owing to lack of recruitability as assessed by the recruitment-to-inflation ratio (0.2) (1), positive end-expiratory pressure (PEEP) of 6 cm H_2O. Chest radiography demonstrated dense bilateral consolidations to the lower lobes and periphery of the mid-lung zones associated with mild to moderate interstitial edema and pulmonary vascular prominence. A computed tomographic scan confirmed bilateral widespread subpleural consolidations associated with patchy peripheral ground-glass opacities with areas of lobular sparing.

On Day 4 after intubation, while the patient was sedated and paralyzed, and in supine semirecumbent position, we noticed that a moderate sustained manual compression at the level of the patient's mesogastrium was associated with a paradoxical and almost immediate drop in both peak and plateau pressures that persisted for the entire duration of abdominal compression (*see* Figure 1 and Video 1) (2). Pressure values returned to baseline as soon as compression was released. This phenomenon was reproducible over the course of several days.

The measured quasistatic (3) airway and static esophageal and bladder pressures (and their derived parameters of lung and chest wall respiratory mechanics; https://rtmaven.com) are shown in Table 1 and Video 1. Visual observation of pressure–time curve profiles revealed a reduction of the pressure over time concavity during abdominal compression (*see* Figure 1 and Video 1) (2). This observation suggests that the pressure applied to the patient's abdomen, by increasing intrathoracic pressure, caused a reduction in the end-expiratory lung volume and a downward shift of the pressure–volume curve, with reduction in tidal hyperinflation and possibly increase in tidal recruitment. The combination of these two effects led to the paradoxical improvement of lung and respiratory system compliance, and of lung stress (4, 5).

Since our original observation in June 2020, we and other groups (5) have identified several patients with severe COVID-19 acute respiratory distress syndrome displaying similar paradoxical improvements of respiratory mechanics during abdominal compression. Such a simple bedside maneuver can detect lung hyperinflation even in patients mechanically ventilated with ultraprotective lung strategies and low PEEP. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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‡A.G. is an Early Career *AJRCCM* Group member, and L.B. is Deputy Editor of *AJRCCM*. Their participation complies with American Thoracic Society requirements for recusal from review and decisions for authored works.

The video can be viewed in the online version of this article.

Am J Respir Crit Care Med Vol 205, Iss 2, pp 245–247, Jan 15, 2022

Originally Published in Press as DOI: 10.1164/rccm.202104-1062IM on November 8, 2021
Internet address: www.atsjournals.org

Table 1. Measured Airway, Esophageal, and Bladder Pressures, and Derived Lung and Chest Wall Respiratory Mechanics Parameters

Parameter	Baseline	During Abdominal Compression
Measured		
Exhaled V_T, ml	384	386
Peak pressure, cm H_2O	30	25
Plateau pressure, cm H_2O	25	21
Total positive end-expiratory pressure, cm H_2O	6	7
End-expiratory esophageal pressure, cm H_2O	3	5
End-inspiratory esophageal pressure, cm H_2O	5	8
Bladder pressure, cm H_2O	14	22
Derived		
Driving pressure, cm H_2O	19	14
Respiratory system compliance, ml/cm H_2O	20	28
Lung compliance, ml/cm H_2O	23	35
Chest wall compliance, ml/cm H_2O	192	129
Elastance lung/elastance respiratory system	0.89	0.79
Transpulmonary plateau pressure (elastance-derived method), cm H_2O	22	17
Airway resistance, cm H_2O/L/s	6	5

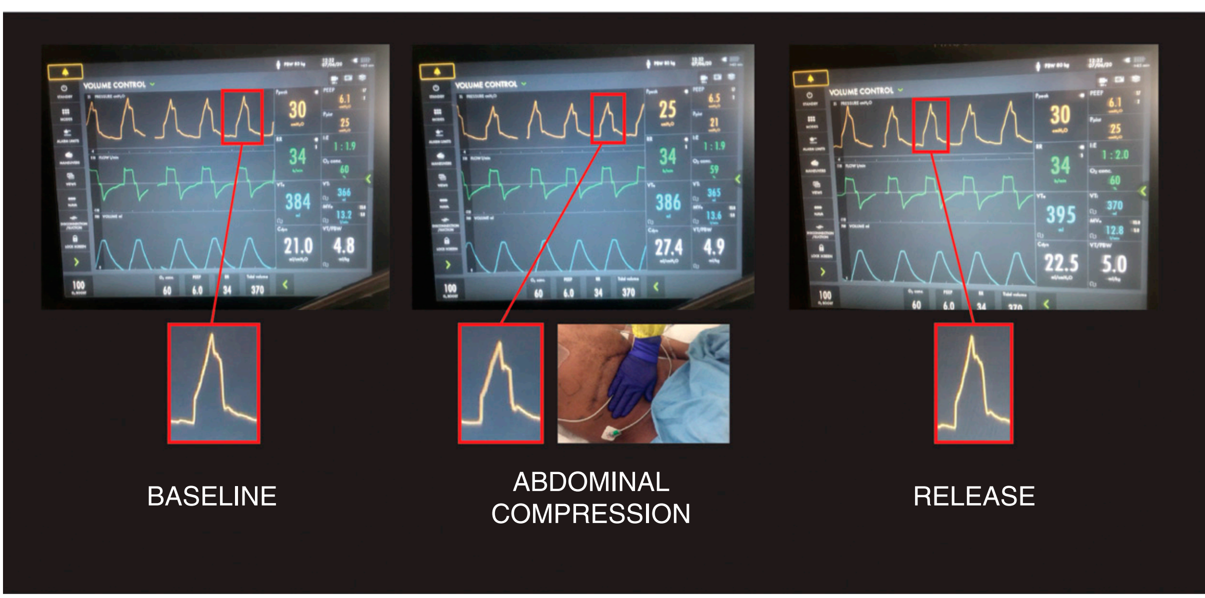
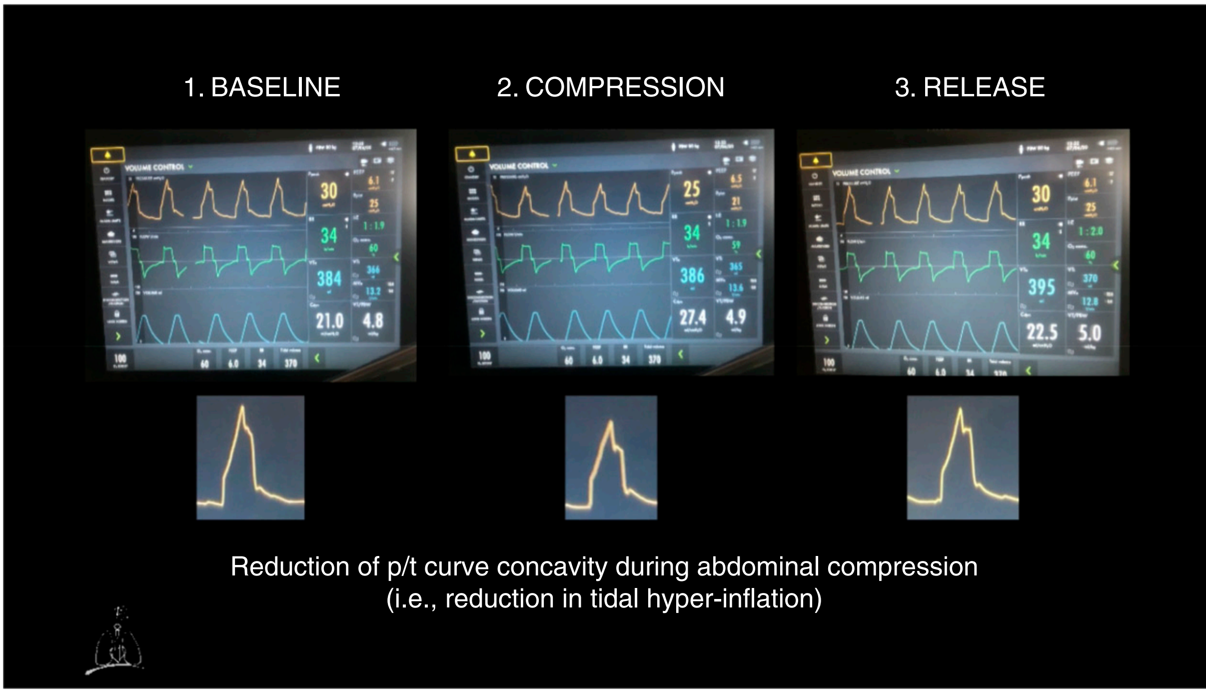


Figure 1. Ventilator screenshots demonstrating the effect of a moderate sustained manual abdominal compression and its release on airway pressures and respiratory mechanics in a sedated and paralyzed patient with severe respiratory failure secondary to coronavirus disease (COVID-19) infection. The red rectangles represent enlargement of the pressure–time curve profiles. A reduction of the pressure over time concavity during abdominal compression, suggesting reduction in tidal hyperinflation, can be seen.



Video 1. Video demonstrating the paradoxical effect of a moderate sustained manual abdominal compression and its release on airway pressures and respiratory mechanics in a sedated and paralyzed patient with severe respiratory failure secondary to coronavirus disease (COVID-19) infection. p/t = pressure–time.

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