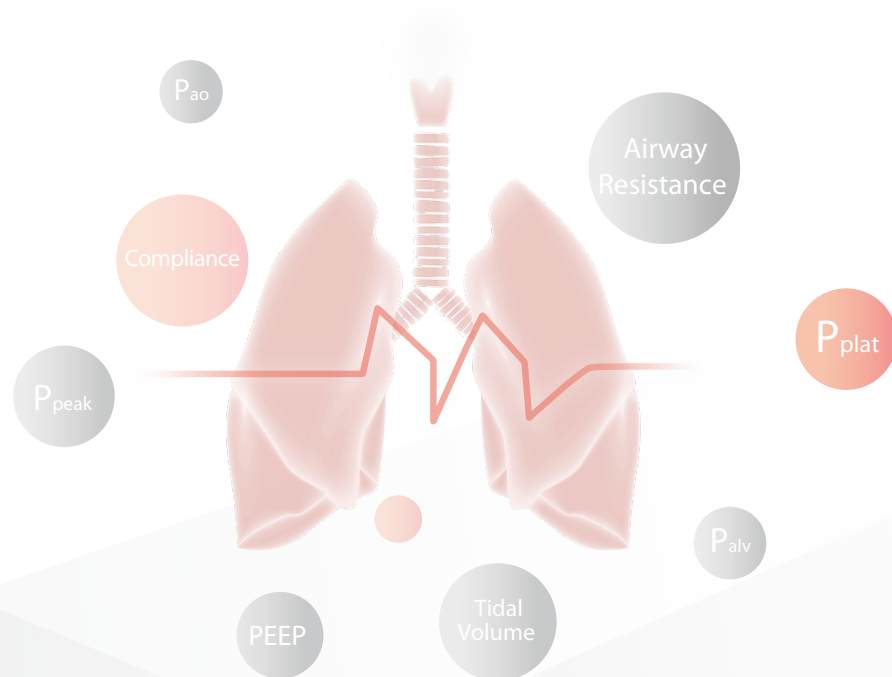
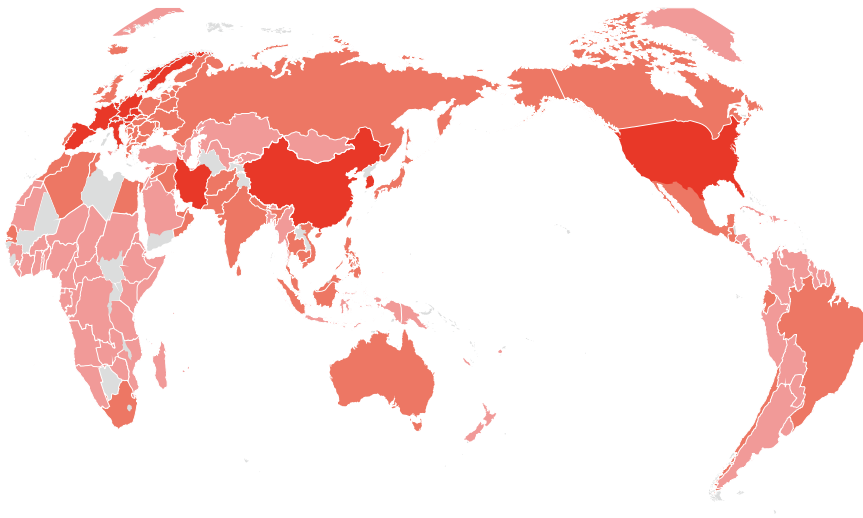


Respiratory Mechanics Monitoring during Mechanical Ventilation for Severe COVID-19



Global Cases Reported by WHO



The virus that causes COVID-19 is infecting people and spreading easily from person to person. Cases have been detected in most countries worldwide and community spread is being detected in a growing number of countries. On March 11, the COVID-19 outbreak was characterized as a pandemic by the WHO. Reported illnesses have ranged from very mild (including some with no reported symptoms) to severe, including illness resulting in death. While information so far suggests that most COVID-19 illness is mild, and serious illness occurs in 16% of cases [1]. As the respiratory system changes based on the severity level, the monitoring of the respiratory mechanic become a vital part of guiding therapeutic strategies and interventions for patients with COVID-19.

SITUATION IN NUMBERS

total and new cases in last 24 hours

Globally

372 757 confirmed
+**39 827** new

Western Pacific Region

96 580 confirmed **3 502** deaths
+**943** new +**29** new

European Region

195 511 confirmed **10 189** deaths
+**24 087** new +**1447** new

South-East Asia Region

1 990 confirmed **65** deaths
+**214** new +**7** new

Eastern Mediterranean Region

27 215 confirmed **1 877** deaths
+**1 840** new +**136** new

Regions of the Americas

49 444 confirmed **565** deaths
+**12 428** new +**100** new

African Region

1 305 confirmed **26** deaths
+**315** new +**3** new

WHO RISK ASSESSMENT

Global Level Very High

Source: WHO, updated as of 10AM CET March 24th 2020



“

Respiration is driven by a complex mechanism of different forces. To comprehend the lungs of a patient as a mechanical system, we have to first know the respiratory mechanics and then adjust the ventilator to the most suitable settings for patient, which is essential for providing individualized respiratory support.

”

Peifeng XU, has been fighting the Pandemic in Hubei Province for nearly two months.

Respiratory Therapist, Respiratory Care Department
Shao Yifu Hospital of Zhejiang University, China

COVID-19 Research and the Importance of Respiratory Mechanics Monitoring

Recent autopsy of deceased COVID-19 patients found that their lung tissue had obvious bleeding and necrotic damage with thick mucus attached deeply in airways. Pathophysiological changes in the lungs can be shown in respiratory mechanics (airway resistance and lung compliance)[2,3]. Therefore, monitoring the respiratory mechanics would help to give early warnings when the patient’s health begins to deteriorate. Therefore, it is highly relevant in guiding ventilation strategies and parameter adjustments for the patient.

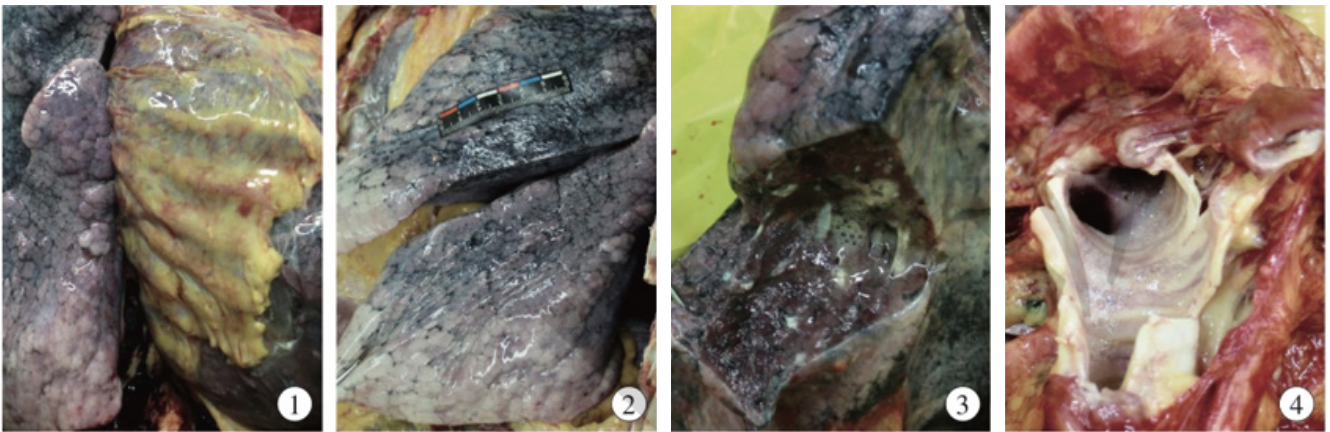
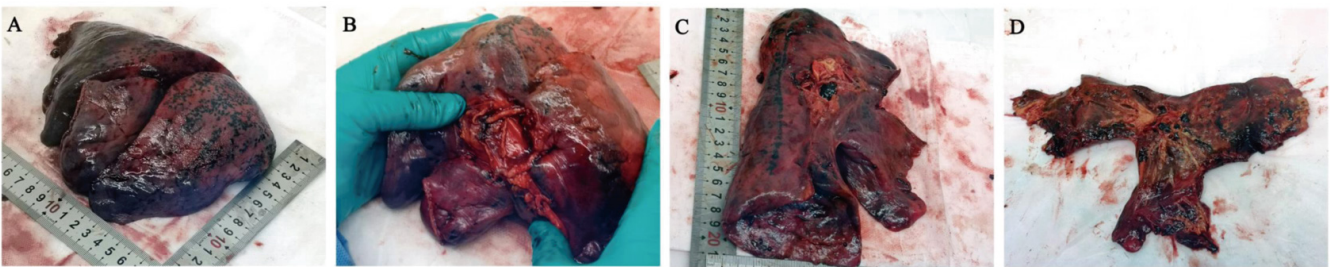


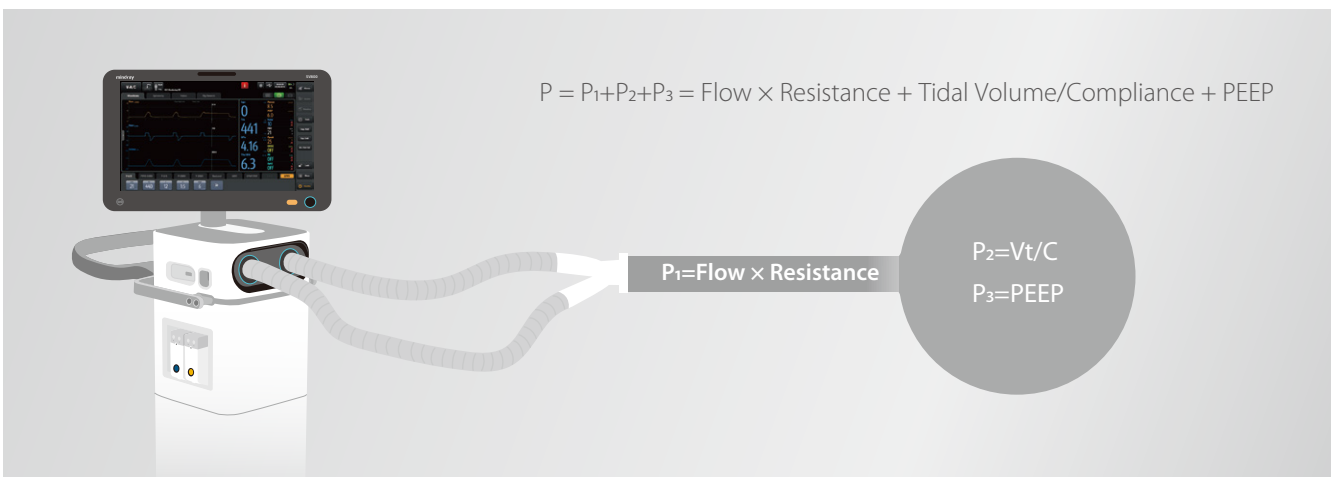
Fig. 1 Right pleura thickening extensive adhesion with the right lung;
 Fig. 2 Gray white patchy lesions in the left lung;
 Fig. 3 Gray white viscous fluid overflow in the lung section, and fiber bands can be seen;
 Fig. 4 White foam mucus in the trachea;



Lung gross examination. Gross morphology of the right lung (A and B) and of the left lung (C and D). Hemorrhagic necrosis is obvious in the outer edge of pulmonary right lobe.

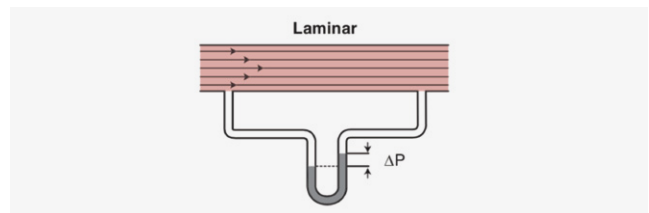
Respiratory Mechanics Monitoring of COVID-19 Patients

Respiratory mechanics are based on Newtonian mechanics, as expressed in the equation of motion. To implicit its simplest form, the respiratory system can be modeled as a balloon connected to a tube. The balloon represents the elastic element (lungs and chest wall), and the tube represents the resistive element (conducting airways). The pressure provided by the ventilator need to overcome the resistance of the airway, to expand the lung with tidal volume and provide with a given PEEP (positive end-expiratory pressure, a positive pressure at the end-of-breath).



► Airway resistance

When gas passes through the artificial airway and the patient's airway to the lungs to generate a tidal volume, it has to overcome the resistance. The pressure to overcome the airway resistance is the difference between the airway opening (P_{ao}) and the intrapulmonary pressure (P_{alv}).



During invasive mechanical ventilation, P_{ao} is the peak pressure (P_{peak}) provided by the ventilator, and P_{alv} can be provided with measurement of plateau pressure (P_{plat}) by inspiratory hold.

$$P_1 = P_{ao} - P_{alv} = P_{peak} - P_{plat} = \text{Flow} \times \text{Resistance}$$

$$\text{Resistance} = (P_{peak} - P_{plat}) / \text{Flow}$$

Measurement technique for P_{plat} :

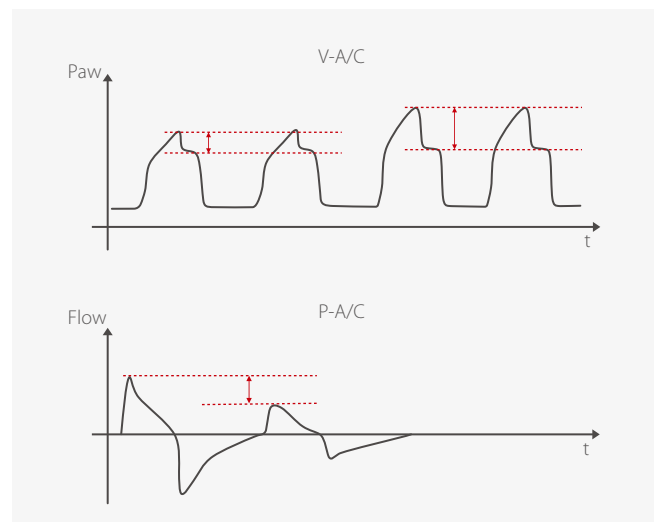
- 1 Under Volume Control Ventilation mode, ensure patient have weak or do not have spontaneous breath
- 2 Square flow (constant flow)
- 3 Inspiratory pause/hold for at least 3s



The normal airway resistance of patients under invasive mechanical ventilation is approximately 5-10 cmH₂O/L/s. When the airway resistance exceeds this range, it means that the airway resistance is too high. Clinicians must be vigilant about the possibilities of causes such as sputum or bronchospasm. Increased airway resistance would have typical waveforms (see the charts):

Under V-A/C mode, when the airway resistance increases, the ventilator pressure-time curve shows an increase in peak pressure and an increase in $P_{peak} - P_{plat}$ as well.

Under P-A/C mode, when the airway resistance increases, the flow-time curve shows a decrease in peak flow, which may result in decrease of tidal volume.



► Compliance

The compliance of the respiratory system mainly reflects the elastic resistance. The compliance refers to the volume change produced by a unit of pressure. During invasive ventilation, when the patient do not have spontaneous breath, the tidal volume (V_t) generated by the driving pressure (DP) can indicate the compliance of the patient's respiratory system.

$$\text{Driving Pressure} = P_{plat} - PEEP$$

Therefore, $\text{Compliance} = V_t / DP$ or $V_t / (P_{plat} - PEEP_{total})$

Generally speaking, $DP > 12$ cmH₂O may increase the risk of lung injury and mortality. P_{plat} generally ≤ 30 cmH₂O is used as a protective lung strategy [4,5]. It should also be noted when calculated compliance of the respiratory system, the PEEP in the formula is not the ventilator setting, but the $PEEP_{total}$ (end-expiratory alveolar pressure)

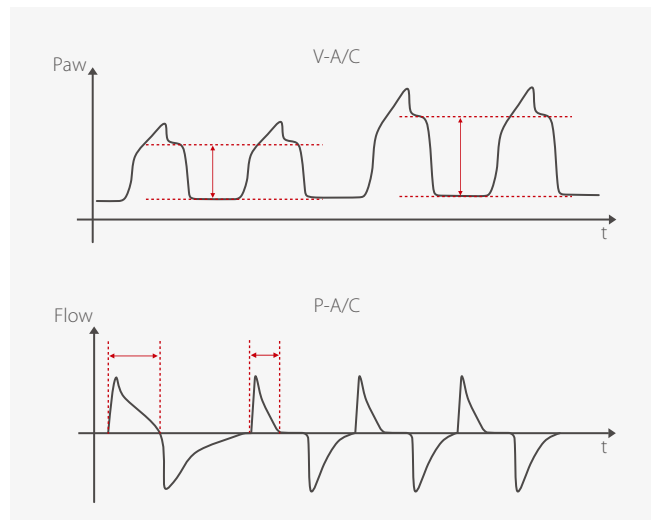
Measurement technique for $PEEP_{total}$:

- ① Under weak or no spontaneous breathing
- ② Expiration pause/hold for at least 2-3s
- ③ If there is no air trapping, $PEEP_{total} = PEEP$



For healthy adult, the compliance of the respiratory system is approximately 100ml/cmH₂O, and the value of patients under mechanical ventilation will be lower, usually around 60ml/cmH₂O. When the patient's compliance is reduced, it means that there are restrictive factors within the lungs, such as pulmonary edema, atelectasis, pulmonary consolidation, chest wall disease, pleural effusion, pneumothorax, etc. Decrease in respiratory compliance would often show waveforms like as the following.

During the V-A/C mode, when the compliance decreases, the ventilator's pressure-time curve shows an increase in peak pressure and $P_{plat}-PEEP$ increases. During P-A/C mode, when the compliance decreases, the ventilator flow-time curve shows a reduction in the effective inspiratory time and therefore a reduction in tidal volume.



► Conclusion

What have been discussed above are typical ways of measuring airway resistance and compliance in clinical setting. The measurement requirements are more precise, and the patient's condition can be analyzed according to the change of respiratory mechanics. The SV600 and SV800 ventilator's Pulmosight can intuitively display patient's lungs based on changes in pressure, flow, and volume, so that the patient's respiratory mechanics can be monitored with real-time feedback. This allows clinicians to quickly detect changes patient's lung status and respond accordingly to conditions such as increases/decrease resistance, increase/-decrease compliance, hyperventilation/hypoventilation, and if the patient shows spontaneous breathing.



PulmoSight in the Mindray SV Series ventilators can closely monitor the changes of respiratory mechanics and display the data in a real-time, graphic way.

Reference

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