Mechanical Ventilation for COVID-19

Waveform Analysis

Introduction

It is important to understand the different scalars that are used in waveform analysis: volume vs time, pressure vs time, and flow vs time.

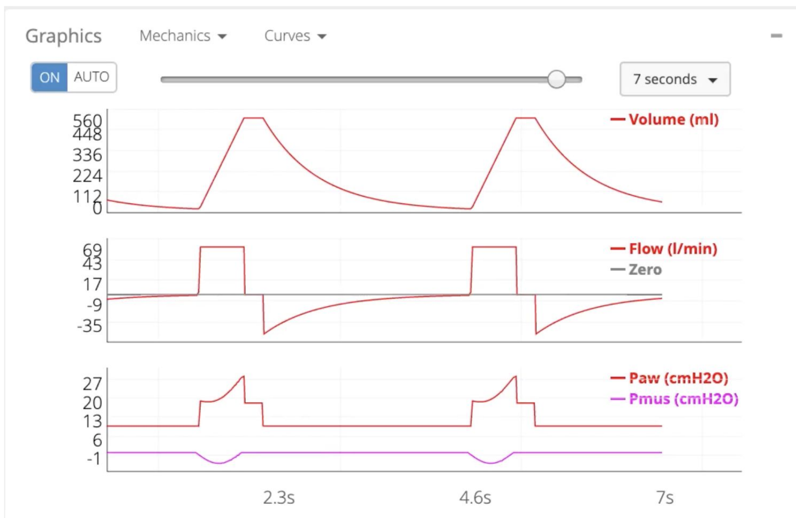
In **volume assist control**, it is common to have a constant flow pattern, which will show up as straight in the **flow** scalar. Adding an inspiratory pause (when flow = 0) will indicate a plateau pressure in the pressure scalar. In volume assist control, effort will cause changes to the **pressure** waveform.

In **pressure assist control**, pressure is held constant over time. The rise time is the time it takes to reach the pressure provided during inspiration. To find the plateau pressure, use an inspiratory pause. In pressure assist control, effort by the patient will change the **flow** waveform.

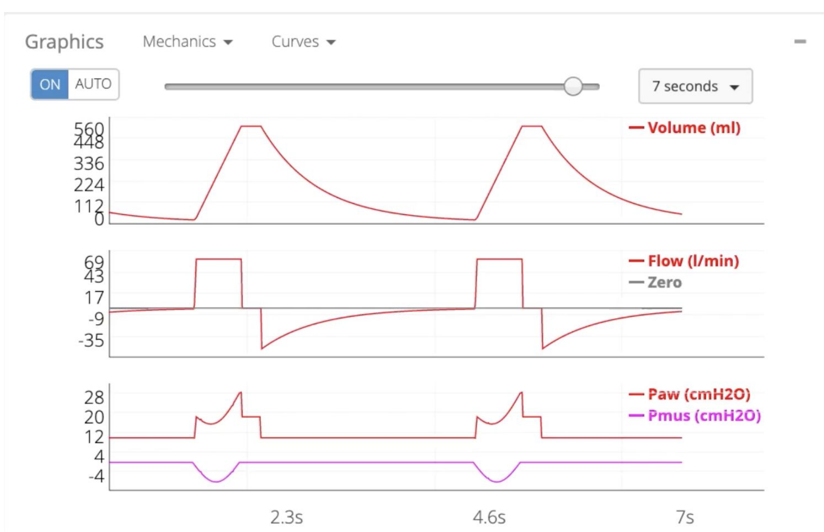
To understand patient behavior, it is important to understand asynchrony, which includes:

- Neurological timing and ventilator timing is out of sync
- Flow starvation (the ventilator does not meet the demand of the patient)
- Patient is unable to meet the trigger criteria

In **volume assist control**, you will see patient effort in the form of negative scooping in the **pressure** waveform, if flow demand is not entirely met for the patient. Patients with COVID-19 often have excessive efforts when they interact with the ventilator. As a result, it is important to monitor the occlusion pressure, or p0.1, to ensure it is not too high and to watch for significant scooping in the pressure waveform.



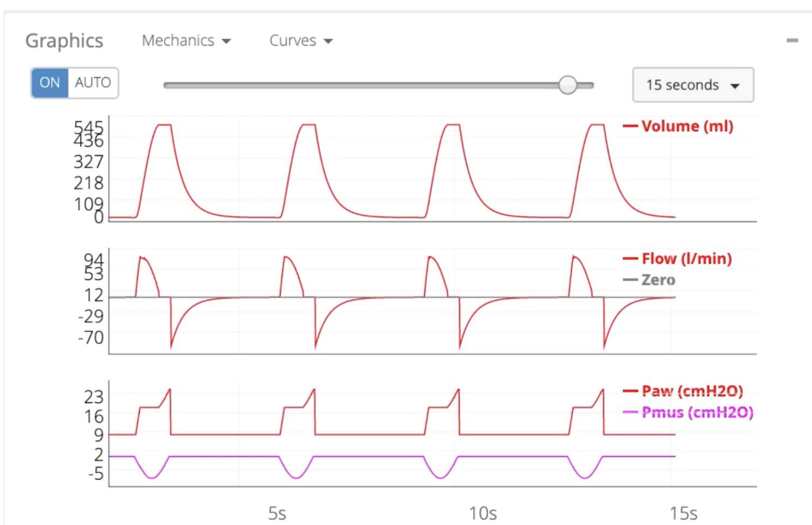
The figure above shows patient effort in volume assist control with a normal amount of scooping (and p0.1 of 2.35 cm H_2O). The figure below indicates excessive effort, which many COVID-19 patients display when they begin to interact with the ventilator, with p0.1 of 4.7.



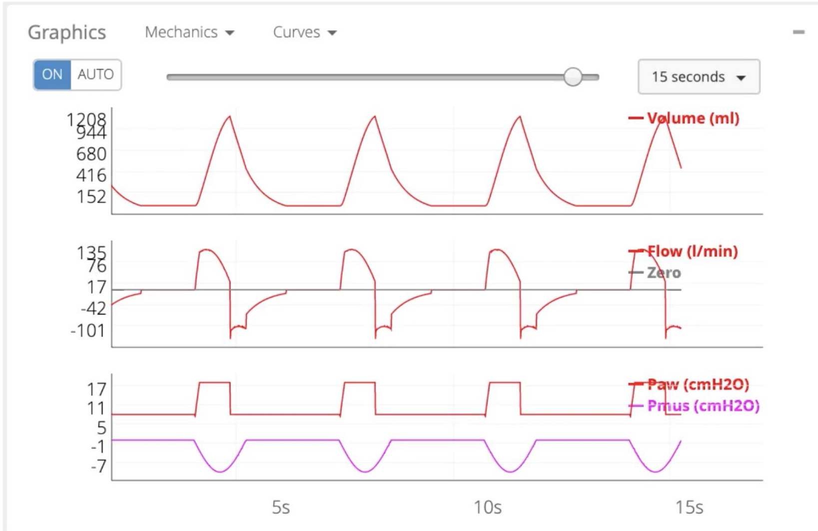
In **pressure assist control**, patient effort should change the **flow** waveform. In this, it is important to check if the flow reaches 0 as pressure reaches 0 during inspiration or if there is dampening of the peak expiratory flow during exhalation to ensure the patient is not experiencing asynchrony with breath timing. This can be adjusted by shortening or lengthening the inspiratory time. Similarly, p0.1 can be monitored to evaluate whether a patient is experiencing excessive effort in which increasing support should be done in an attempt to reduce respiratory drive provided tidal volume is not excessive. PEEP can also be adjusted to attempt to improve the patient's drive.

In **pressure support**, it may be necessary to alter the % of peak inspiratory flow that causes cycling off to eliminate asynchrony. If the patient is demonstrating excessive effort, increasing the pressure support will help decrease the patient's drive. However, if increasing pressure support does not decrease the p0.1, reducing the drive must be prioritized. PEEP can also be adjusted to attempt to improve the patient's drive.

Delayed cycling is another phenomena where the patient wants to exhale but the machine has not cycled off yet. In pressure assist control, if there is an increase in pressure at the end of inspiration with a subsequent rapid deceleration in the expiratory flow, then the patient is most likely experiencing delayed cycling. As a result, the inspiratory time should be shortened. However, the time should not be shortened so much that it causes premature cycling, in which the patient's effort lasts longer than the ventilator's cycle off criteria. This will manifest as a dampening in the peak expiratory flow. Premature cycling can also occur in pressure support, when the cycling-off percentage is too high. This **flow** scalar will look similar to that for premature cycling in pressure assist control.



In the figures provided, delayed cycling (above) and premature cycling (next page) in **pressure assist control** are noticeable by analyzing the **flow** scalar. The inspiratory time should be shortened for delayed cycling and lengthened in premature cycling.



Ineffective efforts are another form of asynchrony that generally occurs when patients are overassisted (too much pressure support) or have too high of airway resistance. Delayed cycling is a common cause of ineffective efforts.

Reverse triggering is another form of asynchrony where the ventilator triggers a breath that then triggers an effort from the patient. This can also lead to breath stacking. The first thing to check when noting reverse triggering is to see if it is bad timing or reflex. To check this, first reduce the respiratory rate. After reducing the respiratory rate, if the patient is triggering the breaths, it was simply bad timing.

However, if the reverse triggering still continues, a few steps should be taken:

- Turn off sedation if possible
- Increase tidal volume to a maximum of 8 mL/kg of IBW
- Keep plateau pressure less than or equal to 27 cm H_2O, and less than 30 cm H_2O for COVID-19 patients (typical ARDS guidelines)
- If there is a known injurious pattern (breath stacking) and sedation cannot be stopped, consider NMB agents to protect the lung and minimize the possibility of barotrauma