STARS AMC SKILLS CHECKLIST

Restrictive Lung Disease

Resources

- AMC DACUM Competency H2.16
- AHS Critical Care MCPs/Respiratory/Ventilation-Mechanical/Normal Lung and Restrictive Lung https://www.ahsems.com/public/protocols/templates/desktop/#set/13

Learning Objectives

AMC will

- Recognize restrictive lung disease and classify patients according to the Ventilation – Mechanical CCMCPs
- List strategies for addressing refractory hypoxemia
- Demonstrate appropriate ventilator "knobology"
- Recognize decreased compliance of the lung or chest wall by utilizing the inspiratory flow waveform on the Hamilton T1 or other pressure-controlled ventilators
- Define the terms permissive hypoxemia and permissive hypercapnia

Instructions

Work through the following case with an AMC peer or an education team member and complete the checklist. The checklist must be completed on CompTracker as well.

Case:

You have been dispatched to transport a 72 year-old with suspected COVID–19 who has been intubated due to respiratory failure. Medical management has been optimized and the patient has stable vital signs aside from severe hypoxemia and tachycardia. The patient is currently being hand bagged with PEEP valve in place (10cmH_2O) with 100% FiO_2.

SKILLS	COMPLETED
1. Review and apply the Normal Lung and Restrictive Lung Mechanical Ventilation Protocol	
2. List options for refractory hypoxemia Demonstrate necessary "knobology" including ● PEEP adjustments ● i-time adjustment to the point of IRV (inverse ratio ventilation) ● Inspiratory hold (recruitment maneuver)	
3. In response to the peak inspiratory pressure alarm use the inspiratory waveform to determine the reason for the alarm (decreased compliance vs. increased resistance). Troubleshoot decreased compliance accordingly	
4. Describe the terms permissive hypoxemia and permissive hypercapnia	

Skill 1. Review and apply the Normal Lung and Restrictive Lung Mechanical Ventilation Protocol

Classification

1. The majority of uncomplicated ventilations fall in this strategy
2. 'Restrictive lung' disease refers to patients with decreased lung compliance or decreased chest wall compliance

Decreased compliance of the lung (pus, blood or fluid)

a. pus e.g. pneumonia
b. blood e.g. pulmonary contusion
c. fluid e.g. pulmonary edema

Decreased compliance of the chest wall

a. obesity

b. tight chest restraints
c. chest wall burns
d. supine patient
e. gastric distension
f. ascites / elevated intra-abdominal pressure

- Practitioners should have an increased suspicion of 'restrictive lung' injury when a patient presents with hypoxemia
- Practitioners should have an increased suspicion of 'restrictive lung' injury when a patient presents with increased lung opacification on a chest x-ray
- Patients with pre-existing shock and metabolic acidosis may be better classified into the Normal Lung and Restrictive Lung Ventilation Protocol given the potential negative hemodynamic effects of the Metabolic Acidosis Ventilation Protocol

Skill 2. List options for refractory hypoxemia

Adjustments

1. The primary goal of restrictive lung ventilation is to optimize oxygenation. Because of the high pressures potentially required, normoxemia may not be safely achieved. Strategies to optimize oxygenation include

a. FiO_2 1.0
b. optimize chest wall compliance (e.g. gastric tube, loosen chest restraints, escharotomy, sit patient up)
c. sedation and paralysis
d. positioning (e.g. good lung down, sit patient up, consider prone position)
e. higher levels of PEEP
f. optimize oxygen delivery (cardiac output)
g. consider accepting lower SpO_2 (permissive hypoxemia)
h. recruitment maneuver

i. increasing i time
j. consider accepting higher plateau airway pressures

2. “Knobology”

a. PEEP - typically start at 5 cmH_2O. Consider matching sending site settings. Increase in 1-5cmH_2O increments depending on hemodynamics and the degree of hypoxemia/hypoxia. Hint - a sudden increase in the Cstat number may indicate optimal PEEP levels. Consult TP for PEEP > 10 cmH_2O

b. Recruitment Maneuver - there are several ways to perform a recruitment maneuver. The easiest way on the Hamilton T1 is to push and hold the manual breath/inspiratory hold key. This button is on the right side of the T1 and is an image of two lungs. Pressing during inspiration results in the ventilator performing a hold maneuver, lasting until the key is released, up to 15 seconds. This is a pressure-controlled ventilator and the pressure will be held at the current peak pressure levels. If the peak pressure is high due to resistance consider performing this maneuver in PCV+ and setting the desired peak pressure

c. i-time Adjustments - increasing the i-time increases the mean airway/alveolar pressures and can be another tool used to improve lung recruitment and oxygenation. Increasing the i-time results in a decreased e-time and can lead to breath stacking which may worsen compliance and make ventilation more challenging

Note: All of these maneuvers have risk and must be weighed against the benefit. All of the maneuvers potentially increase intrathoracic pressures and this can lead to lung injury and worsened hemodynamics. Negatively impacted hemodynamics can result in impaired tissue perfusion resulting in tissue hypoxia. If there is no evidence of end organ dysfunction some of these maneuvers may be withheld as many patients may

employ compensatory responses to avoid hypoxia in the setting of hypoxemia. This is what is meant by “permissive hypoxemia”.

Skill 3. In response to peak inspiratory pressure alarm recognize decreased compliance by interpreting the inspiratory flow waveform and troubleshoot decreased compliance accordingly.

Pressure Controlled Flow Waveforms (all modes on the Hamilton T1 are pressure controlled)

Image 1 and 2 below show an inspiratory waveform for a patient undergoing positive pressure ventilation. In image 1 notice that inspiratory flow gets to zero within the i-time. In this scenario we would expect peak and plateau pressures to equal. In image 2 note that the inspiratory flow does not get to zero within the i-time. In this scenario there will be a gradient between the peak and the plateau pressure. Also, note in image 2 there is increased expiratory resistance as demonstrated by the slope of the expiratory flow waveform.

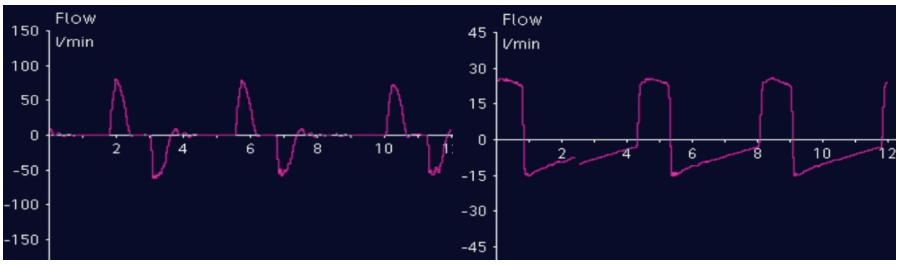

Image 1 **Image 2**

If the peak pressure alarm is activated and the inspiratory flow appears as it does in image 1, then resistance does not need troubleshooting, and you can focus on low compliance. This is the scenario that will often present in patients with ‘restrictive lung’ injury (e.g. COVID-19).

Ideally, plateau airway pressure should be maintained below 30 cmH_2O. Strategies to improve compliance and thus lower peak/plateau pressure include

a. Sitting patient up
b. Ensuring straps are not preventing chest expansion
c. Decompressing the stomach with gastric tube
d. Paralysis and sedation
e. Slowing ventilation if breath stacking is present
f. Treatment of potential causes: e.g. pneumothorax, hemothorax, hydrothorax, pneumonia, pulmonary edema

Consider decreasing the targeted volume if troubleshooting low compliance fails to resolve the high peak pressure alarm. Consider increasing the rate if maintenance of minute ventilation is required and there is no gas trapping. Because of factors like low tidal volumes and higher levels of PEEP, CO_2 may not be ventilated well in this patient population. This is referred to as permissive hypercapnia.

Of note, image 2 above demonstrates inspiratory flow not getting to zero before expiration and this waveform is typically seen in patients with higher inspiratory resistance. Troubleshooting higher resistance includes:

a. suctioning ET tube / trachea
b. ensuring tube holder is not on too tight
c. ensuring tube is not kinked in any way
d. considering empiric use of bronchodilators
e. considering changing HME filter (ensure clamp ET tube during changeover to protect practitioners from aerosolized particles)

In the setting of higher resistance, the above list of troubleshooting maneuvers is likely to lower the peak pressure but unlikely to improve the plateau pressure unless gas trapping is present.

Many patients with restrictive lung disease (low compliance) will prove challenging to ventilate. Achieving normoxemia or eucapnia may not always be possible. The term permissive hypoxemia is a term that may apply more often to the ventilation of patients with restrictive lung disease (decreased compliance). Permissive hypoxemia refers to allowing patients that appear to be compensating well (i.e. absence of hypoxia: normal end organ function, normal lactate levels) to have lower than normal oxygen saturation rather than subject them to the potential harms of high airway pressures.

Safety Alert

If the patient needs to be disconnected from the ventilator for any reason (e.g. ventilator change, HME/$EtCO_2$ change outs) ensure to clamp the ET tube. This will prevent crew exposure to aerosolized particles.