Mechanical Ventilation: Review Questions

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QUESTIONS

Choose the single best answer for each question.

1. **A 24-year-old woman presents to the ICU with acute respiratory distress syndrome (ARDS) caused by urosepsis. She is intubated, started on mechanical ventilation, sedated, and then paralyzed. The ventilator settings are: pressure control-inverse ratio ventilation (PC-IRV) mode with an inspiratory pressure of 25 cm H_2O; respiratory rate (RR), 15 breaths/min; inspiratory time, 2.5 s; FiO_2, 80%; and positive end-expiratory pressure (PEEP), 8 cm H_2O. On these settings, her peak inspiratory pressure (PIP) and plateau pressures (Pp) are 33 cm H_2O, and tidal volume (VT) is 350 mL. SaO_2 is 92% on pulse oximetry. Thirty minutes later, she becomes hypotensive, desaturates, and has decreased breath sounds over the left lung. Chest radiography shows a left-sided pneumothorax. What changes in ventilator parameters do you expect to find at this time?**
   (A) PIP, 60 cm H_2O; Pp, 60 cm H_2O; VT, 350 mL; RR, 15 breaths/min
   (B) PIP, 60 cm H_2O; Pp, 60 cm H_2O; VT, 200 mL; RR, 15 breaths/min
   (C) PIP, 33 cm H_2O; Pp, 33 cm H_2O; VT, 200 mL; RR, 15 breaths/min
   (D) PIP, 33 cm H_2O; Pp, 33 cm H_2O; VT, 350 mL; RR, 40 breaths/min

2. **A 35-year-old asthmatic man develops acute respiratory failure requiring mechanical ventilation. A mucous plug develops acutely. Ventilator graphics at baseline and following the mucous plug are shown in the Figure. According to the Figure, what mode of mechanical ventilation is this patient receiving?**
   (A) Assist/control mode ventilation
   (B) Pressure-control ventilation
   (C) Pressure-support ventilation
   (D) Pressure regulated volume control ventilation (PRVC)

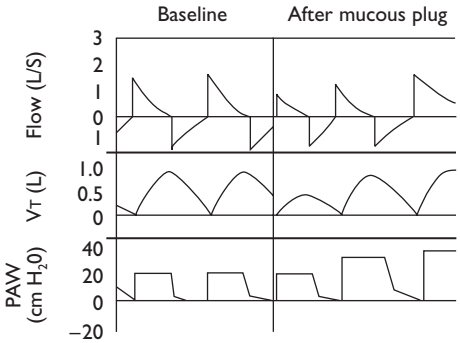

Figure. The patient's ventilator graphics at baseline and after the mucous plug developed. PAW = pulmonary artery wedge pressure.

3. **A 64-year-old man presents to the ED with an exacerbation of COPD. He is intubated and mechanically ventilated on: assist/control mode; RR, 16 breaths/min; VT, 600 mL; inspiratory flow rate (IFR), 60 L/min; PEEP, 0 cm H_2O; and FiO_2, 40%. Physical examination reveals: an anxious man in severe respiratory distress; heart rate, 120 bpm; blood pressure, 80/40 mm Hg; RR, 36 breaths/min; and SaO_2, 85%. Cardiac examination is normal; lung examination reveals bilateral expiratory wheezing with equal breath sounds. PIP is 45 cm H_2O, Pp is 35 cm H_2O, and ventilator graphics show that the expiratory flow waveform does not return to zero before the next ventilator breath is delivered. Chest radiography reveals hyperinflated lung fields. Despite intravenous fluids, bronchodilators, and sedation, the patient remains in respiratory distress and is hypoxic and hypotensive. Which ventilator changes would be most beneficial?**
   (A) Decrease VT, increase IFR, add PEEP
   (B) Increase VT, decrease IFR, add PEEP
   (C) Decrease VT, decrease IFR, continue zero PEEP
   (D) Increase VT, increase IFR, continue zero PEEP

(turn page for answers)

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ANSWERS AND EXPLANATIONS

1. **(C) PIP, 33 cm H_2O; Pp, 33 cm H_2O; VT, 200 mL; RR, 15 breaths/min.** PC-IRV is performed by setting an inspiratory pressure, inspiratory time with the inspiration/expiration ratio greater than 1:1 (normal, < 1 [eg, 1:3]), and RR. Understanding mechanical ventilator support modes is made easier by analyzing 3 variables: trigger (what initiates the breath), target (what controls gas delivery during the breath), and cycle (what terminates the breath). In pressure-control mode, the target is pressure (the set inspiratory pressure) and the cycle is time (inspiration ends after a set inspiratory time passes). VT varies depending on the set inspiratory pressure, inspiratory time, airway resistance (patient and ventilator tubing), and compliance of the lung and chest wall. Inspiratory pressure is rapidly achieved with high initial gas flows, and full inspiratory pressure is reached early in the inspiratory cycle. The selected inspiratory pressure is held throughout the inspiratory cycle and then followed by a rapid deceleration in flow. When lung compliance decreases (mucous plugging, pulmonary edema, or pneumothorax in this case), VT goes down, but the selected inspiratory pressure is maintained throughout the cycle. Because this patient is paralyzed, the RR cannot increase. In volume-control mode, the target is flow (the set IFR), and the cycle is volume (inspiration ends after the set VT is achieved). When lung compliance decreases, airway pressure increases, maintaining the set VT and flow rates. PC-IRV mode may be used in ARDS when severe hypoxemia and ventilation/perfusion mismatch is present. The advantages of PC-IRV mode are alveolar recruitment and auto-PEEP, which may improve oxygenation, compliance, and functional residual capacity (FRC). Disadvantages of using PC-IRV include the need for deep sedation and neuromuscular blockade, risk for barotrauma, and development of hypotension that severely limit its use in hemodynamically unstable patients.[1,2] There are no randomized prospective studies demonstrating improved survival with PC-IRV in ARDS.
2. **(D) PRVC ventilation.** This patient's baseline ventilator graphics (Figure) demonstrate a pressure-controlled mode. When lung compliance decreases after mucous plugging, VT drops and airway pressure increases gradually to restore the delivered VT, which is typical of PRVC ventilation (a newer dual-control mode). Pressure-control and pressure-support modes are pressure-targeted; when lung compliance decreases, VT goes down but pressures remain constant. Assist/control mode is volume-targeted; when lung compliance decreases, pressure goes up, maintaining the set VT. Dual-control modes combine the advantages of volume control ventilation (constant VT) and pressure-control ventilation (rapid variable flow). PRVC is a pressure-targeted, time-cycled mode that uses VT as a feedback control for continuously adjusting the pressure target, which limits airway pressure while maintaining a constant VT and automatically reduces pressure once lung mechanics improve or patient effort increases. When lung or chest wall compliance is reduced, a reduction in VT occurs only transiently with PRVC (versus pressure-control mode) as the pressure is increased in response to the reduction in VT.[3]
3. **(A) Decrease VT, increase IFR, add PEEP.** This patient has high peak airway and Pps. The ventilator graphics show that the expiratory flow rate does not reach zero, which is indicative of air trapping or auto-PEEP (also called occult PEEP or intrinsic PEEP). In patients with obstructive lung disease, emptying is slowed and expiration is interrupted by the next inspiratory effort, causing air to become trapped. Eventually, a static equilibrium volume is reached at higher FRC, but air trapping is still present, which causes positive alveolar pressure at the end of expiration (ie, auto-PEEP). Auto-PEEP is caused by 1 or more factors: reduced elastic recoil, excessively high VT or RR, and increased airway resistance or expiratory flow limitation. Auto-PEEP is not apparent by simply observing the pressure at the end of expiration because the expiratory port is open and allows VT to escape. Therefore, the pressure will display zero at end expiration unless extrinsic PEEP has been added. Simple observation of ventilator graphics showing airflow failing to return to zero at end expiration is the key to recognize auto-PEEP. In the absence of graphics, auto-PEEP can be measured by performing an end-expiratory occlusion (hold) and inspecting for an increase in airway pressure as the trapped air tries to escape. To manage auto-PEEP, minute ventilation should be reduced by decreasing VT or RR, increasing the IFR to allow for an expiratory time long enough to achieve lung emptying, and applying extrinsic PEEP to alleviate the increased breathing effort that auto-PEEP imposes on respiratory muscles. Increasing VT or decreasing IFR will prolong the time for inspiration, thereby reducing expiratory time and exacerbating auto-PEEP.[4]

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