Acute Respiratory Distress Syndrome/Acute Lung Injury: Review Questions

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QUESTIONS

Choose the single best answer for each question.

1. **A 28-year-old woman is admitted to the intensive care unit (ICU) for severe hypoxemia following an emergency caesarean section for placental abruption. She received general endotracheal anesthesia, and although no aspiration was noted, it was a difficult intubation. The patient had not fasted prior to coming to the hospital. The anesthesiologist used FIO_2 of 1.0 to keep the patient's arterial saturation above 93%. Chest radiography was performed (Figure 1). In the ICU, the patient's blood pressure is 115/72 mm Hg, heart rate is 124 bpm, respiratory rate is 36 breaths/min, temperature is 100.6°F, and SaO_2 is 92% on FIO_2 of 1.0. She is intubated and sedated but making active respiratory efforts. Cardiovascular examination reveals tachycardia with a regular rhythm, no murmurs, and a hyperdynamic precordium. Capillary refill is normal. Lung examination discloses diffuse crackles in both lungs without wheezing. Neurologic examination is limited by sedation but is grossly nonfocal. Arterial blood gas (ABG) is as follows: pH, 7.29; PCO_2, 55 mm Hg; and PO_2, 62 mm Hg. The ventilator settings are volume-cycled assist-control (A/C) mode; respiratory rate, 26 breaths/min; tidal volume, 500 mL; positive end-expiratory pressure (PEEP), 10 cm H_2O; and FIO_2, 0.7. The patient's height is 5 ft 5 in, and she weighs 70 kg (postpartum; ideal body weight [IBW], 57 kg). Her plateau (pause) pressure measured on passive breaths is 37 cm H_2O. Which of the following ventilator adjustments should be made?**
   (A) Increase the tidal volume to 600 mL and respiratory rate to 30 breaths/min in an attempt to normalize the pH to 7.40
   (B) Decrease PEEP to 5 cm H_2O to avoid barotrauma
   (C) Increase FIO_2 to 0.8 and PEEP to 15 cm H_2O to raise the PaO_2 above 70 mm Hg
   (D) Decrease the tidal volume to 342 mL (6 mL/kg IBW) and increase the respiratory rate to 34 breaths/min
   (E) Decrease the tidal volume to 420 mL (6 mL/kg actual weight) and increase the respiratory rate to 30 breaths/min

Figure 1. Chest radiograph of the patient in question 1 demonstrating dense bilateral airspace opacities.

2. **Which of the following is not a frequent cause of acute respiratory distress syndrome (ARDS) in a peripartum patient?**
   (A) Amniotic fluid embolus
   (B) Aspiration
   (C) Pneumonia
   (D) Retained products of conception/disseminated intravascular coagulopathy
   (E) Unsuspected mitral valve disease (MVD)

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Figure 2. Chest radiograph of the patient described in questions 4 and 5 demonstrating airspace opacities characteristic of ARDS.

3. A 54-year-old man with non-Hodgkin's lymphoma who underwent allogeneic stem cell transplant 4 months ago is admitted to the hospital for neutropenic fever. The initial chest radiograph is clear, but over the first 2 hospital days the patient develops bilateral dense airspace opacification. The patient continues to have low-grade fevers despite broad-spectrum antibiotics. On hospital day 3, his breathing is labored and he has a new oxygen requirement; he remains only 92% saturated on 6 L by nasal cannula. Physical examination reveals a tachypneic man in respiratory distress who appears fatigued. Blood pressure is 130/72 mm Hg, heart rate is 118 bpm, respiratory rate is 32 breaths/min, temperature is 101.3°F, and Sao_2 is 94% on 40% oxygen by face mask. Neurologic examination is normal. Crackles are heard in both lungs with egophony. Cardiovascular examination is normal except for tachycardia. He has no rash. On 40% oxygen, ABG values are: pH, 7.36; Pco_2, 45 mm Hg; and Pao_2, 61 mm Hg. In this patient, which of the following is true about noninvasive positive pressure ventilation (NIPPV)?

(A) Immunosuppressed patients have a greater risk for aspiration with NIPPV; thus, it should not be used
(B) Immunosuppressed patients with acute respiratory failure benefit from NIPPV
(C) NIPPV may be used at inspiratory positive airway pressure (IPAP) 35 cm H_2O and expiratory positive airway pressure 10 cm H_2O for less than 1 hour while closely monitoring the patient
(D) NIPPV should not be attempted in a patient with acute lung injury (ALI)
(E) The maximum noninvasive inspiratory pressure is 12 cm H_2O IPAP to avoid the possibility of skin breakdown

Questions 4 and 5 refer to the following case:

A 24-year-old man sustains several pelvic and long bone fractures in a motor vehicle accident and requires 9 U of packed red blood cells (RBCs). He has no obvious chest wall trauma or rib fractures. His FAST examination discloses no intra-abdominal or pericardial fluid collections. The fractures are reduced and externally fixed in the operating room, and all vascular injuries are repaired. On day 2 in the trauma unit, the patient demonstrates an increasing oxygen requirement and is intubated. He is afebrile and hemodynamically stable; urine output is adequate (> 50 mL/hr). Breath sounds are coarse bilaterally. Chest radiography is performed (**Figure 2**). Initial ventilator settings are volume-cycled A/C mode; respiratory rate, 20 breaths/min; tidal volume, 420 mL; PEEP, 10 cm H_2O; and Fio_2, 1.0. On these settings, ABG is pH, 7.39; Pco_2, 39 mm Hg, and Pao_2, 62 mm Hg.

4. Which of the following is the most appropriate volume management strategy for this patient?

(A) Bolus with isotonic intravenous solution using a central venous catheter (CVC) to maintain the right atrial pressure at or above 10 cm H_2O
(B) Diuresis guided by a CVC to obtain the lowest right atrial pressure while maintaining adequate perfusion
(C) Insert a pulmonary arterial catheter (PAC) and maintain the pulmonary artery occlusion pressure (PAOP) at or above 12 cm H_2O
(D) Insert a PAC and use the PAOP to guide diuresis to the lowest PAOP while maintaining adequate perfusion
(E) Transfuse packed RBCs to increase the hemoglobin level to 14 g/dL

5. Despite careful ventilator and volume management, the patient remains extremely hypoxemic on Fio_2 of 1.0. Which of the following statements is true regarding salvage therapy for ARDS?

(A) High-frequency oscillatory ventilation decreases mortality

(B) Inhaled nitric oxide (NO) increases the number of ventilator-free days but does not decrease mortality
(C) Inhaled NO, prone positioning, and high-frequency oscillatory ventilation have been shown to improve oxygenation but not mortality
(D) Intratracheal surfactant (recombinant surfactant protein-C–based surfactant) given for 24 hours increases the number of ventilator-free days and survival
(E) Prone positioning has been shown to increase morbidity and is therefore not recommended

ANSWERS AND EXPLANATIONS

1. **(D) Decrease the tidal volume to 342 mL (6 mL/kg IBW) and increase the respiratory rate to 34 breaths/min.** To date, no pharmacologic intervention has been shown to reduce mortality in ARDS. The only therapy that has reduced mortality in ARDS is a careful ventilator strategy aimed at minimizing alveolar overdistension by limiting the patient's tidal volume and plateau (or pause) pressure. In a study of groups ventilated with tidal volumes of 6 mL/kg IBW and those ventilated at 12 mL/kg IBW, the 6 mL/kg group (plateau airway pressures maintained < 30 cm H_2O) had a 9% absolute reduction in mortality and spent approximately 2 fewer days on the ventilator.[1] A corollary to the low tidal volume strategy is that P_{CO_2} may rise due to the decreased minute ventilation. A strategy of "permissive hypercapnia," in which the P_{CO_2} is allowed to rise and induce a respiratory acidosis, has been shown to be safe in patients with ARDS.[2] Increasing tidal volume and respiratory rate is incorrect because a tidal volume of 600 mL would be overdistending and injurious; the pH does not need to be normalized. Higher PEEP was not associated with an excess of barotraumas in a large randomized trial.[3] Because there is no evidence to suggest that an Sa_{O_2} of 98% is superior to 89% and since oxygen therapy can induce lung injury, the goals for oxygenation in patients with ARDS are Sa_{O_2} of 88% or greater or Pa_{O_2} of 55 mm Hg or greater.[1] While there is no absolute threshold for oxygen toxicity, most practitioners attempt to reduce the F_{IO_2} below 60% when possible. Tidal volume should be based upon IBW, not actual body weight.

2. **(E) Unsuspected MVD.** Each of the entities listed may provoke pulmonary edema in a pregnant or peripartum patient; however, the definition of ARDS requires (1) acute onset; (2) bilateral radiographic abnormalities; (3) severe hypoxemia, with Pa_{O_2}/F_{IO_2} ratio less than 200; and (4) absence of left atrial hypertension.[4] ALI requires the same conditions but requires a Pa_{O_2}/F_{IO_2} ratio less than 300. MVD may be discovered for the first time during pregnancy, but it causes pulmonary edema on the basis of increased hydrostatic pressure via an increased left atrial pressure. Thus, MVD does not meet criteria for ARDS. Pneumonia, aspiration (especially with caesarean section), amniotic fluid embolism, and retained products of conception leading to diffuse intravascular coagulation have the potential to cause ALI/ARDS.

3. **(B) Immunosuppressed patients with acute respiratory failure benefit from NIPPV.** Although intubation with invasive mechanical ventilation is often necessary for patients with ALI/ARDS, immunosuppressed patients benefit greatly by avoiding an endotracheal tube and its attendant risk of infection. Immunosuppressed patients with early respiratory failure randomized to NIPPV versus high-flow oxygen alone demonstrated decreased rates of intubation, ICU mortality, and hospital mortality.[5] Thus, a brief trial of NIPPV with close monitoring is appropriate. Adequate noninvasive ventilation for ALI often requires IPAP of at least 15 cm H_2O and PEEP of 6 cm H_2O to 8 cm H_2O.[5] Skin necrosis may be a problem, particularly at the bony prominences of the face in contact with the NIPPV mask (eg, bridge of the nose, chin). Skin necrosis occurs when IPAP exceeds capillary perfusion pressure; therefore, IPAP should not exceed 22 cm H_2O. Aerophagia, or swallowing of air, is also a potential problem with NIPPV and is generally an issue when IPAP exceeds 20 cm H_2O. Immunosuppressed patients do not have a higher rate of aspiration than other hospitalized patients.

4. **(B) Diuresis guided by a CVC to obtain the lowest right atrial pressure while maintaining adequate perfusion.** In a randomized trial comparing 2 catheter strategies (CVC versus PAC) and 2 volume strategies (volume-liberal versus volume-conservative), researchers found no benefit and a potential increase in adverse events with the use of PAC.[6] Therefore, PACs are not recommended for the routine care of patients with ARDS. Comparing the volume strategies, there was a reduction in the number of days on the ventilator and a trend towards decreased mortality for patients whose volume strategy pursued aggressive diuresis to achieve a low intravascular volume once hemodynamically stable.[7] It is recommended that hemodynamically stable patients with ARDS undergo aggressive diuresis to decrease

edemagenesis. RBC transfusion may be associated with increased mortality in critically ill patients, and thus there is no recommendation to pursue high levels of hemoglobin for patients with ARDS.[8]

5. **(C) Inhaled NO, prone positioning, and high-frequency oscillatory ventilation have been shown to improve oxygenation but not mortality.**[9] No pharmacologic therapy has been shown to improve mortality for patients with ARDS. Recombinant surfactant, while extremely successful in treating respiratory distress of the newborn, has not been shown to decrease mortality or number of days on the ventilator in adults with ARDS. Inhaled NO, a rapidly inactivated vasodilator, improves oxygenation more rapidly than placebo but does not improve mortality or duration of ventilatory support. Likewise, prone positioning improves oxygenation but has not translated into improved mortality. The prone position may increase pressure sores in unusual areas (eg, cheek, breast, iliac crest) and may increase the potential for retinal ischemia, but the procedure is safe when these sites are monitored vigilantly. High-frequency oscillatory ventilation (HFOV) is a ventilatory strategy whereby the lung is oscillated at a set airway pressure with minimal deflation of the lungs. Thus, HFOV uses an almost unmeasurably low tidal volume, avoiding overdistension. HFOV is safe, has a comparable mortality to conventional treatment of ARDS, and appears to improve oxygenation compared with conventional ventilation. To date, HFOV has not been shown to improve mortality.

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