MANAGEMENT OF VENTILATION IN A COVID PATIENT

Neuro-anesthesia Quiz # 65

Quiz Team
Shobana Rajan, MD
Suneeta Gollapudy, MD
Marie Angele Theard, MD
Hui Yang, MD PhD
Verghese T Cherian, MD

Will S Hazard, MD
Associate Professor of Anesthesiology
Penn State Health College of Medicine
Hershey, PA
Question 1: Lessons learned from prior epidemics

Question 2: Causes of hypoxemia

Question 3: Prone ventilation

Question 4: Ventilation Perfusion inequality

Question 5: Measurement of respiratory mechanics
Respiratory paralysis was a feared complication of the polio epidemics that swept Europe and the US in the 1930’s and 40’s. Which of the following about it is **TRUE**:

A: The polio epidemic lead to the development of the first negative pressure ventilator

B: The first negative pressure ventilator to be used successfully in clinical practice was the “iron lung”

C: The mortality of polio induced respiratory paralysis was about 50%

D: Positive pressure ventilation was not utilized during the polio epidemic
A: The polio epidemic lead to the development of the first negative pressure ventilator

The first negative pressure ‘tank’ respirator was produced by Dalziel in 1832. The patient sat in an airtight box with a seal around their neck and the head sticking out. Negative pressure was applied around the body, using a large syringe, that drew air from the atmosphere through the patient’s airways into the lungs.

*Dalziel J. On sleep and an apparatus for promoting artificial respiration. Br Assoc Adv Sci 1838;2:127*
The first negative pressure ventilator to be used successfully in clinical practice was the “iron lung” developed by Drinker-Shaw. The body was enclosed within a sheet metal tank sealed with the patient’s head protruding through the upper end with a close-fitting rubber collar.

Emerson, JH The Evolution Of Iron Lungs. Cambridge, MA 1978
JAMA 1986: 255
The mortality of polio-induced respiratory paralysis was **85%**. Poliovirus is a member of the Enterovirus genus, family Picornaviridae. Picornaviruses are small, ether-insensitive viruses with an RNA genome. Poliovirus causes polio, or poliomyelitis, a highly infectious disease.

Most people infected with poliovirus (72%) will not have any visible symptoms. About 1 out of 4 people (24%) will have flu-like symptoms. These symptoms usually last 2 to 5 days.

About 1% of people will have weakness or paralysis in their arms, legs, or both. The paralysis can lead to permanent disability and death is usually due to paralysis of the respiratory muscles.


cdc.gov
D: Positive pressure ventilation was not utilized during the polio epidemic

During the epidemic it is estimated that 1500 medical and dental students worked around the clock providing bag ventilation to help support these patients. The lack of ventilators was a serious crisis. At the outbreak of the epidemic the Blegdam Hospital in Copenhagen had only one Emerson tank respirator and six cuirass respirators (jackets that fitted around the chest and assisted ventilation by changing the pressure outside the thorax and only useful for mild respiratory impairment).

The solution: manually ventilate the patients by squeezing a rubber bag attached to a tracheostomy tube. The bag was connected to a tank of 50% oxygen in nitrogen together with a soda lime absorber. Medical and dental students took shifts and ventilated blindly, sometimes relying on communication with eye movements signaling shortness of breath in the patient or simply the color of the lips and skin. At the height of the epidemic, there were 70 patients requiring 24/7 manually ventilation. The mortality rate after the adoption of this system dropped from ~90% to ~25%.

A 42y male, involved in an ATV accident after a binge drinking with H/O brief loss of consciousness, is currently being managed in isolation as he tested positive for COVID. He is hypoxic despite being transitioned from nasal cannula to a non-rebreathing bag. All of the following could be the cause for his hypoxemia, **EXCEPT:**

A: Hypoventilation

B: Pulmonary Shunt

C: Decreased diffusion capacity

D: Hyperventilation
A: Hypoventilation

Hypoventilation is one of the important causes for hypoxemia after head injury.

Causes of hypoventilation include (but are not limited to), raised ICP, medications that decrease respiratory drive, chest wall injury, damage or paralysis of respiratory muscles.
B: Pulmonary Shunt

Shunt is the fraction of venous blood that pass through un-ventilated or poorly ventilated areas of the lungs (low V/Q ratio). This blood does not get oxygenated and causes arterial hypoxemia. This hypoxemia cannot be compensated by giving a higher FIO$_2$, as the blood passing through ventilated areas of the lung is already saturated and higher FIO$_2$ can only increase the dissolved oxygen, which is minimal.

However, shunt does not increase the PaCO$_2$, as the compensatory hyperventilation can expel the CO$_2$.

Causes for increased shunt could be basal atelectasis, due to inadequate respiratory excursions due to pain, residual paralysis, or over narcotization and aspiration of gastric content.
C: Decreased diffusion capacity

In this patient, impaired diffusion across the alveolar-capillary membrane leading to hypoxemia could be caused by

• inflammatory responses in the alveoli due to aspiration of gastric content or secondary to COVID infection
• over-transfusion of resuscitative fluids following trauma
Great Job!! Correct.

D: Hyperventilation

Hyperventilation is usually the result of hypoxemia, hypercarbia, acidosis, or pain and not the cause for hypoxemia.
A patient with COVID 19 remains persistently hypoxic despite an FIO2 of 100%. You consider turning the patient prone. Which of the following statements about prone position is FALSE:

A: Prone position reduces the V/Q mismatch

B: Prone positioning does not appear to alter regional distribution of pulmonary blood flow

C: Prone positioning can improve oxygenation in an awake patient

D: Prone positioning increases the pleural pressure gradient between dependent and non-dependent lung regions
A: Prone position reduces the V/Q mismatch

Prone position generates more homogenous lung aeration and strain distribution, thus enhancing recruitment of dorsal lung units

B: Prone positioning does not appear to alter regional distribution of pulmonary blood flow

Prone positioning does not appear to alter regional distribution of pulmonary blood flow, with perfusion predominating towards dorsal lung aspects due to non-gravitational factors

C: Prone positioning can improve oxygenation in an awake patient

Recent guidance by the UK Intensive Care Society (ICS) advocates awake prone positioning to become standard of care for suspected or confirmed COVID-19, in patients requiring an FiO2 ≥28%


D: Prone positioning increases the pleural pressure gradient between dependent and non-dependent lung regions

Prone positioning **decreases** the pleural pressure gradient

This is believed to generate more homogenous lung aeration and strain distribution, thus enhancing recruitment of dorsal lung units

With improvements in ventilatory homogeneity and relatively constant perfusion patterns, a subsequent reduction in shunting is observed.


You are caring for a patient with COVID 19. He has clotted off several hemodialysis catheters which needed replacement. In addition to renal failure the patient has persistent hypoxemia despite recent chest CT showing minimal ground glass opacifications. You suspect micro emboli within the pulmonary vasculature. Which of the following statements regarding the measurement of Ventilation Perfusion inequality are FALSE:

A: Radiopharmaceuticals can be used to determine topographical differences in ventilation and blood flow

B: An elevated alveolar / arterial PO$_2$ difference would suggest hypoventilation as the cause of arterial hypoxemia

C: The alveolar / arterial PO$_2$ difference can determine if V/Q mismatch is the cause of arterial hypoxemia

D: Ventilation perfusion mismatch is a common cause for hypoxemia
A ventilation–perfusion (VQ) scan is a nuclear medicine scan that uses radioactive material (radiopharmaceutical) to examine airflow (ventilation) and blood flow (perfusion) in the lungs.

In the ventilation phase of the test, a gaseous radionuclides such as xenon-133 in an aerosol form is inhaled by the patient.

The perfusion phase of the test involves the intravenous injection of radioactive technetium macro aggregated albumin (Tc99m-MAA).

A gamma camera acquires the images for both phases of the study.
B: An elevated alveolar / arterial PO2 difference would suggest hypoventilation as the cause of arterial hypoxemia

Physiologic V/Q mismatch exists because of differences in the perfusion and ventilation in the different zones. This mismatch is (in part) responsible for the difference in oxygen tension between the alveoli and arterial blood. Physiologic A-a gradient changes with age. \[A-a \text{ gradient} = \left(\frac{\text{Age} + 10}{4}\right)\]

<table>
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<th>A-a gradient</th>
<th>Corrected with high FIO2?</th>
<th>Causes</th>
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<td>Low FIO2</td>
<td>Normal</td>
<td>Yes</td>
<td>High altitude, hypoxic gas mixture</td>
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<td>Hypoventilation</td>
<td>Normal</td>
<td>Yes</td>
<td>Residual anesthetic, muscle relaxants</td>
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<td>Diffusion</td>
<td>Elevated</td>
<td>Yes</td>
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<td>V/Q mismatch</td>
<td>Elevated</td>
<td>Yes</td>
<td>Mucus plug, pulm embolism, COPD</td>
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<td>Elevated</td>
<td>No</td>
<td>Atelectasis, ARDS</td>
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C: The alveolar / arterial PO$_2$ difference can determine if V/Q mismatch is the cause of arterial hypoxemia

Alveolar Gas Equation: $PA_{O2} = PI_{O2} - PA_{CO2}/R$

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D: Ventilation perfusion mismatch in a common cause for hypoxemia

Micro-emboli would reduce perfusion through ventilated alveoli leading to dead space ventilation. This would lead to elevated A-a O2 gradient.

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On a patient suspected of COVID, the Respiratory Therapist has been steadily increasing the inspiratory pressure, throughout the day, to achieve adequate exhaled tidal volume. Which of the following regarding respiratory mechanics is **FALSE**:

A: This can be attributed to ‘Auto-PEEP’ and can lead to hemodynamic instability

B: Normal compliance of the pulmonary system is about 100 ml/cm H$_2$O

C: This situation can be remedied by resorting to Inverse ratio ventilation

D: Measurement of auto-PEEP is carried out on a ventilator through an expiratory pause
A: This can be attributed to ‘Auto-PEEP’ which can lead to hemodynamic instability

Auto-PEEP is commonly found in acute severe asthma, chronic obstructive pulmonary disease, or patients receiving inverse ratio ventilation. Factors predisposing to auto-PEEP include a reduction in expiratory time by increase in the respiratory rate, tidal volume or inspiratory time.

Auto-PEEP predisposes the patient to increased work of breathing, barotrauma, hemodynamic instability and difficulty in triggering the ventilator.

B: Normal compliance of the pulmonary system is about 100 ml/cm H₂O

Lung compliance: alveolar-intrapeural pressure gradient $\sim 200 \text{ml.cmH}_2\text{O}^{-1}$

Chest-wall compliance: intrapeural-ambient pressure gradient $\sim 200 \text{ml.cmH}_2\text{O}^{-1}$

Total Pulmonary compliance: alveolar-ambient gradient $\sim 100 \text{ml.cmH}_2\text{O}^{-1}$

C: This situation can be remedied by resorting to Inverse ratio ventilation

Factors predisposing to auto-PEEP include a reduction in expiratory time by increase in the respiratory rate, tidal volume or inspiratory time and is commonly found in patients receiving inverse ratio ventilation

Auto-PEEP predisposes the patient to increased work of breathing, barotrauma, hemodynamic instability and difficulty in triggering the ventilator.

The best way to remedy this is by prolonging the expiratory time by reducing the respiratory rate rather than increasing inspiratory flow.

D: Measurement of auto-PEEP is carried out on a ventilator through an expiratory pause

An expiratory pause closes the expiratory valve at the end of expiration and equilibrates the pressure within the alveoli across different lung units.

If the airway pressure records a pressure above the set PEEP, it indicates auto-PEEP.

Respir Care. 2014; 59:1773–94.