Ventilation and Oxygenation Indices -- in Mechanical Ventilation

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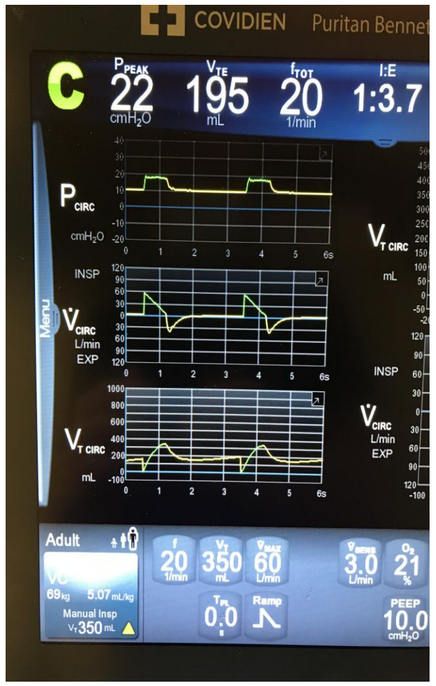
Acknowledgments

- This presentation is a variation of one created by me, and two of my colleagues at Atlantic Health System, Mike Squillante, RRT and Rakesh Mistry, RRT.
- It was presented to respiratory therapists, nurses and resident physicians within this organization to help expand their knowledge base in this area.

Learning Objectives

- Describe Variables Which Affect Oxygenation
- Examine Oxygenation Indicies
  - How they are calculated, ranges and limitations
  - Strategies to Enhance Them
- Describe Variables Which Impact Ventilation
- Review Various Ventilatory Indicies
  - How they are calculated, ranges and limitations
  - Strategies to Enhance Them
- Review Some Case Examples
- Furnish Additional Resources



Factors Impacting Oxygenation

Primarily:

- Fractional Inspired Oxygen (FIO2)
- Positive End Expiratory Pressure (PEEP)
- Pulmonary Vasodilators (Inhaled Prostacyclin, Inhaled Nitric Oxide)

Secondary:

- Ventilation
  - Respiratory Rate, Tidal Volume, Minute Ventilation
- Inspiratory Time.
- Mean Airway Pressure (P_{MEAN})
- Prone positioning
- Patient-ventilator synchrony

Factors Impacting Oxygenation (cont.) FIO2 & PEEP

- Range: 21 – 100%

- Delivery via non-invasive or invasive means.
  - Noninvasively: Low Flow devices (NC, NRM), HFNC, NIV (BIPAP)
  - Invasively: Intubation and Mechanical Ventilation

- If patient does not respond concomitantly to increases in FIO2 or they require FIO2 above 60%, they are probably shunting and need positive pressure.
  - Either Noninvasively: NIV (BiPAP)
  - Invasively: Intubation, mechanical ventilation, therapeutic PEEP.

P/F Ratio

- Monitoring adequacy of arterial oxygenation
  - **PaO_2/F_IO_2 ratio**
    - A “normal” P/F ratio breathing room air would be 95/0.21 or about 450
    - American Thoracic Society:
      - Acute Lung Injury (ALI): 200 to 300
      - ARDS: < 200
      - Severe ARDS: < 100
    - Berlin:
      - 200-300 Mild ARDS
      - 100-200 Moderate ARDS
      - Less than100 Severe ARDS

- Example:
  - A PO2 of 88 torr on 50% = 88/.5 = 176 = Moderate ARDS

Oxygen Index (OI)

(OI) = Mean Airway Pressure (MAP) X FIO2 X 100 / PO2

- Lower OI is better -- Targeted OI less than 20-25
  - OI values less than 5 are considered acceptable
  - Values in the 10 to 20 range indicate impaired oxygenation
  - OI above 25 associated with a severe oxygenation disturbance and poor clinical outcomes

  - Unlike P:F Ratio, OI considers patient ***response to both PEEP*** & FIO2

  - **PEEP is a major contributor to MAP**

- **Example:**
  - **MAP= 22**
  - **FIO2 = 60%**
  - **PO2 = 72**

  - **22 X .60 X 100 / 72 = 18.3 (Moderately impaired Oxygenation)**

Strategies for Enhancing Oxygenation

- Increase FIO2 to 50-60%
- Increase PEEP
  - Subject to keeping Driving Pressures < 15 and Plateau Pressures ≤ 30 cm H2O
- Inhaled pulmonary vasodilators
  - INO Max
  - Epropostenol (Flolan)
- Open Lung Strategies—Airway Pressure Release Ventilation (APRV)
- Spontaneous Breathing Patients: Intermittent CPAP
- Prone Positioning - With severe hypoxemia
- Paralytics - Severe hypoxemia

Monitoring Tissue Oxygenation & Cardiac Output

- Arterial-mixed venous oxygen content difference, $C(a-\bar{v})O_2$ reflects the difference in oxygen content between arterial and venous blood
  - Normal: 4 to 6 volume%
  - Increased: low cardiac output, increasing VO_2
  - Decreased: septic shock, increased cardiac output, anemia

Fick Equation: Cardiac Output = VO 2 / (C a - C v)

Monitoring Tissue Oxygenation

- Blood lactate
  - Anaerobic metabolism = lactic acid production
  - Normal: Less than 1.7 to 2.0 mM/L
  - Is often elevated with sepsis
  - Greater than 3.83 mM/L = 67% mortality
  - Greater than 8 mM/L = 90% mortality
  - β-adrenergics drugs increase lactate levels because of glycolysis
  - β-blockers decrease blood lactate levels

Assessing Ventilation: Factors which Impact Ventilation

Physiology/Cause:

- **Compliance**
  - Too Low- ARDS, Pulmonary Fibrosis
  - Too High – Emphysema
- **High Resistance**
  - Asthma
  - Upper Airway Edema
  - Too small of an artificial Airway
- **Respiratory Muscle Weakness**
  - Guillain Barre
  - Myasthenia Gravis
  - Muscular Dystrophy

Assessing Ventilation (RSBI):

- Rapid shallow breathing index (RSBI)
  - RSBI = RR (breaths/min)/V_T (liters)
  - RSBI greater than 105: prognostic of failure
  - RSBI lower than 105: indicative of greater likelihood of success

    - RSBI Example: RR = 25, VT = 500. RSBI = 50

- Special Considerations
  - Pain and anxiety may result in an artificially high RSBI
  - Post-op patients recovering from surgery may have a very low RSBI and are not quite ready for extubation.

    - Example: RR 7, VT 900. RSBI = 9.

- **Assess initially and after 30-60 minutes to follow trends.**

Assessing Ventilation (Bedside Mechanics - VC & NIF)

- **Negative Inspiratory Force (NIF):**
  - Normal -60 to -100 cm H2O
  - Less than -20 to -25 cm H2O suggests insufficient respiratory muscle strength.

- **Vital capacity (VC)**
  - Normal: 65 to 75 mL/kg IBW
  - If intubated: VC equal to or greater than10 to 15 mL/kg indicative of greater success for weaning and extubation.
  - Pre-op: FVC less than 20 mL/kg indicative of higher risk of pulmonary complications and poor success with weaning and extubation.

- Trending Matters!
  - Rapid deterioration toward critical thresholds often warrant quick action!

Strategies for Enhancing Ventilation

- Invasive
  - Pressure Support Titration
    - Especially of ET tube size < 7.5
  - “Boutique” Ventilator Modes
    - Tube compensation
    - Volume Support
    - Proportional Assist Ventilation
- Non-Invasive
  - BiPAP
  - AVAPS—Average Volume Assured Pressure Support
  - Intermittent CPAP

Combined Indices—Integrated Weaning Index (IWI):

- **Integrated weaning index (IWI)**
  - Possibly a better predictor of successful liberation from mechanical ventilation.
  - Calculated by multiplying respiratory system compliance by arterial oxygen saturation and then dividing by RSBI.
    - **Elastance = Change in Pressure / Change in Volume**
- An IWI equal to or greater than 25 mL/cm H_2O breaths/min/L or more is associated with a higher success of liberation from mechanical ventilation.
- Formula: IWI = **(CRS x SaO2)/ (f/VT)**

Combined Indices -- ROX Index

- The utilization of high flow oxygen devices have become first line treatment for hypoxemic respiratory failure.
- The ROX index score can be used to assist in the in the prediction of success or failure of high flow oxygen use.
- Evaluation of ROX index should be monitored for the first 12 hours. (2,6,12 hours of utilization)
  - A value of 4.88 or greater in non-COVID patients has been shown to be a predictor of success with high flow oxygen therapy.
  - A value below 3.84 indicates need for high flow oxygen therapy
  - A trend of the score dropping is a potential sign of failure and consideration of a different mode of respiratory support, possibly intubation, should be considered.

ROX Index—Continued

- How to Calculate ROX INDEX
- SpO2/FiO2/Respiratory Rate
- Example:
  - Spo2: 90% Fio2 .70, RR= 30
  - ➢ (90/.7)=128.57

128.57/30= 4.28

ROX score is 4.28

(Indicates a need to re-evaluate at 2, 6 and 12 hours for trending.)

Case 1- P/F Ratio & OI

- 62 YO, 5’4”, 130 lbs. (59 Kg) (IBW 127lbs/58Kg) female Covid 19 Pneumonia. Patient day 7 of mechanical ventilation with settings of AC-350-20-60%-12 PEEP. $P\overline{aw}$ = 14, Ppl = 24
- ABG 7.37-37-62-23- +1 - 91%.

- What is his P:F ratio?
  - 62/.60 =
  - 103

- What is his OI ($P\overline{aw}$ × F_IO_2 × 100/PaO_2)?
  - 14 X .6X100/62 =
    - = 14

- ***What recommendations would you make regarding the care plan?***

Case 2- P/F Ratio & OI

- 54 YO, 5’10”, 175 lbs. (75 Kg) male post - chest trauma patient day 7 of mechanical ventilation with settings of AC-500-20-50%-8 PEEP. $P\overline{aw}$ = 11, Ppl = 25 His ABG is 7.44-35-71-26- +1 - 93%.

- What is his P:F ratio?
  - 142

- What is his OI ($P\overline{aw}$ × F_IO_2 × 100/PaO_2)? 11X.5X100/71 =
  - 7.8

- ***What recommendations would you make regarding the care plan?***

Case 3-RSBI

- 21 YO 5’5” 120lb female S/P abdominal surgery (4 hrs. prior) is clinically stable with vital signs and blood chemistry WNL, SPO2 of 98% on 35% FIO2. She is weaning on PSV + 6. Her sedation is being reduced and her RASS is 0. Her RR is 22 and a VT of 400.

- What is her RSBI?
  - 22 / .4 =
  - 51

- ***What recommendations do you have regarding her ventilator-patient management?***

RASS Scale

Richmond Agitation and Sedation Scale (RASS)		
+4	Combative	violent, immediate danger to staff
+3	Very Agitated	Pulls or removes tube(s) or catheter(s); aggressive
+2	Agitated	Frequent non-purposeful movement, fights ventilator
+1	Restless	Anxious, apprehensive but movements not aggressive or vigorous
0	Alert & calm	
-1	Drowsy	Not fully alert, but has sustained awakening to *voice* (eye opening & contact ≥ 10 sec)
-2	Light sedation	Briefly awakens to *voice* (eye opening & contact < 10 sec)
-3	Moderate sedation	Movement or eye-opening to *voice* (but no eye contact)
-4	Deep sedation	No response to voice, but movement or eye opening to *physical* stimulation
-5	Unarousable	No response to *voice or physical* stimulation

Case 3 continued--RSBI

- Due to staffing shortages, the same patient described in the preceding slide remains intubated and mechanically ventilated for another 45 minutes. They now appear agitated with a RASS of +3 a RR of 34 and a VT of 288 mls. The nurse wants to re-sedate the patient. The 1st year surgical resident appears unsure as to what to do.
- What is the patient's RSBI?
  - RSBI=118
- What recommendation do you have for the nurse and surgical resident?

Case 4- RSBI

- 69 YO 5’5” 170 lbs. male S/P abdominal surgery (3 hrs. prior) is clinically stable with vital signs and blood chemistry are WNL, SPO2 of 98% on 35% FIO2. He is weaning on PSV + 6. He is still sedated, and RASS is -2. His RR is 6 and a VT of 900.

- What is his RSBI?
  - 7

- ***What recommendations do you have regarding his ventilator-patient management?***

Case 5: NIF and VC

- 42 YO 5’9” 170 lbs. male admitted with generalized weakness, difficulty with walking and moderate hand weakness. He is clinically stable with vital signs and blood chemistry WNL, SPO2 of 96% on 40% FIO2 and 50LPM HFNC with a spontaneous RR 22.

- What is his NIF? Negative 23cmH2O

- What is his VC? 2.6liters (approximately 65%)

- What is his ROX? 10.9

- ***What recommendations do you have regarding patient management?***

Case 6- NIF & VC

- 54 YO 5’1” 145 lbs. female admitted with generalized weakness and aspiration pneumonia, unable to stand, walk, and failed bedside swallow evaluation. She is clinically stable with vital signs and blood chemistry WNL, SPO2 of 91% on 70% FIO2 and 60LPM HFNC with a spontaneous RR 35.

- What is her NIF? Negative 18 cmH2O
- What is her VC? .9 liters (approximately 36%)
- What is her ROX? 3.71
- ***What recommendations do you have regarding patient management?***

Summary

- We have several tools to assess a patient's respiratory status.
- Always keep in mind the overall clinical picture when assessing your patient.
- Not all tools are foolproof…An extubation failure rate as high as 10% is the accepted standard.
  - Goals should always include patient safety
  - Ventilator associated events can only occur when a patient is on a ventilator.
  - The longer a patient remains intubated the higher their associated mortality and morbidity will be.

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Questions?