The Management of the COVID-19 Patient with Respiratory Failure

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Coronaviruses

- Hosts: humans, other mammals, birds
- Frequent cause of the common cold
  - Accounts for 5-10% of adult URIs
- Typical symptoms: fever, cough, sore throat
- Can cause viral pneumonia or bronchitis
- Primarily occur in winter and early spring
- Spread by aerosol droplets and contact with secretions
- No effective vaccines or approved antivirals
  - Investigational antivirals available for compassionate use

COVID-19

- Virus = SARS-CoV-2
- Originated in Wuhan, China November 2019
- Coronavirus strains causing severe illness:
  - SARS*
  - MERS*
  - COVID-19 *

*These strains do NOT present like the common cold and present with flu-like symptoms
Mortality Rates Of Viral Outbreaks

- 1918 – 1919 Influenza 10%
- 2002 – 2004 SARS 10%
- 2014 – 2017 MERS 37%
- 2019 – 2020 COVID-19 3.7%

Influenza 2019-2020 Season

CDC estimates* that, from October 1, 2019, through March 7, 2020, there have been:

- 36,000,000 – 51,000,000 flu illnesses
- 17,000,000 – 24,000,000 flu medical visits
- 370,000 – 670,000 flu hospitalizations
- 22,000 – 55,000 flu deaths
COVID-19 mortality by age

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Mortality Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20</td>
<td>0.2%</td>
</tr>
<tr>
<td>20-29</td>
<td>0.2%</td>
</tr>
<tr>
<td>30-39</td>
<td>0.2%</td>
</tr>
<tr>
<td>40-49</td>
<td>0.4%</td>
</tr>
<tr>
<td>50-59</td>
<td>1.3%</td>
</tr>
<tr>
<td>60-69</td>
<td>3.6%</td>
</tr>
<tr>
<td>70-79</td>
<td>8.0%</td>
</tr>
<tr>
<td>&gt; 80</td>
<td>14.8%</td>
</tr>
</tbody>
</table>

Common Presenting Symptoms

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Percent of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever</td>
<td>100.00%</td>
</tr>
<tr>
<td>Cough</td>
<td>80.00%</td>
</tr>
<tr>
<td>Productive...</td>
<td>60.00%</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>40.00%</td>
</tr>
<tr>
<td>Fatigue or...</td>
<td>20.00%</td>
</tr>
</tbody>
</table>

N = 201

Symptoms at Presentation

- Fever with cough: 100.00%
- Fever with dyspnea: 60.00%
- Fever with fatigue, myalgia, or headache: 40.00%
- Fever alone: 0.00%

Combined Symptoms: N = 201

Median Timeline of Disease Progression

- Onset of Illness: 7 days
- Hospital Admission
- Dyspnea: 8 days
- ARDS: 9 days
- Mechanical Ventilation: 10.5 days
- ICU Admission

84 of 201 patients (42%) developed ARDS
- 44 of 84 patients (52%) died
- Average hospital stay – 13 days
- 71% discharged (6.5% still hospitalized at time of writing)

ARDS risk factors:
- Older age
- Neutrophilia
- Elevated LDH or D-dimer
- High fever at presentation was a risk for ARDS but was also associated with a lower mortality

Respiratory Management: 
Wuhan Jinyintan Hospital, China

![Graph showing respiratory management]


Clinical Characteristics of Hospitalized Patients: 
Zhongnan Hospital of Wuhan University, China

- 138 patients
- 40 of these were healthcare workers
- Median age = 56 years
  - ICU median = 66 years
  - Non-ICU = 51 years
- Symptoms:
  - Fever (98.6%)
  - Fatigue (69.6%)
  - Cough (59.4%)
- Chest CT: bilateral patchy or ground glass infiltrates in all patients

JAMA 2020; 323:1061-9
Clinical Characteristics of Hospitalized Patients: Zhongnan Hospital of Wuhan University, China

- 36 patients (26.1%) of patients required ICU care; of these:
  - ARDS (61.1%)
  - Arrhythmia (44.4%)
  - Shock (30.6%)
- Median time intervals:
  - Symptom onset to dyspnea: 5 days
  - Symptom onset to hospitalization: 7 days
  - Symptoms onset to ARDS: 8 days
- Average hospital stay = 10 days
- Average mortality = 4.3%

JAMA 2020; 3231061-9

Clinical Characteristics of Hospitalized Patients: Zhongnan Hospital of Wuhan University, China

- ICU respiratory management:
  - 11.1% heated high flow oxygen
  - 41.7% non-invasive ventilation
  - 47.2% intubation and mechanical ventilation
    - 4 of these switched to ECMO
  - 36% of patients required vasopressors
  - 2 patients required dialysis

JAMA 2020; 3231061-9
Patients Needing ICU Care

- Older persons (mean age is about 60 years old)
- Co-morbid disease
  - Diabetes
  - Cardiac disease
  - Hypertension
- Most common reason for needing ICU = ARDS

JAMA. Published online March 11, 2020. doi:10.1001/jama.2020.3633

Cause of Death due to COVID

- Respiratory Failure
- Respiratory Failure with Myocardial Damage/Heart Failure

Risks for mortality in COVID-19 infection

- Older age
- Co-morbidities
  - Hypertension
  - Diabetes
  - Heart disease
- Persistent lymphopenia
- Rising D-dimer
- Rising LDH
- Rising troponin

www.thelancet.com Published online March 9, 2020
https://doi.org/10.1016/S0140-6736(20)30566-3
ICU Utilization: Italian Lombardi ICU Network

Day 1 to Day 14: sharp and steady increase in ICU admissions

10% of all +COVID-19 patients required ICU admission (n=556/3420)

As of March 7, 16% of hospital admissions required ICU admission (n=359/2217)


CT Findings In COVID

- 17 patients admitted to West China - Guang’an Hospital of Sichuan University
  - Average 4 days symptoms prior to admission
  - Findings:
    - 70% ground glass opacities
    - 30% ground glass + consolidative opacities
- Location:
  - 82% bilateral
  - 18% unilateral
  - 88% had both upper & lower lobe involvement
- There were no
  - Pleural effusions
  - Tree-in-bud infiltrates
  - Cavities

Day #3
Management of Respiratory Failure in COVID19

- Certain procedures and therapies may result in aerosolization of the virus

- Consider avoiding
  - High flow nasal cannula (>6LPM O2)
  - Heated high flow nasal cannula
  - Non-Invasive Positive Pressure Ventilation (unless closed exhalation circuit)
  - Nebulizers, intrapulmonary percussive ventilation, percussive chest physiotherapy, and Metanebs
  - Bronchoscopy

Management of Respiratory Failure in COVID19

- If feasible, consider early intubation in patients requiring >6LNC
  - Reduces aerosols. Also, temporizing measures may delay intubation
  - Experienced intubator
  - Rapid Sequence Intubation (RSI) with paralytic.
  - Video Laryngoscopy may allow operator more distance from airway
  - Bougie may increase first pass success
  - PPE: N95, contact, and droplet precautions
  - Airborne Infection Isolation Room
Management of Critical Illness

• Hemodynamic supports as needed, keep MAP ≥ 65
  • 1\textsuperscript{st} line in septic shock: norepinephrine
  • 2\textsuperscript{nd} line: vasopressin
  • 3\textsuperscript{rd} line: epinephrine
• Judicious fluid resuscitation in hypoxic respiratory failure
• Evaluate for organ dysfunction: Urine output/creatinine, liver function testing and echocardiogram,
• Consider impact of testing on hospital decontamination; will bedside or point of care testing suffice?

Don’t Miss The Mimics

Cardiogenic pulmonary edema

• Physical exam: S3 or S4, elevated JVP, moist crackles?
• Elevated BNP level?
• Cardiac echo?

Other forms of pneumonia

• Influenza
• Bacterial pneumonia
• If they present with sepsis, start antibiotics immediately
Respiratory failure in COVID-19 is due to ARDS

Normal (low power)

ARDS (high power)
Fluid Balance across the Lung

Movement of fluid across each compartment can be predicted by "Starling's Law."

Starling's Law can be completely derived by Ω's Law

\[ I = VR = \frac{V}{R} \]

where \( I \) is the current (or flux of volume), \( V \) is the voltage (or pressure gradient), and \( R \) is the resistance (or conductance). In the context of fluid balance across the lung:

\[ Jv = Kfc[(P_{pc} - P_T) - \sigma(\Pi_p - \Pi_T)] \]

- \( Jv \): Flux of volume
- \( Kf \): Permeability (filtration) coefficient for H2O
- \( c \): Coefficient for H2O
- \( P_{pc} \): Pulmonary capillary hydrostatic pressure
- \( P_T \): Tissue hydrostatic pressure
- \( \Pi_p \): Plasma oncotic pressure
- \( \Pi_T \): Tissue oncotic pressure
- \( \sigma \): Reflection coefficient (1.0 means all reflected)

Diagram:

- Normal lung
- Alveolus
- Basement membrane
- Capillary
- Hydrostatic
- Colloid oncotic
**Effect of lying down supine**

- **Zone 1**
  - Anterior - chest
  - $P_A > P_a > P_v$

- **Zone 2**
  - $P_a > P_A > P_v$
  - $P_a > P_v > P_A$

- **Zone 3**
  - Posterior - back
  - $P_A = $ alveolar pressure
  - $P_a = $ arterial pressure
  - $P_v = $ venous pressure
In ARDS, the dependent parts of the lung are often the worst.

So, what if you could flip the patient over?
The treatment of ARDS is PEEP
Normal Alveolus
Inhalation

Normal Alveolus
Exhalation

Atelectatic
Alveolus
Exhalation

Normal ARDS

Normal Alveolus
Inhalation

Normal Alveolus
Exhalation

Atelectatic
Alveolus
Exhalation

Normal ARDS
Atelectatic Alveolus
Exhalation

Addition Of
10 cm PEEP:
Exhalation

Over-Distended
Alveolus
Inhalation

Addition Of
10 cm PEEP:
Inhalation

No PEEP

PEEP
How The Mortality Rate Of ARDS Was Reduced By 22%

- High Volume Group
  - Starting Vt = 12 ml/kg
  - Kept plateau pressure < 50 cm
- Low Volume Group
  - Starting Vt = 6 ml/kg
  - Kept plateau pressure < 30 cm

**COVID-19 Do’s and Don’ts**

**DO:**
- DVT prophylaxis
- GI prophylaxis
- 30-45 degree bed elevation
- Vasopressors for MAP < 65
- Enteral nutrition within 24-48 hours

**DON’T:**
- Routinely use corticosteroids
- Over-sedate patients
- Routinely use paralytics
- Use hypotonic crystalloids or colloid solutions for shock

WHO guideline: *Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected*

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**The disaster that you drill for is not the disaster that you get**
Planning for ICU surge capacity

- Are there other hospital locations that can be converted to ICU?
  - Step-down units
  - Surgical post-op recovery areas
  - Cath lab recovery areas
  - Endoscopy rooms and recovery areas
  - Operating rooms
- Are there other staff that can be deployed for ICU care?
- Can you acquire additional ventilators?
- Do you have additional dialysis capacity?

The Management of the COVID-19 Patient with Respiratory Failure

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Mechanical ventilation topics

1. Ventilators
   a) Modes
   b) Oxygenation and ventilation
   c) Settings
2. ARDS
   a) Low tidal volume ventilation
   b) Prone positioning
3. Refractory hypoxemia
4. Liberation from the vent

Ventilator modes

- Assist Control
- SIMV
- Pressure Support
Ventilator modes

- Assist Control
- SIMV
- Pressure Support
- No set rate

Set respiratory rate

- Assist Control: Full support each breath
- SIMV: Full support on ventilator-initiated breaths
- Pressure Support: Partial support on patient-initiated breaths
Ventilator modes

- Assist Control
  - Volume Control
  - Pressure Control

Assist Control - Volume Control
- RR
- VT
- PEEP
- FiO2

Assist Control - Pressure Control
- RR
- DP*
- PEEP
- FiO2
Ventilation and Oxygenation

Ventilation

RR x VT = minute ventilation

Oxygenation

Inspiratory time and expiratory time

- I:E ratio = how much time spent in inspiration vs expiration

- ↑ I:E → ↓ Oxygenation, ↑ Ventilation
- ↓ I:E → ↑ Oxygenation, ↓ Ventilation
Inspiratory time and expiratory time

- I:E ratio = how much time spent in inspiration vs expiration
  - Normal = 1:1.5 or higher

- Ways to control this depending on ventilator and mode
  - I-time (seconds)
    - usually 1-1.5 sec
  - Flow rate (L/min)
    - usually 60-120 L/min

<table>
<thead>
<tr>
<th>I-time</th>
<th>RR</th>
<th>Inspiration</th>
<th>Expiration</th>
<th>I:E ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 sec</td>
<td>20</td>
<td>30 seconds</td>
<td>30 seconds</td>
<td>1:1</td>
</tr>
<tr>
<td>1 sec</td>
<td>20</td>
<td>20 seconds</td>
<td>40 seconds</td>
<td>1:2</td>
</tr>
</tbody>
</table>

Picking and changing settings

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage
Picking and changing settings

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage

Initial settings - hypoxemic respiratory failure with or at risk for ARDS

<table>
<thead>
<tr>
<th>Assist Control - Volume Control</th>
<th>RR</th>
<th>$V_T$</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-24 bpm</td>
<td>6-8 mL/kg PBW</td>
<td>5-10 cmH$_2$O</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assist Control - Pressure Control</th>
<th>RR</th>
<th>DP</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-24 bpm</td>
<td>15 cmH$_2$O</td>
<td>5-10 cmH$_2$O</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
**Initial settings - obstructive lung disease (COPD or asthma)**

<table>
<thead>
<tr>
<th>Assist Control - Volume Control</th>
<th>RR</th>
<th>V&lt;sub&gt;T&lt;/sub&gt;</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-14 bpm</td>
<td>8 mL/kg PBW</td>
<td>0-5 cmH&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assist Control - Pressure Control</th>
<th>RR</th>
<th>DP</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-14 bpm</td>
<td>15-20 cmH&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>0-5 cmH&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

**Initial settings - metabolic acidosis (DKA, AKI, shock, toxins)**

<table>
<thead>
<tr>
<th>Pressure Support</th>
<th>RR</th>
<th>PS</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
</table>

Example: Initial values of pH 7 / PaCO<sub>2</sub> 14 with HCO<sub>3</sub> 5 mmol/L + “normal” assist control settings → ineffective ventilation and worsening acidosis
Initial settings - metabolic acidosis (DKA, AKI, shock, toxins)

Pressure Support

<table>
<thead>
<tr>
<th>RR</th>
<th>PS</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-5 cmH₂O</td>
<td>5-10 cmH₂O</td>
<td>100%</td>
</tr>
</tbody>
</table>

Example: Initial values of pH 7 / PaCO₂ 14 with HCO₃ 5 mmol/L + “normal” assist control settings → ineffective ventilation and worsening acidosis

Picking and changing settings

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage
Monitors & Goals

- Blood gas
  - pH
  - PaCO₂
  - PaO₂

- Pulse oximetry
  - SpO₂

- Oxygenation
  - PaO₂ ~60 mmHg
  - SpO₂ ~90%

- Ventilation
  - pH 7.2-7.45
  - PaCO₂
    - permissive hypercapnia except with increased intracranial pressure

Adjusting for oxygenation or ventilation

<table>
<thead>
<tr>
<th></th>
<th>RR</th>
<th>Vₜ</th>
<th>PEEP</th>
<th>FiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaO₂ too low</td>
<td></td>
<td></td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>PaO₂ too high</td>
<td></td>
<td></td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>pH too low pH 7.1 / PaCO₂ 70</td>
<td>↑</td>
<td></td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td></td>
<td>↑</td>
<td></td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>pH too high pH 7.5 / PaCO₂ 30</td>
<td>↓</td>
<td></td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

* hypoventilating so increase minute ventilation
* hyperventilating so decrease minute ventilation
Picking and changing settings

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage

Issues to avoid with mechanical ventilation

- Volutrauma
- Auto peeping
Volutrauma

- Also known as overdistention of alveoli
- More important contributor to ventilator induced lung injury than barotrauma
  - Recommend conservative tidal volumes
  - Specifically low tidal volume ventilation with ARDS

Auto peeping

- Also known as “dynamic hyperinflation” or “breath stacking”
- What it is:
  - When not enough time to exhale before a new breath is delivered
- Why it is bad:
  - Not appropriately ventilating
  - Thoracic over-inflation can lead to cardiovascular compromise
Auto peeping

• How to tell:
  • Ventilator flow waveform
  • Expiratory hold maneuver

• What to do:
  • Decrease respiratory rate
  • Lower I:E ratio
    • Shorter inspiration time and longer expiration time

Mechanical ventilation topics

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   a) Low tidal volume ventilation
   b) Prone positioning
3. Refractory hypoxemia
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ARDS definition

<table>
<thead>
<tr>
<th>Imaging</th>
<th>Bilateral opacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etiology</td>
<td>Not fully explained by heart failure or volume overload</td>
</tr>
<tr>
<td>Timing</td>
<td>≤ 1 week since onset or insult</td>
</tr>
<tr>
<td>Severity:</td>
<td>Mild ARDS</td>
</tr>
<tr>
<td>(with PEEP ≥ 5)</td>
<td>200-300 mmHg</td>
</tr>
</tbody>
</table>
| PaO₂/FiO₂ ratio | \[
\begin{array}{c}
\text{PaO}_2 \\
\text{FiO}_2
\end{array}
\begin{array}{c}
150 \\
0.5
\end{array}
\quad \begin{array}{c}
\text{PaO}_2 \\
\text{FiO}_2
\end{array}
\begin{array}{c}
50 \\
1.0
\end{array}
\]

1. Diagnose ARDS
2. Set up ventilator with low tidal volume ventilation
   • 6 mL/kg PBW, as based on sex and height
3. Adjust Vₜ and RR to reach pH and plateau pressure goals
4. Adjust PEEP and FiO₂ to reach oxygenation goal
Plateau pressure

- Plateau pressure goal ≤ 30 mmHg
- Measure Pplat every 4 hours and with changes in PEEP or VT

<table>
<thead>
<tr>
<th>Lower PEEP/higher FIO2</th>
<th>FI O₂</th>
<th>0.3</th>
<th>0.4</th>
<th>0.4</th>
<th>0.5</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEP</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>FI O₂</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEEP</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>24</td>
<td></td>
<td></td>
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</tbody>
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<th>FI O₂</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.4</th>
<th>0.4</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEP</td>
<td>5</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>FI O₂</td>
<td>0.5</td>
<td>0.5-0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
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<td></td>
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<tr>
<td>PEEP</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>24</td>
<td></td>
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</tbody>
</table>
Plateau pressure

- If Pplat > 30:
  - decrease VT by 1 mL/kg incrementally (minimum = 4 mL/kg)

- If Pplat < 25 and VT < 6 mL/kg:
  - increase VT by 1 mL/kg until Pplat > 25 or VT 6 mL/kg

- If Pplat < 30 and breath stacking or dyssynchrony:
  - increase VT by 1 mL/kg incrementally to 7-8 mL/kg if Pplat remains ≤ 30

---

OXYGENATION GOAL: PaO₂ 55-80 mmHg or SpO₂ 88-95%.
Use a minimum PEEP of 5 cm H₂O. Consider use of incremental FIO₂/PEEP combinations such as shown below (not required) to achieve goal.

<table>
<thead>
<tr>
<th>Lower PEEP/higher FIO₂</th>
<th>FIO₂</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
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<tbody>
<tr>
<td></td>
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<td>5</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>12</td>
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<tr>
<td></td>
<td>PEEP</td>
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PLATEAU PRESSURE GOAL: ≤ 30 cm H₂O
Check Pplat (0.5 second inspiratory pause), at least q 4h and after each change in PEEP or VT.
If Pplat > 30 cm H₂O: decrease VT by 1mL/kg steps (minimum = 4 mL/kg).
If Pplat < 25 cm H₂O and VT < 6 mL/kg: increase VT by 1 mL/kg until Pplat > 25 cm H₂O or VT = 6 mL/kg.
If Pplat < 30 and breath stacking or dysynchrony occurs: may increase VT in 1mL/kg increments to 7 or 8 mL/kg if Pplat remains ≤ 30 cm H₂O.
Other therapies for ARDS

• Prone positioning
• ECMO

Prone positioning

• Early prone positioning in severe ARDS has mortality benefit
  • Consider early on in patient’s course if P:F < 150

• How it works:
  • ↓ compression of left lung by the heart
  • ↓ dependent atelectasis from interstitial edema
  • Allows more lung regions to be functional
  • Improves V/Q mismatch
**Prone positioning - contraindications**

- **Absolute contraindication:**
  - Open wound of neck, chest, or abdomen

- **Relative contraindications:**
  - Hemodynamic instability
  - Elevated intracranial pressure
  - Recent trauma or surgery
    - Unstable fractures
    - Face/neck 15 days
    - Sternotomy 30 days
  - Pregnancy
  - >20% BSA burns
  - Requiring impending surgery/procedure

**Prone positioning – logistics**

- P-F < 150
- Manually prone patient x 16+ hours
- FIO₂ < 100% AND SpO₂ > 92% or PaO₂ > 70%
- Supine for up to 6 hours for care
- Prone trial failed if hemodynamic or respiratory instability
- Return to supine
Prone positioning – logistics

Mechanical ventilation topics

1. Ventilators
   a) Modes
   b) Oxygenation and ventilation
   c) Settings
2. ARDS
   a) Low tidal volume ventilation
   b) Prone positioning
3. Refractory hypoxemia
4. Liberation from the vent
Refractory hypoxemia

- Prone positioning
- ECMO
- Inhaled epoprostenol or nitric oxide
- Neuromuscular blockade

Caution against nebulized medications with confirmed COVID-19 or PUI

Neuromuscular blockade

- 2010 ACURASYS trial → mortality benefit
- 2019 ROSE trial → no mortality benefit compared to lighter sedation

Bottom line:
- Not needed for all ARDS patients
- Still useful for significant vent dyssynchrony OR refractory hypoxemia

If used:
- Ensure adequate continuous sedation and analgesia
- Ensure DVT prophylaxis
Mechanical ventilation topics

1. Ventilators
   a) Modes
   b) Oxygenation and ventilation
   c) Settings

2. ARDS
   a) Low tidal volume ventilation
   b) Prone positioning

3. Refractory hypoxemia

4. Liberation from the vent

The ICU Liberation Bundle
= ABCDEF bundle

• A = assess, prevent, manage pain
• B = both SAT + SBT
• C = choice of analgesia and sedation
• D = delirium: assess, prevent, and manage
• E = early mobility and exercise
• F = family engagement and empowerment
**SAT + SBT**

| SAT | Criteria:  
| • No active seizures, withdrawal, myocardial ischemia, elevated ICP | Performance:  
| • Hold all continuous sedation | Failure:  
| • Anxiety, agitation, pain | • RR > 35  
| • SpO₂ < 88% | • Acute arrhythmia  
| SBT | Criteria:  
| • SpO₂ ≥ 88%  
| • PEEP ≤ 8  
| • FiO₂ ≤ 50%  
| • Hemodynamically stable | Performance:  
| • 30-60 minutes of minimal vent support | Failure:  
| • RR > 35 or < 8  
| • SpO₂ < 88%  
| • Respiratory distress  
| • Mental status change  
| • Acute arrhythmia  

*Daily to determine if eligible for extubation*

**Resume sedation at ½ dose**

**Resume prior vent settings**