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 anti-virals
  - Investigational anti-virals 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

<table>
<thead>
<tr>
<th>Year</th>
<th>Mortality Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1918–1919 Influenza</td>
<td>10%</td>
</tr>
<tr>
<td>2002–2004 SARS</td>
<td>10%</td>
</tr>
<tr>
<td>2014–2017 MERS</td>
<td>37%</td>
</tr>
<tr>
<td>2019–2020 COVID-19</td>
<td>3.7%</td>
</tr>
</tbody>
</table>

### 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
  - 23,000 - 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>1.2%</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

- Fever
- Cough
- Productive
- Dyspnea
- Fatigue

**Symptoms at Presentation**

- Fever with cough
- Fever with dyspnea
- Fever with fatigue, myalgia or headache

Combined Symptoms

Percent of Patients

0.00%  20.00%  40.00%  60.00%  80.00%  100.00%

\[ N = 201 \]


**Median Timeline of Disease Progression**

<table>
<thead>
<tr>
<th>Onset of Illness</th>
<th>7 days</th>
<th>8 days</th>
<th>9 days</th>
<th>10.5 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Admission</td>
<td>Dyspnea</td>
<td>ARDS</td>
<td>Mechanical Ventilation</td>
<td>ICU Admission</td>
</tr>
</tbody>
</table>


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**Risk Factors for Respiratory Failure: Wuhan Jinyintan Hospital, China**

- 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)


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**Risk Factor for Respiratory Failure: Wuhan Jinyintan Hospital, China**

- 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

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

- 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%

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


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

Risks for mortality in COVID-19 infection

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ICU Utilization: Italian Lombardi ICU Network


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 #1

Day #2
Day #3

Management of Respiratory Failure in COVID-19

- 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

- 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
  - 1st line in septic shock: norepinephrine
  - 2nd line: vasopressin
  - 3rd 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

<table>
<thead>
<tr>
<th>Cardiogenic pulmonary edema</th>
<th>Other forms of pneumonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical exam: S3 or S4, elevated JVP, moist crackles?</td>
<td>Influenza</td>
</tr>
<tr>
<td>Elevated BNP level?</td>
<td>Bacterial pneumonia</td>
</tr>
<tr>
<td>Cardiac echo?</td>
<td>If they present with sepsis, start antibiotics immediately</td>
</tr>
</tbody>
</table>

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 Ohm's Law

\( V = IR \)

\( J_v = K_f c[(P_{pc} - P_T) - \sigma(P_H - P_T)] \)

- \( J_v \): Flux of volume
- \( K_f \): Permeability (filtration) coefficient for H2O
- \( c \): Coefficient for H2O
- \( P_{pc} \): Pulmonary capillary hydrostatic pressure
- \( P_T \): Tissue hydrostatic pressure
- \( P_H \): Hydrostatic pressure
- \( \sigma \): Reflection coefficient
- 1.0 means all reflected

**Normal Lung**

**Cardiogenic Pulmonary Edema**

**Acute Respiratory Distress Syndrome**
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
**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

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**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

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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

Ventilator modes

- Set respiratory rate
  - Assist Control
  - SIMV
  - Pressure Support

  - Full support each breath
  - Full support on ventilator-initiated breaths
  - Partial support on patient-initiated breaths

Ventilator modes

- Volume Control
- Pressure Control

Ventilator modes

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

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

- Ventilation
  - RR x \( V_t \) = minute ventilation
  - RR = Respiratory Rate
  - \( V_t \) = Tidal Volume

- Oxygenation
  - 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

Ventilation and Oxygenation

- Inspiratory time and expiratory time
  - I:E ratio = how much time spent in inspiration vs expiration
  - ↑ I:E
    - Oxygenation
    - Ventilation
  - ↓ I:E
    - Ventilation
    - Oxygenation

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

<table>
<thead>
<tr>
<th>RR</th>
<th>VT</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 cmH2O</td>
<td>100%</td>
</tr>
</tbody>
</table>

Initial settings - obstructive lung disease (COPD or asthma)

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<th>RR</th>
<th>VT</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 cmH2O</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RR</th>
<th>DP</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-24 bpm</td>
<td>15 cmH2O</td>
<td>5-10 cmH2O</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>RR</th>
<th>PS</th>
<th>PEEP</th>
<th>FiO2</th>
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<td></td>
<td></td>
<td></td>
<td></td>
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Example:
Initial values of pH 7 / PaCO2 14 with HCO3 5 mmol/L
+ “normal” assist control settings
→ ineffective ventilation and worsening acidosis
Initial settings - metabolic acidosis (DKA, AKI, shock, toxins)

<table>
<thead>
<tr>
<th>Pressure Support</th>
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<tr>
<td>RR</td>
</tr>
<tr>
<td>10-5 cmH2O</td>
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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
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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>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>
</tr>
<tr>
<td>PaO2 too high</td>
<td>↓</td>
<td>↓</td>
<td></td>
</tr>
</tbody>
</table>
| pH too low
  pH 7.1 / PaCO2 70 | ↑ | ↑ | ↑|
  *hyperventilating so increase minute ventilation
| pH too high
  pH 7.5 / PaCO2 30 | ↓ | ↓ |   |
  *hypoventilating 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

1. Ventilators
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2. ARDS
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   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: (with PEEP ≥ 5)</td>
<td>Mild ARDS</td>
</tr>
<tr>
<td>PaO₂/FiO₂ ratio</td>
<td>200-300 mmHg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PaO₂</th>
<th>150</th>
<th>PaO₂</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>FiO₂</td>
<td>0.5</td>
<td>FiO₂</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1. Diagnose ARDS
2. Set up ventilator with low tidal volume ventilation
   - 6 mL/kg PBW, as based on sex and height
3. Adjust V₉ and RR to reach pH and plateau pressure goals
4. Adjust PEEP and FiO₂ to reach oxygenation goal
Plateau pressure

- If Pplat > 30:
  - decrease V₉ by 1 mL/kg incrementally (minimum = 4 mL/kg)

- If Pplat < 25 and V₉ < 6 mL/kg:
  - increase V₉ by 1 mL/kg until Pplat > 25 or V₉ 6 mL/kg

- If Pplat < 30 and breath stacking or dyssynchrony:
  - increase V₉ by 1 mL/kg incrementally to 7-8 mL/kg if Pplat remains ≤ 30
Other therapies for ARDS

- Prone positioning
- ECMO

Prone positioning

- Early prone positioning in severe ARDS has mortality benefit
  - Consider early on 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

1. Prone trial failed if hemodynamic or respiratory instability
2. Supine for up to 6 hours of care
3. Manually prone patient x 16 hours
4. P:F < 150
5. PO2 < 100% AND MAP > 150, or PAO2 > 50% or PaO2 > 25%
Prone positioning – logistics

Mechanical ventilation topics

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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**

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**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**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Performance</th>
<th>Failure</th>
</tr>
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<tbody>
<tr>
<td>No active seizures, withdrawal, myocardial ischemia, elevated ICP</td>
<td>Hold all continuous sedation</td>
<td>Anxiety, agitation, pain, RR &gt; 35, SpO₂ &lt; 88%, Acute arrhythmia</td>
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**SBT**

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<td>SpO₂ ≥ 88%</td>
<td>30-60 minutes of minimal vent support</td>
<td>RR &gt; 35 or &lt; 8, SpO₂ &lt; 88%, Respiratory distress, Mental status change, Acute arrhythmia</td>
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* Daily to determine if eligible for extubation

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**SAT + SBT**

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<th>Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpO₂ ≥ 88%, PEEP ≤ 8, FiO₂ ≤ 50%, Hemodynamically stable</td>
<td>30-60 minutes of minimal vent support</td>
<td>RR &gt; 35 or &lt; 8, SpO₂ &lt; 88%, Respiratory distress, Mental status change, Acute arrhythmia</td>
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Resume sedation at ½ dose

Resume prior vent settings