NETEC COVID-19 Webinar Series:
Ventilator Support for Patients with COVID-19: Initial Approach and Advanced Modalities
Welcome: Sonia Bell, NETEC

Ventilator Strategies: Vikram Mukherjee, MD

Challenges to Using Non-Invasive Ventilator Devices for Invasive Ventilation if Needed for Surge Capacity Use:
Frank Freihaut, BS, RRT-ACCS
Matthew Klopman, MD, FASA, FASE

Adjuncts to Mechanically Ventilated COVID-19 Patients:
James Sullivan, MD

NETEC Resources: Sonia Bell, NETEC

Questions and Answers with NETEC
Welcome

National Emerging Special Pathogens Training and Education Center

Mission Statement

To increase the capability of the United States public health and health care systems to safely and effectively manage individuals with suspected and confirmed special pathogens

For more information

Please visit us at www.netec.org
or email us at info@netec.org
**NETEC Overview**

**Assessment**
- Empower hospitals to gauge their readiness using **Self-Assessment**
- Measure facility and healthcare worker readiness using **Metrics**
- Provide direct feedback to hospitals via **On-Site Assessment**

**Education**
- Provide self-paced education through **Online Trainings**
- Deliver didactic and hands-on simulation training via **In-Person Courses**
- COVID-19 focused **Webinars**

**Technical Assistance**
- **Onsite & Remote Guidance**
- Compile **Online Repository** of tools and resources
- Develop customizable **Exercise Templates** based on the HSEEP model
- Provide **Emergency On-Call Mobilization**

**Research Network**
- **Online Repository**
  - Built for rapid implementation of clinical research protocols
- **Develop Policies, Procedures and Data Capture Tools**
  - to facilitate research
- Create infrastructure for a **Specimen Biorepository**

**Cross-Cutting, Supportive Activities**
Ventilator Strategies

Vikram Mukherjee, MD
Critically ill patients with COVID-19 predominantly present with acute hypoxic respiratory failure

Some common themes
- Acute viral pneumonia causing ARDS
- Significant degrees of shunt fraction and dead space fraction
- High sedation needs
- Prolonged need for mechanical ventilation

Some variations
- Variable response to PEEP
- Variable degrees of compliance
Typical COVID-19 ARDS CXR
Ventilator Strategies

Approach

- Nasal cannula
- High flow nasal cannula
- Early prone positioning
- Avoidance of non-invasive Ventilation
- Invasive mechanical ventilation
NIV (Non-Invasive Ventilation): FLORALI Study

Reasons to Avoid NIV

- Inability to reliably deliver lung protective ventilation
- Aerosol generation
- High degree of encephalopathy
  - Inability to protect airway
- Prone positioning difficult when on NIV
Lung protective strategy

- 6 cc/kg of Ideal Body Weight
- Goal Pplat < 30 cm water
- Goal Dp < 17 cm water
- Acceptable hypoxia
- Acceptable hypercapnia and acidosis
### PEEP (Positive End Expiratory Pressure)

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More Individualized Approach
Prone Positioning

Early
• Even on Patients who are spontaneously breathing

Prolonged
• >16 hr/day

Reassess need daily
• P/f < 150pm PEEP of 10cm water, Fio2 fo 60%

Maintain vigilance on complications

Protocolize approach
Ventilator Strategies

Sedation and Neuromuscular Blockade

- Significant degree of ventilator dyssynchrony
- Consistent need for RASS-4
  - Fentanyl
  - Propofol
  - Ketamine
  - Versed
- Neuromuscular blockade
Step Wise Escalation

- Lung Protective Strategy
- Prone Positioning
- PEEP titration
- Neuromuscular Blockade
- Inhaled NO
- ECMO evaluation
Long Term Consequences

- Progression of fibroproliferative ARDS
- Significant Post ICU Syndrome
  - Neuromuscular weakness: paralytics, long duration on ventilators
  - Delirium: Benzodiazepines, long ICU LOS
  - Cognitive dysfunction: too early to assess
- Tracheostomy program
- Long Term Acute Care (LTAC) needs
Challenges to Using Non-Invasive Ventilator Devices for Invasive Ventilation if Needed for Surge Capacity Use

(Note: CPAP mode and or devices will not provide ventilation, Bilevel pressure modes and devices are required for ventilation assistance)

Frank Freihaut, BS, RRT-ACCS
Matthew Klopman, MD, FASA, FASE
### Challenges to Using Non-Invasive Ventilator Devices for Invasive Ventilation

NIV volumes delivered are calculated based on flow and leak estimations versus direct measurements on invasive devices for both inspired volume and exhaled volume. Reduced leaks will have more accurate volume estimations, (thus utilizing an ETT in place of a mask will increase accuracy of volume delivered).

NIV devices utilize a leak port, either on the mask or on the circuit for exhaled gasses to escape. Their circuit can not operate correctly if entirely closed and will be dangerous to the patient. Since exhaled gas is not coming back to the machine a filter should be utilized on the leak port to reduce healthcare worker exposure.

<table>
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<th>Versus</th>
<th>ICU Ventilator Double Limb Circuits</th>
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When Using NIV Devices for Invasive Ventilation

Add a humidification system, either passive heat moisture exchange filters or active humidifiers, since the upper airway is bypassed when not using a mask interface.

When possible utilize NIV devices that use oxygen blender not low flow oxygen “bleed in” to achieve an increased FiO2. It will be difficult if not impossible to achieve both a high FiO2, (.6-1.0), and a high minute volume with a low flow device.
Challenges to Using Non-Invasive Ventilator Devices for Invasive Ventilation

Suggested Modes for Use of NIV Device for Invasive Ventilation

- Utilize the ventilator modes that have the ability to set a mandatory Respiratory Rate and Inspiratory Time. Note higher set rates and pressures will be required for the “stiff” ARDS/COVID lungs than are conventionally used with NIV devices.
  
  Examples:
  
  - Spontaneous Timed, ST
  - Pressure Control
  - AVAPS, Average Volume Assured Pressure Support

- Set appropriate alarms, that often are silenced during Non-invasive use but should be required for invasive use, to at least warn of inadvertent disconnect.
Challenges to Using Non-Invasive Ventilator Devices for Invasive Ventilation

Be Aware of Pressure Gradient Differences

IPAP, (Inspiratory Positive Airway Pressure), and EPAP, (Expiratory Positive Airway Pressure), on NIV devices do not add to achieve the PIP, (peak inspiratory pressure).

Example:
- When making a PEEP increase on many ICU ventilators, the Pressure Support setting will add above the PEEP. The inspiratory pressure above PEEP will remain the same as the PEEP is adjusted, keeping the tidal volume stretch about the same.

- However, when making an EPAP increase the IPAP does not change. Thus the inspiratory pressure above the expiratory pressure difference will be reduced. This drop in the inspiratory pressure gradient may cause a detrimental drop in tidal volume stretch. By reviewing both the IPAP and EPAP settings whenever changing one of these pressure thresholds you can prevent inadvertent volume changes.
Challenges to Using Non-Invasive Ventilator Devices for Invasive Ventilation

NIV Volume Targeted Modes Are Controlled Differently than ICU Volume Targeted Modes

ICU ventilator volume target modes, (PRVC Getinge, APV Hamilton, VG Draeger), have relatively quick response time to lung compliance changes, i.e. usually breath to breath adjustments will be made.

NIV volume targeted modes, (AVAPS Philips, iVAPS Resmed), usually intended for chronic patients utilize a longer breath averaging algorithm often using several breaths or a few minutes of measurements before making pressure changes due to lung compliance changes.
Anesthesia Machines as ICU Ventilators

Plumbing
Anesthesia Machines as ICU Ventilators

Anesthesia Machine

- Require startup by trained individual
- Intended to be fully attended/monitored
- Allows rebreathing
  - CO2 management, condensation
- Passive humidification
- Daily calibration
- No automatic leak compensation
- Spontaneous vent modes may not have a backup mode
- Can’t vent excess pressure to atmosphere unless P>110 cmH20
Anesthesia Machines as ICU Ventilators

Anesthesia Machine ➔ ICU Ventilator

Off label use
- FDA will allow during public health crisis if conventional vent not available

Equipment Considerations

Staffing Considerations
## Equipment Considerations

### System Startup
- System check out q24-72h
  - Alternative vent equipment

### Heat/Moisture Exchanger/Filter (HMEF)

### Fresh Gas Flow > minute ventilation
- Supply of CO₂ absorbers

### Water Traps

### OR versus ICU versus floor/PACU/etc.

### Bellows function/drive gas

### Scavenging system
Anesthesia Machines as ICU Ventilators

Staffing Considerations

- Rounding and immediate availability of trained anesthesia personnel
  - +/- Cross train select team members on basic settings and initial alarm response
  - Limit parameter changes to trained personnel

- Geographic cohorting
Anesthesia Machines as ICU Ventilators

Reference and How-to Guides

www.asahq.org/ventilators


https://www.gehealthcare.com/corporate/covid-19


Adjuncts to Mechanically Ventilated COVID-19 Patients

James Sullivan, MD
### Case

- 32-year-old male
- No previous medical history but found to have an A1C of 10 on admission
- COVID positive at outside hospital 4 days prior and sent home to quarantine
- Presented to UNMC comfortable but feeling mildly short of breath
- Oxygen saturations in the 20’s
- Did not respond to increasing oxygen therapy
- Intubated in the emergency room
### Case: Initial Vent Settings

- Pressure regulated volume control
- FiO2 100%
- PEEP 18
- TV 360 (6cc/kg)
- Proned, muscle relaxant
- 11 days
- No change
Case:
Clinically Worsened on Day 14 of Illness / 10 days Hospitalization

- TV in 150 (2.5 ml/kg IBW) range with Plateaus of 48-50
- “Best PEEP challenge” – 10mm H2O
- Cannulated for VV ECMO (Fem/Fem)
- PEEP dropped to 10 to try to lessen plateau
- Still hypoxic despite 4-5 liter flows, 100% oxygenator, 0.6 FiO2, PEEP 10, plateau in the 30 range, inhaled epoprostenol started without effect
- POC ultrasound – cardiac function hyperdynamic but normal
CT When Decompensated
Case

- 5 days with no recovery of pulmonary function
- Esophageal manometry started
- Airway Plateaus in the 35 range with TV 150-170 (2.5-3 ml/Kg IBW)
- With manometry guidance increased PEEP to 16 despite airway plateau pressure on the ventilator into the 50 range. No changes for 8 hours. (NOTE: Transthoracic Plateau calculated well under 25cmH2O with the PEEP increase)
- Gained compliance, (PIP and Plateau decreased over night). PEEP increased to 18. Small pneumothorax
- PEEP dropped to 16 TV increased to 200 range. (Transthoracic pressures stayed well below 25)
- PEEP kept at 16, increased TV to 320 as Transthoracic Plateau stayed under 25
Esophageal Pressure tracing

Location of esophageal catheter best behind the heart, thus look for oscillations matching arterial pressure tracing
Adjuncts to Mechanically Ventilated COVID-19 Patients

Inhaled Vasodilators

- Pulmonary arteriolar vasodilator
- Synthetic prostacyclin

Prostacyclin
- synthesized on multiple organ vascular smooth muscle
- works on G protein couple receptors
- in lung it has multiple actions
  - pulmonary artery dilatation
  - improves V/Q matching
  - inhaled agent has a ceiling effect around 20-30 ng/kg/min
Adjuncts to Mechanically Ventilated COVID-19 Patients

### Inhaled Vasodilators

- Greatest benefit in those with right ventricular dysfunction
- MUCH less expensive than iNO
- Can be used in ARDS due to both primary and secondary injury
- No randomized trial shows clear survival benefit despite increased oxygenation
- Minimal to no systemic side effects
- Increased surfactant via cAMP pathway
- Increased degradation at lower pH (permissive hypercapnia)
- Decreases pulmonary artery pressures with no change in SVR/MAP
- Inhibits platelet aggregation?
  - only validated in the intravenous form
## Inhaled Nitric Oxide

- Formed naturally in paranasal sinuses
- Bronchodilator
- Pulmonary vasodilator
- ? Possible inactivation of viral replication
- Activates ciliary movement
- Activates mucous production
- Expensive
Adjuncts to Mechanically Ventilated COVID-19 Patients

Esophageal Manometry

- Transmural pressure of lung = stress on the lung

- Equal to $P_{alveolar} - P_{plural}$

- At no flow alveolar pressure should equal transpleural pressures without mitigating factors
  - Chest wall rigidity
  - Obesity
  - Kyphoscoliosis
Adjuncts to Mechanically Ventilated COVID-19 Patients

Ventilator Associated Lung Injury

**Static conditions**

- Alveolar pressure = airway pressure
- Pleural pressure = esophageal pressure
- Transrespiratory pressure = airway – atmospheric
- Chest wall pressure = esophageal – atmospheric
- Pleural = airway - esophageal
In Static conditions:

\[ \text{Palv} = \text{Pw} \]

\[ \text{Ppl} = \text{Pes} \]

\[ \text{Prs} = \text{Paw} - \text{P}_{\text{ATM}} \]

\[ \text{Pcw} = \text{Pes} - \text{P}_{\text{ATM}} \]

\[ \text{PI} = \text{Paw} - \text{Pes} \]
Adjuncts to Mechanically Ventilated COVID-19 Patients

Goal of Mechanical Ventilation

- Keep lungs open to prevent atelectattrauma
- Prevent further harm/inflammation due to overdistention
Heterogeneously injured lung is difficult to ventilate successfully

- Higher local pressures in one area - barotrauma
- Low pressures in others – atelectatraction
- High negative transpulmonary pressures

Transpulmonary pressures many times negative at end expiration leading to collapse – PEEP titration offsets closing pressure
NETEC Resources

Sonia Bell, NETEC
NETEC is Here to Help

NETEC will continue to build resources, develop online education, and deliver technical training to meet the needs of our partners.

Ask for help!

Send questions to info@netec.org - they will be answered by NETEC SMEs.

Submit a Technical Assistance request at NETEC.org
Questions and Answers