A Neurosurgeon's Guide to Pulmonary Critical Care for COVID-19

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Introduction

As the number of people infected with the novel coronavirus rapidly increases, some neurosurgeons are being asked to participate in the care of critically ill patients, even those without neurological involvement. This presentation is meant to be a basic guide to help neurosurgeons achieve this mission.

Disclaimer

- The protocols discussed in this presentation are from the Mission: Possible program at University Hospitals of Cleveland, based on guidelines and recommendations from several medical societies and the Centers for Disease Control (CDC).
- Please check with your own hospital or institution to see if there is any variation from these protocols before implementing them in your own practice.

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COVID-19

- Coronavirus disease 2019 (COVID-19) is a respiratory tract infection caused by a newly emergent coronavirus, SARS-CoV-2, that was first recognized in Wuhan, China, in December 2019.
- Genetic sequencing of the virus suggests that SARS-CoV-2 is a betacoronavirus closely linked to the SARS.

Personal Protective Equipment

When taking care of COVID-19 patients, please adhere to all of your institution's policies regarding personal protective equipment (PPE)

To help others, you must stay healthy yourself!

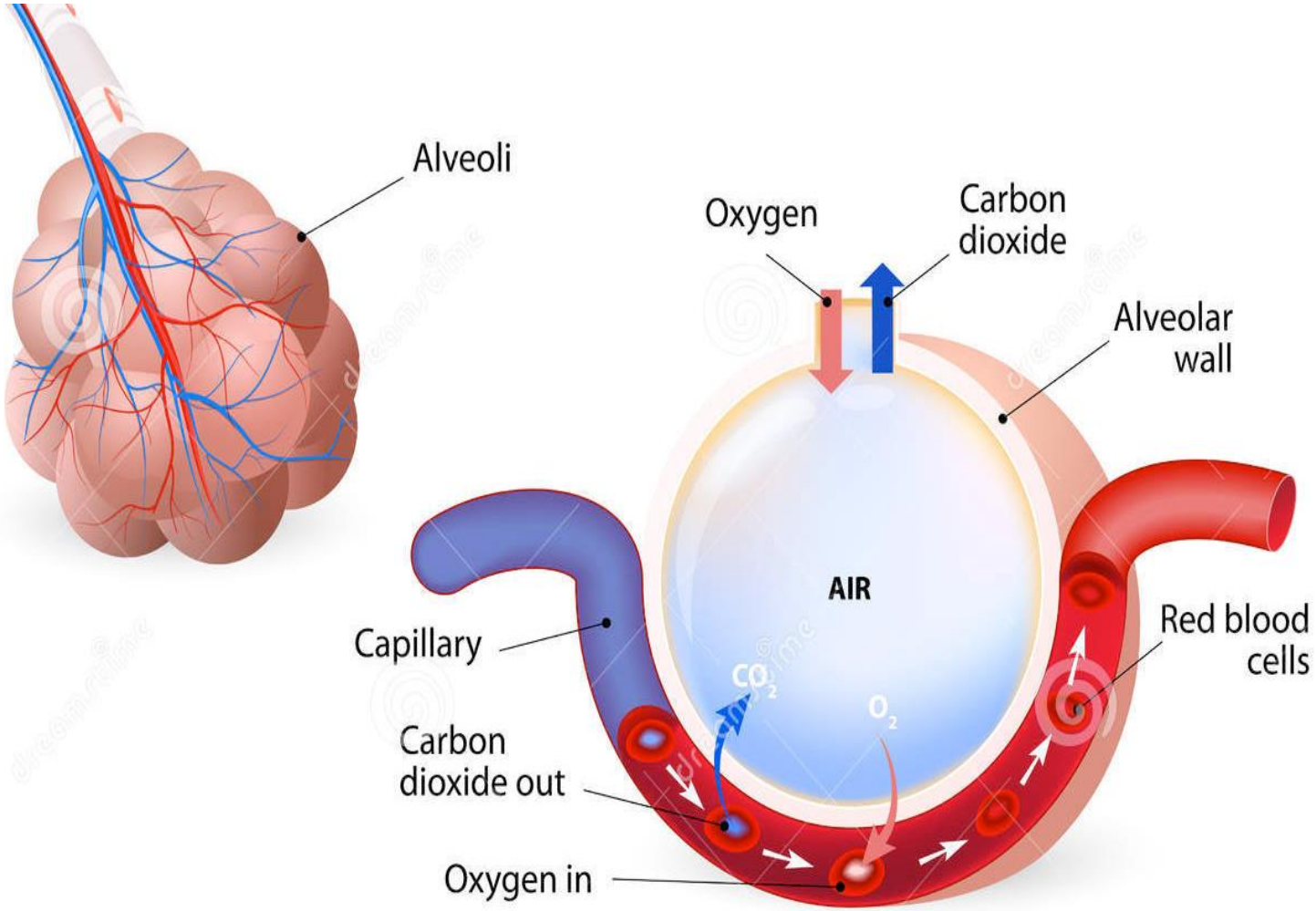
Our Isolation Protocols

- Admit to negative pressure room if available; if not enough negative pressure rooms available for all admitted COVID patients, preference given to non-intubated patients since their respiration is in an open system and they may require intubation
- Patient requires surgical mask when out of room for tests/procedures and when on HFNC
- Patient must remain in room with door closed
- No visitors unless comfort measures are being implemented – then, provide visitors with PPE and educate on procedures – one visitor at a time
- Use clear cassette drape/probe covers for portable imaging to minimize equipment contamination
- Staff require strict contact and droplet precautions
- Nurses to perform lab draws from lines to minimize contact among staff
- Minimize number of staff interacting with patients
- Bundle patient care duties to minimize number of interactions with patient by nurse (medications, vitals, I/Os, lab draws, meal service, etc)

ICU Admission for COVID-19

- Pneumonia with hypoxic respiratory failure
- Acute Respiratory Distress Syndrome (ARDS)
- Sepsis
- Septic shock
- Post cardiac arrest

Pulmonary System



Pulmonary Function

- Gas exchange occurs in the alveoli of the lung
  - Respiration: oxygen exchange
  - Ventilation: CO_2 exchange

- Acid-base balance: Because CO_2 is in equilibrium with H^+, ventilation affects pH

Causes of Respiratory Symptoms

- Inflammation or fluid in the alveoli preventing adequate gas exchange
- Airway sections
- Airway inadequacy
- Reactive airway disease
- Gas trapping
- Gas exchange abnormalities

Clinically significant hypoxia is defined by:

- SpO_2 ≤90% in non-pregnant adults
- SpO_2 ≤92-95% in pregnant patients

Managing Hypoxia

- **Standard supplemental oxygen therapy – by nasal cannula -** Start immediately to patients with SARI (severe acute respiratory infection) and respiratory distress, hypoxemia, or shock.
- **Initiate oxygen therapy** at 6L/min low flow nasal cannula or with face mask with or without reservoir bag (flow rates of 10-15 L/min, which is typically the minimum flow required to maintain bag inflation; FiO_2 0.60-0.95)

Managing Hypoxia

High-flow nasal oxygen (HFNC)

- Use in pure hypoxic respiratory failure – aim for SpO_2 ≥94%
- Start flow at 20-30 L and FiO_2 50%
- If FiO_2 > 80%, may increase flow up to a maximum of 40 L
- Use an isolation mask on top of the HFNC
- Patient should be closely monitored
  - Increases in flow or FiO_2 should prompt immediate reassessment for intubation, especially if accompanied by an increase in respiratory rate

Managing Hypoxia

Non-invasive ventilation (NIV)

- Use in selected group of patients
- Don't transfer on NIV
- If used, all personnel in room must wear N95 masks
- Must have viral filter placed prior to expiratory limb
- Titrate EPAP to 8-10 cm H_2O
- Monitor every 2 hours
  - If FiO_2 needs or EPAP continue to increase, consider early initiation of mechanical ventilation

Bronchodilators

- In spontaneously breathing patients, **avoid nebulizing medication**
  - Increases risk of provider infection due to aerosolized particles
  - MDIs are preferred
- In mechanically ventilated patients, nebulizers are tolerated because the circuit is closed
  - If MDI is used, use 4 puffs with a spacer per dose

Mechanical Ventilation

Mechanical ventilation is to be implemented early in patients with COVID-19 pneumonia in respiratory failure

Positive pressure ventilation (PPV)

Most common mode is Volume Control

- Delivers a set volume with each breath
- Airway pressures will vary with respiratory mechanics and must be monitored to avoid further injury to the lungs

Goals Of Mechanical Ventilation

- Oxygenation - PaO_2 55-80 mmHg or oxygen saturation (SpO_2) 88-95% in ARDS in general
  - Improved outcomes in COVID-19 patients when SpO_2 is kept above 94%
- I:E ratio- Duration of inspiration ≤ duration of expiration as long as tolerated hemodynamically in patients with ARDS

Ventilator Parameters

- FiO_2- percent inspired oxygen
- RR- respiratory rate
- V_T- tidal volume
- PEEP- positive end-expiratory pressure

Minute ventilation = RR x V_T

Initiating Mechanical Ventilation

- Calculate predicted body weight (PBW) in kg
  - **Males** = 50 + 2.3 [height (inches) - 60]
  - **Females** = 45.5 + 2.3 [height (inches) -60]
- Select ventilator mode as volume control/assist control
- Set ventilator breath at V_T = 8 ml/kg PBW
- Set initial rate to approximate baseline minute ventilation (not > 35 breaths/min)
- If Pplat > 28-30, Reduce V_T by 1 ml/kg at intervals ≤ 2 hours until V_T = 6ml/kg PBW and Plat < 30

Initiating Mechanical Ventilation

- Start PEEP at 10 cm H_2O. Titrate PEEP/FiO_2 as guided by chart below
- If patient develops hypotension associated with increased PEEP do not continue to increase PEEP
- Initially, low PEEP strategies should be used. High PEEP may be used for patients who require increased support and have low lung compliance.

ARDSnet table

Lo	FiO2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	1.0
	PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18-24
Hi	FiO2	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0
	PEEP	12	14	14	16	16	16	18	20	20	20	20	22	22	22-24

Hemodynamic Effects of PPV

Decreased preload

- Mechanism - Positive alveolar pressure
  - → compression of the heart by the inflated lungs
  - → the intramural pressure of the heart cavities rises
  - → venous return decreases
  - → preload is reduced
  - → stroke volume decreases
  - → cardiac output and blood pressure may drop
- Treatment – fluid therapy
  - restore adequate venous return and preload
  - Over-resuscitation however should be avoided in this patient population
- Conditions sensitive to change in preload include

  hypovolemia, pericardial tamponade, Pulmonary embolism, pulmonary HTN, and severe air trapping like asthma and COPD

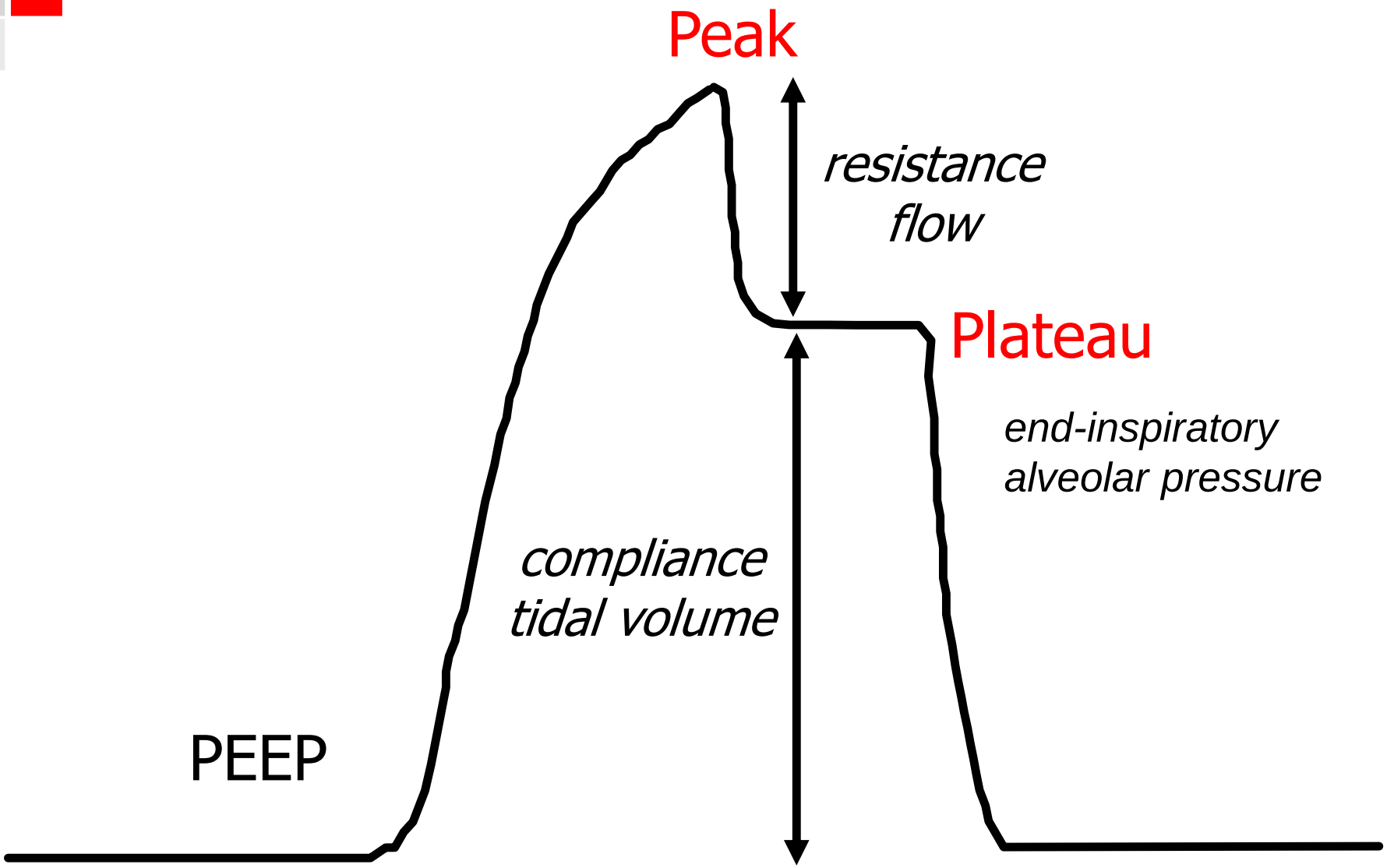
Hemodynamic Effects of PPV

Reduced afterload

- Lung expansion increases extramural pressure (which helps pump blood out of the thorax) and thereby reduces LV afterload
- When the cardiac performance is mainly determined by changes in afterload than in preload conditions (e.g., hypervolemic patient with systolic heart failure), PPV may be associated with an improved stroke volume. PPV is very helpful in patients with cardiogenic pulmonary edema, as it helps to reduce preload (lung congestion) and afterload. As a result stroke volume tends to increase.

Ventilator Airway Pressures

- Peak pressure
  - Maximal airway pressure any time during inspiration
  - Amount of pressure necessary to overcome airway resistance and expand the thoracic cage
- Plateau pressure
  - Amount of pressure necessary to overcome the elastic recoil of the lung and thoracic cage
  - Measured at the end of an Inspiratory Hold maneuver


Peak
resistance
flow
Plateau
end-inspiratory
alveolar pressure
compliance
tidal volume
PEEP

Goals Of Mechanical Ventilation

Plateau pressure goal: ≤ 30 cm H_2O

- Check P_{plat} (0.5 second inspiratory pause) at least q 4h and after each change in PEEP or tidal volume (V_T)
  - **If Pplat > 30 cm H_2O:** decrease V_T by 1ml/kg steps (minimum = 4 ml/kg)
  - **If Pplat < 25 cm H_2O and VT< 6 ml/kg**, increase V_T by 1 ml/kg until Pplat > 25 cm H_2O or V_T = 6 ml/kg.
  - **If Pplat < 30 and breath stacking or dyssynchrony occurs:** may increase V_T by 1ml/kg increments to 7 or 8 ml/kg if Pplat remains < 30 cm H_2O

Acid-Base Management

- Arterial blood gas
  - pH, PaO_2, $PaCO_2$, calculated bicarbonate level
- Comprehensive metabolic panel
  - measured bicarbonate level, anion gap

Baseline pH and CO_2 levels may be altered in patients with chronic conditions such as COPD and kidney disease. Adjustments to treatment goals may be necessary

Acid-Base Management

Respiratory acidosis

- pH<7.4, $PaCO_2$>40
- Treat by increasing minute ventilation (avoid increasing V_T if barotrauma is a concern)

Metabolic acidosis

- pH<7.4, $PaCO_2$<40
- Anion gap acidosis: consider elevated lactate from hypoperfusion or sepsis, ketoacidosis, etc.
- Non-anion gap acidosis: often from renal dysfunction
- Treat underlying condition

Acid-Base Management

Respiratory alkalosis

- pH>7.4, PaCO2<40
- Treat by decreasing minute ventilation

Metabolic alkalosis

- pH >7.4, $PaCO_2$>40
- Contraction alkalosis (hypovolemia)
  - Treat with intravascular volume resuscitation
- Loss of acid such as gastric suctioning

Acid-Base Management

pH goal: 7.30-7.45

Acidosis Management: (pH < 7.30)

- **If pH 7.15-7.30:** Increase RR until pH > 7.30 or $PaCO_2$ < 25 (Maximum set RR = 35)
- **If pH < 7.15:** Increase RR to 35.
- If pH remains < 7.15, V_T may be increased in 1 ml/kg steps until pH > 7.15 (Pplat target of 30 may be exceeded)

Alkalosis Management: (pH > 7.45) Decrease vent rate if possible

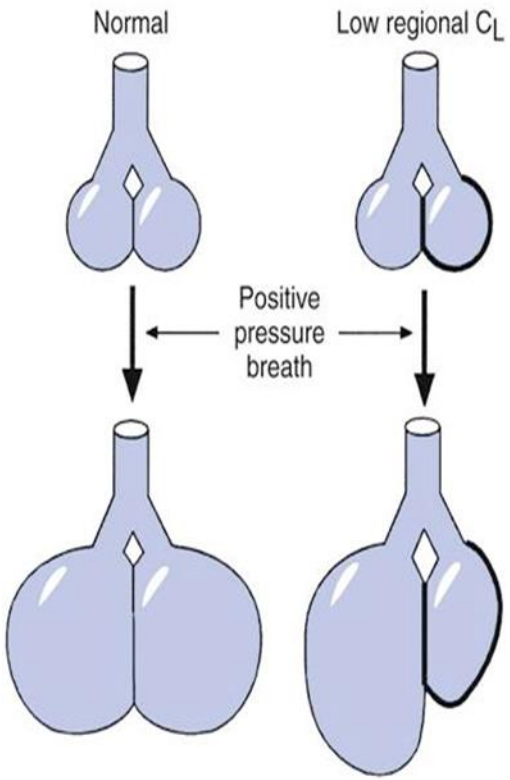
Berlin Definition of ARDS

- Timing: Within 1 week of a known clinical insult or new or worsening respiratory symptoms
- Chest imaging: Bilateral opacities not fully explained by effusions, lobar/lung collapse, or nodules
- Origin of edema: Respiratory failure not fully explained by cardiac failure or fluid overload. Need objective assessment (e.g., echocardiography) to exclude hydrostatic edema if no risk factor present
- Oxygenation
  - Mild 200 mmHg < PaO_2/FIO_2 ≤300 mmHg with PEEP or CPAP ≥5 cmH_2O
  - Moderate 100 mmHg < PaO_2/FIO_2 ≤200 mmHg with PEEP ≥5 cmH_2O
  - Severe PaO_2/FIO_2 ≤100 mmHg with PEEP ≥5 cmH_2O

Barotrauma

Inflammation and fluid accumulation may result in stiffening of alveoli and inability to expand. When this occurs, positive pressure is shunted away from these alveoli into healthy alveoli. This can result in over-distention and injury, known as barotrauma.

An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: Mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome



Avoid Barotrauma: lung-protective measures

- 4-8 ml/kg tidal volumes (ideal body weight based on height)
- Higher positive end-expiratory pressure (PEEP) in patients with moderate or severe ARDS
- Plateau pressures <30 cm H_2O

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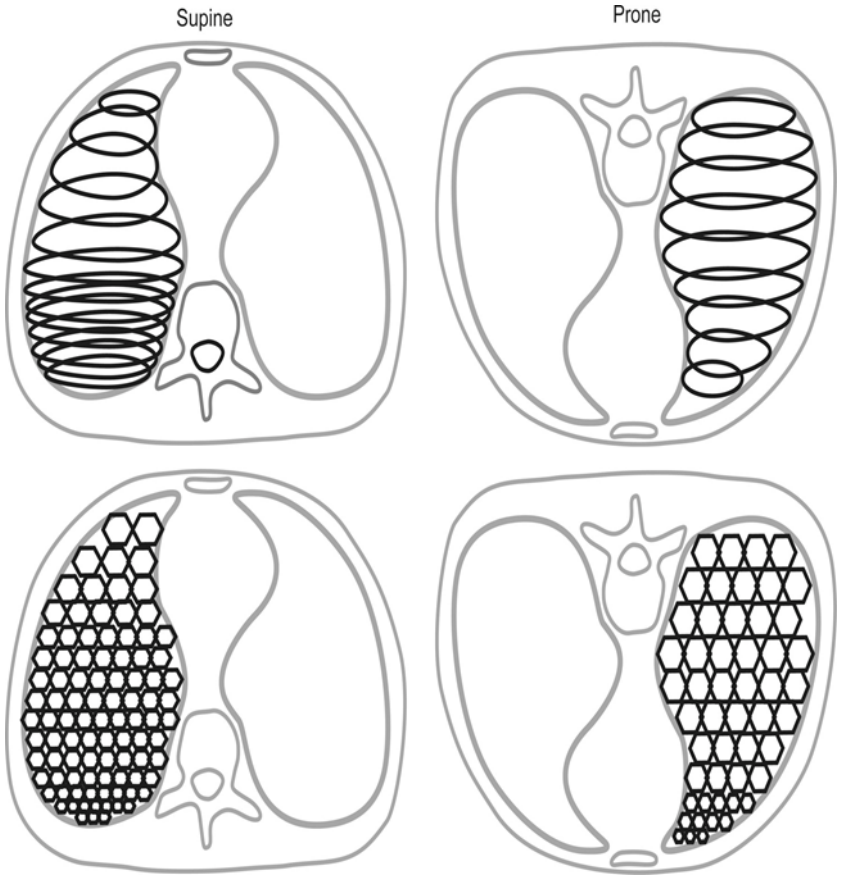
Rescue Therapy

For patients requiring FiO_2>70% with optimal PEEP

- Proning
- Recruitment maneuvers
- Airway Pressure Release Ventilation (APRV)
- Inhaled Epoprostenol
- ECMO

An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: Mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome



Proning

- Prone positioning for12-16 hours/day in severe ARDS in an option

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Proning- Contraindications

- Shock (eg. Mean arterial pressure < 65mg)
- Acute bleeding (eg. hemorrhagic shock, massive hemoptysis)
- Multiple fractures or trauma (eg. unstable fractures of femur, pelvis, face)
- Spinal instability
- Pregnancy
- Raised intracranial pressure > 30mmHg or cerebral perfusion pressure < 60 mmHg
- Tracheal surgery or sternotomy within two weeks

Proning- Relative Contraindications

- Recent DVT treated for < 2days
- Anterior chest tube(s) with air leaks
- Recent pacemaker
- Clinical conditions limiting life expectancy (eg. Oxygen or ventilator dependent respiratory failure)
- Severe burns
- Lung transplant recipient
- Prior use of rescue therapies

Proning- Immediate Interruption

- Inadvertent extubation
- ETT obstruction
- Hemoptysis
- SpO_2 < 85% or PaO_2 < 55 for more than 5 min
- Cardiac arrest
- HR < 30 for more than 1 minute
- SBP < 60 mm Hg for more than 5 minutes

Proning- Technique

Prepare patient

Have one sheet under patient

Enteral feedings off for 1 hour

Pad face and contact points

Lubricate eyes

Proning- Technique

Prepare patient

Account for all lines and catheters

Remove ventral EKG leads

Have emergency airway equipment on hand in case of unplanned extubation

Pre-oxygenate with 100% O_2

Sedate to RAS -4 to -5

Neuromuscular blockade after sedation

Proning- Technique

Proning

Place second sheet (remove wrinkles) over patient

Place 3 pillows over the chest, pelvis, and shins

Place third sheet over pillows

Roll all sheets toward the patient until the patient is tightly held between them

Proning- Technique

Proning

Account for all lines and catheters, avoid placing under tension

Disconnect ventilator

Slide patient away from ventilator

Roll patient toward ventilator

Proning- Technique

After Proning

Turn head to one side

Reconnect ventilator

Remove sheet on back (first sheet)

Place dorsal EKG leads

Monitor for hemodynamic instability and treat (may last up to 10 minutes after proning)

Proning- Technique

After Proning

Place patient in swimmer's pose

- Arm up on the side to which the head is turned
- Other arm at the patient's side
- Alternate head position every 2 hours

May place patient in reverse Trendelenburg position if hemodynamically stable

Reverse technique to place supine

Proning- Complications

- Nerve Compression (eg. Brachial plexus injury)
- Crush injury
- Venous stasis (eg. Facial edema)
- Dislodging endotracheal tube
- Diaphragm limitation
- Pressure sores (eg. facial)
- Dislodging vascular catheters or drainage tubes
- Retinal damage
- Transient reduction in arterial oxygen
- Vomiting
- Transient arrhythmias

Proning Non-Ventilated Patients

There may be a role for proning patients not on mechanical ventilation to improve oxygenation and possibly prevent intubation

Please check with your local institution for their protocol regarding non-invasive ventilation strategies

Recruitment Maneuvers

Ensure Cuff is well inflated and patient hemodynamically stable

Set PEEP according to ARDSnet table

Switch to CPAP at 35-40 cm H_2O for 20-40 seconds

Return to original settings and PEEP

- **STOP** if hypotension, arrhythmias or desaturation < 85% O_2
- ***Recruitability criteria*** -SpO_2 increase > 5% Or compliance increase > 10% O_2
- **Contraindications** - Obstructive lung disease (bullous disease, COPD, Asthma) - Unilateral disease - Pneumothorax - Hemodynamic instability - Increased intracranial pressure

Other Rescue Therapies

Consult your pulmonologist regarding the need for:

- Airway Pressure Release Ventilation (APRV)
- Inhaled Epoprostenol
- Extracorporeal Membrane Oxygenation (ECMO)

Hemodynamic Goals in COVID-19

- Goal is euvolemia – WHO and ARDSnet recommended FACTT Algorithm
- Attempt de-resuscitation within 24-48 hours of achieving stability
- Point of care ultrasound of IVC and cardiac output maybe utilized in selected patients
- Pharmacy to concentrate all IV medications
- Enteral fluids to be determined on case by case basis by intensivist

ICU Procedures

Aerosol generating procedures – Maximal Precautions

Intubation	Extubation
suctioning	Bronchoscopy
Hi flow O2	Procedures in agitated patients
NIV	Tracheostomy
CPR prior to intubation	

Shock

	Intravascular Volume Status	Cardiac Output	Systemic Vascular Resistance
Distributive	↓	↑	↓
Hypovolemic	↓	↑	↑
Cardiogenic		↓	↑
Neurogenic		↓	↓

CONFERENCE REPORTS AND EXPERT PANEL

Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016

Andrew Rhodes[1*], Laura E. Evans[2], Waleed Alhazzani[3], Mitchell M. Levy[4], Massimo Antonelli[5], Ricard Ferrer[6], Anand Kumar[7], Jonathan E. Sevransky[8], Charles L. Sprung[9], Mark E. Nunnally[2], Bram Rochwerg[3], Gordon D. Rubenfeld[10], Derek C. Angus[11], Djillali Annane[12], Richard J. Beale[13], Geoffrey J. Bellinghan[14], Gordon R. Bernard[15], Jean-Daniel Chiche[16], Craig Coopersmith[8], Daniel P. De Backer[17], Craig J. French[18], Seitaro Fujishima[19], Herwig Gerlach[20], Jorge Luis Hidalgo[21], Steven M. Hollenberg[22], Alan E. Jones[23], Dilip R. Karnad[24], Ruth M. Kleinpell[25], Younsuk Koh[26], Thiago Costa Lisboa[27], Flavia R. Machado[28], John J. Marini[29], John C. Marshall[30], John E. Mazuski[31], Lauralyn A. McIntyre[32], Anthony S. McLean[33], Sangeeta Mehta[34], Rui P. Moreno[35], John Myburgh[36], Paolo Navalesi[37], Osamu Nishida[38], Tiffany M. Osborn[31], Anders Perner[39], Colleen M. Plunkett[25], Marco Ranieri[40], Christa A. Schorr[22], Maureen A. Seckel[41], Christopher W. Seymour[42], Lisa Shieh[43], Khalid A. Shukri[44], Steven Q. Simpson[45], Mervyn Singer[46], B. Taylor Thompson[47], Sean R. Townsend[48], Thomas Van der Poll[49], Jean-Louis Vincent[50], W. Joost Wiersinga[49], Janice L. Zimmerman[51] and R. Phillip Dellinger[22]

2016 Sepsis Guidelines

- Obtain cultures before starting antibiotics
- Start broad-spectrum i.v. antibiotics within one hour
- Volume resuscitation with i.v. crystalloids > 30 mL/kg within the first 3 hours
- Colloid fluids may also be given if large amounts of crystalloids are being used

Treatment of Septic Shock

- Initial target MAP >65 mmHg in patients with septic shock requiring vasopressors
- Norepinephrine is the first choice vasopressor for septic shock
- Vasopressin or epinephrine may be added if necessary

Treatment of Septic Shock

- Hemodynamic/cardiac assessment may be necessary (echo, cardiac output monitoring) if clinical examination does not reveal the cause of the shock
- Hydrocortisone may be used as a supplement to pressors
- Lactate measurement can be used to guide extent of resuscitation with the goal of returning to normal lactate levels.

General Critical Care

- GI prophylaxis
  - H2 blocker
  - Proton pump inhibitor
- DVT prophylaxis
  - There have been reports of a prothrombotic state associated with COVID-19. Standard VTE prophylaxis may need to be adjusted for this. Consult your institutional protocols for your standard of care.
- Nutrition
- Glycemic control
  - Goal blood glucose levels 140-180 g/dL

You May As Well Get Credit For This

Neurosurgeons are certified by the American Board of Neurological Surgery to provide critical care for patients.

Critical Care Billing

Based on time spent delivering critical care

- Examining the patient
- Reviewing laboratory, imaging, and other data
- Communicating and carrying out care plan

99291- 30-75 minutes of critical care

99292- each additional 30 minutes of critical care

Critical Care Documentation

Consider organizing notes by organ systems

- Pulmonary
- Cardiovascular
- Neurologic
- Renal
- GI
- Fluids/Electrolytes/Nutrients
- Hematologic
- Endocrine
- Infectious Disease
- Prophylaxis
- Code Status

Critical Care Billing

Requires documentation of critical illness diagnosis:

"The patient is critically ill with…"

Common diagnoses may include:

- Acute respiratory failure (document hypoxia, hypercapnea, ARDS, etc.)
- Respiratory distress
- Pneumonia
- Sepsis
- Septic shock

Critical Care Billing

Requires attestation of time and involvement:

"I have seen and examined the patient. I have reviewed the relevant clinical, laboratory, and imaging data. I have spent (insert time) minutes providing critical care for this patient."

The End

Remember:

Follow your local protocols

Stay safe and healthy

Appendix 1: Vasoactive Drugs

ADULT PATIENTS ONLY

Dosing and Titration Recommendations for Vasoactive Agents

ALL titration endpoints need to be double-checked with the prescriber.

Drug (infusion rate)	Concentration (EMR available concentrations listed)	Starting Dose	Upper Dosing Range	Bidirectional Titration Frequency	Bidirectional Titration Dose	Titration Endpoint/Goal	Alaris Min/Max
Clevidipine (mg/hr)	25mg/50mL Premix (fat emulsion)	1-2 mg/hr	1-21 mg/hr	1.5 min -10 min	≤ 50% hourly dose	MAP or SBP	1-16 mg/hr Hard Max: 32
Diltiazem (mg/hr)	125mg/125mL D5W/NS 250mg/250mL D5W/NS	**Bolus$_1$**: 0.25 mg/kg (Avg. 20 mg) **Bolus$_2$**: 0.35 mg/kg (Avg. 25 mg) **Infusion**: 5 mg/hr	10-15 mg/hr	2-5 min	5 mg/hr	HR between 80 to 100 bpm	1-15 mg/hr Hard Max: 20
Dobutamine (mcg/kg/min)	1000mg/250mL D5W Premix	2.5-5 mcg/kg/min	20 mcg/kg/min	5-10 min	2.5 mcg/kg/min	CI ≥ 2.5 L/min/m^2 or MAP	0.5-20 mcg/kg/min Hard Max: 40
Dopamine [V] (mcg/kg/min)	400mg/250mL [P] D5W Premix 800mg/250mL [C] D5W/NS	5 mcg/kg/min	>20 mcg/kg/min not beneficial	2-5 min	0.5-2.5 mcg/kg/min	MAP between 60 and 70 mmHg	0.5-20 mcg/kg/min
Epinephrine [V] (mcg/kg/min)	4mg/250mL [C] D5W/NS 10mg/250mL [C] D5W/NS	0.01-0.05 mcg/kg/min	0.5-1 mcg/kg/min	1-5 min	0.01-0.05 mcg/kg/min	MAP between 60 and 70 mmHg	0.01-1 mcg/kg/min
	Peripheral administration: 4mg/250mL at a MAX rate of 0.2 mcg/kg/min for MAX of 8 hours						
Esmolol [V] (mcg/kg/min)	2500mg/250mL NS 2000mg/100mL NS (premixed)	**Bolus1**: 500 mcg/kg **Infusion:** 50 mcg/kg/min	200-300 mcg/kg/min	4 min	50 mcg/kg/min	HR between 80 to 100 bpm	50-300 mcg/kg/min
Isoproterenol (mcg/kg/min)	1mg/250mL D5W	0.01 mcg/kg/min	0.01-0.2 mcg/kg/min	1-2 min	0.01 mcg/kg/min	HR between 60 and 80	0.01-0.09 mcg/kg/min Hard Max: 0.2
Labetalol (mg/min)	300mg/300mL D5W/NS 500mg/100mL(undiluted)	**Bolus$_1$**: 10-20 mg **Infusion:** 0.5-2 mg/min (0.1 mg/min after 300 mg infused)	6-8 mg/min	5-15 min	0.5-1 mg/min	MAP or SBP	1-6 mg/min Hard Max: 8

Appendix 1: Vasoactive Drugs

ADULT PATIENTS ONLY

Drug (infusion rate)	Concentration (EMR available concentrations listed)	Starting Dose	Upper Dosing Range	Bidirectional Titration Frequency	Bidirectional Titration Dose	Titration Endpoint/Goal	Alaris Min/Max
Milrinone (mcg/kg/min)	20mg/100mL D5W Premix	0.1 (Heart Failure) - 0.375 mcg/kg/min	0.5-0.75 mcg/kg/min	2 hours	0.1 mcg/kg/min	CI ≥ 2.5 L/min/m² or MAP	0.15-0.75 mcg/kg/min Hard Max: 0.75
Nitroprusside (mcg/kg/min)	50mg/100mL NS Premix	0.25-0.5 mcg/kg/min	3-5 (Max 5mcg/kg/min for 10 min., if BP not controlled switch agents)	3-5 min	0.5 mcg/kg/min	MAP or SBP	0.1-3 mcg/kg/min Hard Max: 5
Norepinephrine [V] (mcg/kg/min)	8mg/250mL[C] 16mg/250mL[C] D5W/NS	0.01-0.05 mcg/kg/min	0.5-1 mcg/kg/min Add VP around 0.2; > 0.5 mcg/kg/min not recommended	1-5 min	0.01-0.05 mcg/kg/min	MAP between 60 and 70 mmHg	0.01-3 mcg/kg/min Hard Max: 3.3
	Peripheral administration: 8mg/250mL at a MAX rate of 0.2 mcg/kg/min for MAX of 8 hours						
Phenylephrine[V] (mcg/kg/min)	10mg/250mL[P] 80mg/250mL[C] D5W/NS	0.5-1 mcg/kg/min	2 mcg/kg/min (Standard conc.) 9 mcg/kg/min (High conc.)	1-5 min	0.5 mcg/kg/min	MAP between 60 and 70 mmHg	0.1-4 mcg/kg/min Hard max: 9.1
Vasopressin [V] (units/min)	20units/100mL[C] D5W/NS	0.03 units/min	0.03 units/min	Titration per provider request in certain patient populations		MAP between 60 and 70 mmHg	0.01-0.06 units/min Hard max: 0.1
	Peripheral administration: MAX rate of 0.03 units/min for MAX of 8 hours						
Nicardipine (mg/hr)	40mg/200mL[P] NS Premix	2.5-5 mg/hr	10-15 mg/hr	5-15 min	2.5-5 mg/hr	MAP or SBP	0.5-15 mg/hr
Nitroglycerin (mcg/min)	50mg/250mL D5W Use PVC Free tubing	5 mcg/min	200 mcg/min	3-5 min	5-10 mcg/min	MAP or SBP or chest pain relief	1-200 mcg/min

[V] = "vesicant", [P] = "peripheral line", [C] = "central line"

Appendix 2: Sedative Drugs

ADULT PATIENTS ONLY

Dosing and Titration Recommendations for Analgesia, Sedation and Paralysis

ALL titration endpoints need to be double-checked with the prescriber

Drug (infusion rate)	Concentration (EMR available concentrations listed)	Starting Dose	Upper Dosing Range	Bidirectional Titration Frequency	Bidirectional Titration Dose	Titration Endpoint/Goal	Alaris Min/Max
Fentanyl (mcg/hr) *use Sedation Algorithm	1000 mcg/100mL NS 2500 mcg/250mL NS	Bolus: 25-50 mcg Infusion: 25 mcg/hr	200-300 mcg/hr	30 min	25 mcg/hr	RASS of 0 to -2 and/or CPOT	10-300 mcg/hr+
Propofol (mcg/kg/min) *use Sedation Algorithm	1000 mg/100mL Premix (fat emulsion)	5 mcg/kg/min	50-100 mcg/kg/min	5 min	5 mcg/kg/min	RASS of 0 to -2	5-50 mcg/kg/min Hard max: 600
Midazolam (mg/hr) *use Sedation Algorithm	100 mg/100mL D5W/NS	Bolus: 2-4 mg Infusion: 2 mg/hr	15-20 mg/hr	30 min – 1hr	25%	RASS of 0 to -2	0.5-20 mg/hr+
Dexmedetomidine (mcg/kg/hr) *use Sedation Algorithm	400 mcg/100mL NS Premix	0.2 mcg/kg/hr	1-1.4 mcg/kg/hr	30 min	25%	RASS of 0 to -2	0.1-1.4 mcg/kg/hr Hard max: 2.5
Lorazepam (mg/hr) *use Sedation Algorithm	50 mg/50mL D5W	Bolus: 2-4 mg Infusion: 1 mg/hr	5-10 mg/hr	30 min – 1 hr	25%	RASS of 0 to -2	0.5-10 mg/hr
Ketamine¶ (mg/kg/hr) Doses vary highly based on indication	500mg/250 mL NS	Bolus: 0.1 mg/kg Infusion: 0.05 mg/kg/hr	1-2 mg/kg /hr	15 min	25%	RASS of 0 to -2	0.05-6 mg/kg/hr
Morphine (mg/hr) *End of Life ONLY, use Withdrawal of LST Algorithm or End of Life Ordersets	100 mg/100mL NS	Bolus: 2-4 mg Infusion: 2 mg/hr	20-30 mg/hr	15-30 min	1 mg/hr	RDOS < 3#	0.5-10 mg/hr
Cisatracurium (mcg/kg/min) *use Paralysis Algorithm	200 mg/100mL D5W/NS	Bolus: 0.1 mg/kg Infusion: 3 mcg/kg/min	7.5-10 mcg/kg/min	30 min- 1 hr	25%	TOF 2-3 out of 4	0.5-10 mcg/kg/min Hard max: 10
Rocuronium (mcg/kg/min) *use Paralysis Algorithm	1000/250mL D5W/NS	Bolus: 0.6 mg/kg Infusion: 8 mcg/kg/min	12 mcg/kg/min	30 min-1 hr	25%	TOF 2-3 out of 4	1-12 mcg/kg/min

+ = High concentration drips available for patients with high dose requirements, call local pharmacy for assistance

Respiratory Distress Observation Scale ¶Separate dosing regimens available for Chronic Pain and Status Epilepticus, Depression and Migraine.

Appendix 3: Surviving Sepsis Campaign: Guidelines for the Management of COVID-19

I. Infection Control

- For aerosol-generating procedures, use fitted respirator masks (N95 respirators, FFP2, or equivalent) (best practice).
- Perform aerosol-generating procedures in negative pressure room (best practice).
- For usual care for non-ventilated patients, use surgical/medical masks (weak recommendation).
- For non-aerosol-generating procedures on ventilated patients, use surgical/medical masks (weak recommendation).
- For intubation, use video-guided laryngoscopy over direct laryngoscopy (weak recommendation).
- Intubation should be performed by provider most experienced with airway management (best practice).

II. Laboratory Diagnosis and Specimens

- For intubated and mechanically ventilated adults:
  - Obtain lower respiratory tract over nasopharyngeal/oropharyngeal samples (weak recommendation).
  - Obtain endotracheal aspirates over bronchial wash/bronchoalveolar lavage samples (weak recommendation).

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III. Supportive Care

- Use dynamic parameters, skin temperature, capillary refilling time, and/or serum lactate over static parameters to assess fluid responsiveness (weak recommendation).
- Use conservative over liberal fluid strategy (weak recommendation).
- Use crystalloids over colloids (strong recommendation).
- Use buffered/balanced crystalloids over unbalanced crystalloids (weak recommendation).
- Do not use hydroxyethyl starches (strong recommendation).
- Do not use gelatins (weak recommendation).
- Do not use dextrans (weak recommendation).
- Do not routinely use albumin for initial resuscitation (weak recommendation).
- Use norepinephrine as first-line vasoactive agent (weak recommendation).
- If norepinephrine not available, use vasopressin or epinephrine (weak recommendation).
- Do not use dopamine if norepinephrine is available (strong recommendation).
- Add vasopressin as second-line agent if target MAP can't be achieved by norepinephrine alone (weak recommendation).
- Titrate vasoactive agents to target MAP of 60-65 mmHg (weak recommendation).
- For cardiac dysfunction and persistent hypoperfusion despite fluid resuscitation and norepinephrine, add dobutamine (weak recommendation).
- For refractory shock, use low-dose corticosteroid therapy (weak recommendation).
- Start supplemental O2 if SPO2 is < 92% (weak recommendation) and if SPO2 is < 90% (strong recommendation).

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- Maintain SPO2 no higher than 96% (strong recommendation).
- For acute hypoxemic respiratory failure despite conventional O2 therapy, use HFNC (weak recommendation).
- In acute hypoxemic respiratory failure, used HFNC over NIPPV (weak recommendation).
- If HFNC not available and no urgent indication for intubation, trial NIPPV with close monitoring (weak recommendation).
- No recommendation regarding use of helmet NIPPV compared with mask NIPPV.
- Recommend close monitoring for worsening of respiratory status (best practice).
- Use low tidal volume ventilation (Vt 4-8 mL/kg) (strong recommendation).
- Target plateau pressures (Pplat) of < 30 cm H2O (strong recommendation).
- For moderate to severe ARDS, use higher PEEP strategy (weak recommendation).
- For ARDS, use conservative fluid strategy (weak recommendation).
- For moderate to severe ARDS, use prone ventilation for 12 to 16 hours (weak recommendation).
- For moderate to severe ARDS:
  - Use intermittent boluses of neuromuscular blocking agents over continuous infusion (weak recommendation).
  - If persistent ventilator dyssynchrony, use continuous NMBA infusion for up to 48 hours (weak recommendation).
- Do not routinely use inhaled nitric oxide (strong recommendation).
- In severe ARDS and hypoxemia, trial inhaled pulmonary vasodilator; if no rapid improvement, treatment should be tapered off (weak recommendation).
- For hypoxemia despite optimizing ventilation, use recruitment maneuvers (weak recommendation).
- For recruitment, do not use staircase (incremental PEEP) recruitment maneuvers (strong recommendation).
- In refractory hypoxemia despite optimizing ventilation, rescue therapies, and proning, use venovenous ECMO (weak recommendation).

Appendix 3: Surviving Sepsis Campaign: Guidelines for the Management of COVID-19

IV. COVID-19 Therapy

- In respiratory failure (without ARDS), do not routinely use systemic corticosteroids (weak recommendation).
- In ARDS, use systemic corticosteroids (weak recommendation).
- In respiratory failure, use empiric antimicrobials/antibacterial agents (weak recommendation).
- For fever, use acetaminophen for temperature control (weak recommendation).
- Do not routinely use IVIG (weak recommendation).
- Do not routinely use convalescent plasma (weak recommendation).
- In critically ill adults:
  - Do not routinely use lopinavir/ritonavir (weak recommendation).
  - Insufficient evidence on the use of other antiviral agents.
- Insufficient evidence on the use of recombinant rIFNs.
- Insufficient evidence on the use of chloroquine or hydroxychloroquine.
- Insufficient evidence on the use of tocilizumab.