Just-In-Time Tools for Training Non-Critical Care Providers: Basics of Respiratory Failure

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Source of financial support: None

Disclosures:
The authors have no conflicts of interest, financial or otherwise, to report regarding the content of this manuscript and no involvement with organization(s) with financial interest in the subject matter. Each author contributed equally to the creation of his manuscript.

*P.A.K. is a Senior Deputy Editor of ATS Scholar. Her participation complies with American Thoracic Society requirements for recusal from review and decisions for authored works.

ATS-SCHOLAR Articles in Press. Published April 14, 2020 as 10.34197/ats-scholar.2020-0039IN

There is a limited number of critical care providers in the United States with nearly half of US hospitals operating without one dedicated intensivist.[1] During a pandemic, such as the outbreak of SARS-CoV-2, even well-staffed hospitals can be exhausted of both physical and human resources.[2] One potential response to this problem is redeployment of non-critical care providers to increase the supply of available clinicians. To support efforts to increase capacity as part of surge preparation for the COVID-19 outbreak in Seattle, Washington, the University of Washington School of Medicine's Division of Pulmonary, Critical Care and Sleep Medicine created an online educational resource for non-intensivist providers to learn basic critical care content. Among those materials, we created a series of one-page learning guides for the management of common problems encountered in the intensive care unit (ICU). These guides were meant to be used as just-in-time tools to guide problem-solving during the provision of ICU care.

The recommendations in each one-page document were designed with several assumptions that may not be universally true at all institutions. Many of the frameworks presented here assume availability of the technology and resources present in a modern ICU and rely heavily on the presence of a multidisciplinary team including a critical care nurse, respiratory therapist and pharmacist. The guides also assume that a critical care "consultant" is available (in person or virtually) whenever care must deviate from the included schema or the complexity of a problem is beyond the scope of these basic algorithms. Because many providers who may be called to help in the ICU will lack training in specific procedures, interpretation of hemodynamic data, or point-of-care ultrasonography (POCUS), these aids intentionally deemphasize these skills. Despite these assumptions, these guides were drafted to be appropriately broad, such that a non-critical care trained provider can perform core critical care tasks.

This set of documents addresses the initial management of hypoxemia, spanning issues that arise both before and after intubation is required. We also focus on choosing initial ventilator settings for the newly intubated patient, blood gas analysis, and liberation from mechanical ventilation. Volume control ventilation is assumed in these guides as the primary mode due the fact that is our local institutional practice. Additionally, local sedation practices lean heavily towards a guideline-concordant analgesia-first regimen[3] with as-needed fentanyl and reserving propofol as the first-line agent when continuous sedative infusion is required.

The approaches in this section are meant to provide a general framework for the initial management of hypoxemic patients including those on mechanical ventilation. These recommendations are based upon guidelines[4,5] and on the usual practice of the contributing authors. We acknowledge that different critical care providers may have their own practices which vary from those presented below. Each patient is unique and more nuanced management may be necessary than can be provided in a one-page document. We designed the content to be simple, streamlined, and easy to use at the bedside by providers with varying levels of experience. Throughout these documents we use the phrase "**Call for Help!**" to designate times when management has progressed beyond the basics and the reader should consult with a critical care provider. These materials are not meant to replace or supersede local policies or practices and should not be used in place of critical care specialists when available.

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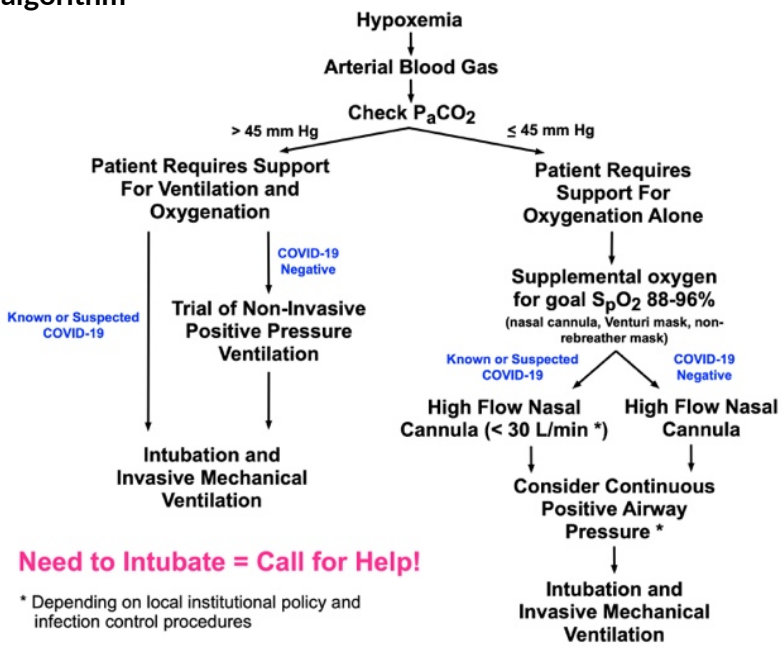
My Non-Intubated Patient Is Hypoxemic… Now What Do I Do?

1) **Ensure the pulse oximeter is providing accurate oxygen saturation (S_pO_2) data**
   Bad pulse oximetry waveforms suggest erroneous data. If unable to rectify the problem, check an arterial blood gas to measure the arterial partial pressure of oxygen (P_aO_2).

2) **Obtain the following studies upon initial presentation**

   - Plain chest radiograph
   - Arterial blood gas
   - Basic laboratory studies (WBC count, B-type natriuretic peptide)
   - Electrocardiogram (if indicated)

3) **Initial management algorithm**



Note: The decision to intubate is never based on specific S_pO_2 or P_aO_2 threshold and, instead must take into account an assessment of the entire clinical picture including the patient's work of breathing, mental status and hemodynamic stability.

4) **Initiate disease/problem specific interventions**

Problem	Intervention
Heart failure and/or volume overload	Diuresis
Large pleural effusions	Diuresis, consider thoracentesis
Pneumonia	Antibiotics
Lobar or whole lung collapse	Chest physiotherapy
COPD / Asthma exacerbation	Corticosteroids, inhaled bronchodilators
Suspected pulmonary embolism	Consider CT pulmonary angiogram *, lower extremity duplex, empiric anticoagulation **

* For known or suspected COVID-19 patients, discuss the risk/benefits of traveling for CT scan
** If not contraindicated

5) **What is the target S_pO_2 and P_aO_2?**

   - S_pO_2: 88-96%
   - P_aO_2: 60-90 mm Hg

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My Patient Just Got Intubated… Now What Do I Do?

1) Choose Your Ventilator Settings

Mode: Volume assist control

Tidal Volume: 8 ml/kg of ideal body weight

Rate: Based on an assessment of the patient's minute ventilation needs. This can be done based on an assessment of the patient's bicarbonate:

Bicarbonate (mEq/L)	Target Minute Ventilation (L/min)
22-26	6-8
16-20	10-12
< 12	15-20

F_IO_2: 1.0

PEEP: 5 cm H_2O

2) Place Orogastric Tube

This is for enteral access for medications. Tube feeds can be held at this stage and should not be immediately started in patients on escalating doses of vasopressors.

3) Choose Your Sedation and Pain Management Plan

Sedative: Propofol infusion. Titrate for Richmond Agitation Sedation Score (RASS) score of 0-1. Further information on RASS can be found at: https://doi.org/10.1164/rccm.2107138

Pain Control: Start with fentanyl boluses (25-100 µg q 30 min prn); Change to infusion if insufficient.

4) Check a Chest Radiograph to Confirm Position of Endotracheal and Orogastric Tube

5) Obtain a Blood Gas in 15-30 minutes

- Check the acid-base status: Adjust ventilator rate accordingly with the goal of achieving a pH relatively close to normal (7.35-7.45). This can be difficult to achieve with a severe primary metabolic acidosis. Further details on how to adjust the ventilator rate is provided in the information sheet "I Just Got The Blood Gas Results… Now What Do I Do?"

- Check the P_aO_2: If the P_aO_2 > 100 mm Hg, decrease the F_IO_2 to target S_pO_2 > 88%. Further changes in PEEP and F_IO_2 can be made by monitoring S_pO_2 rather than checking repeat blood gases. For patients with ARDS, follow the PEEP/ F_IO_2 ladder (http://www.ardsnet.org/files/ventilator_protocol_2008-07.pdf).

- To avoid oxygen toxicity, do not allow the S_pO_2 to remain at 100%.

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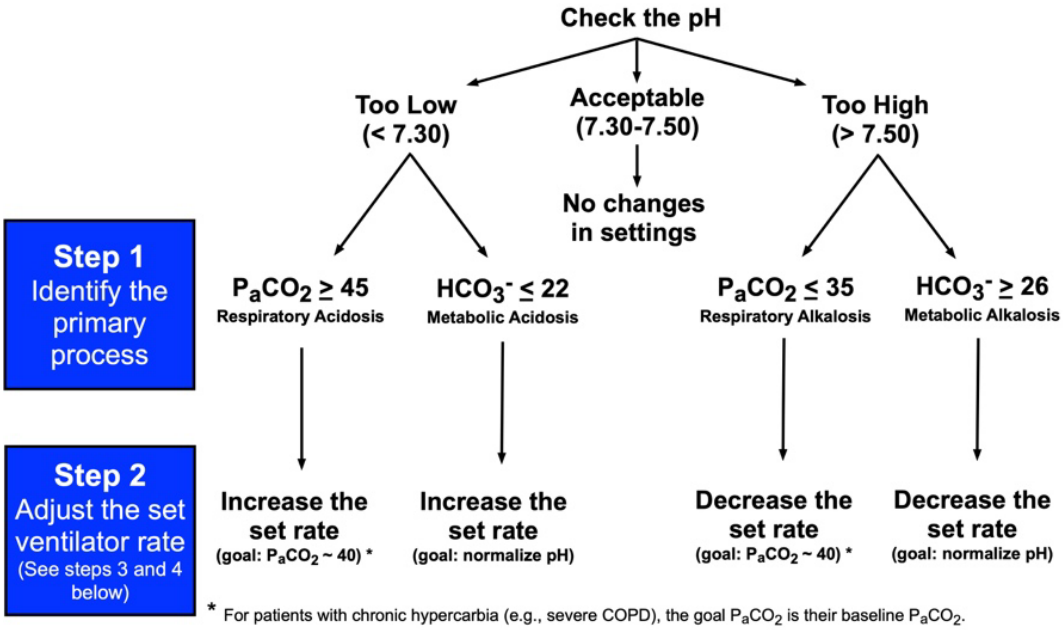
I Just Received Blood Gas Results On My Ventilated Patient… Now What Do I Do?

1) Assess oxygenation (this cannot be done with a venous blood gas)

- P_aO_2 < 60: Increase F_IO_2 and/or increase PEEP
- P_aO_2 > 100: Decrease F_IO_2 until S_pO_2 90-96%

2) Assess and address the acid-base status



3) Adjustments in the ventilator rate
A simple rule of thumb can be used to determine the proper change in the respiratory rate:

$$New\ rate = Current\ rate\ x\ \frac{Current\ P_aCO_2}{Target\ P_aCO_2}$$

Call for Help if desired rate is > 35

Monitor for signs of auto-PEEP with increases in respiratory rate (review with the respiratory therapist)

4) In What Situations Will I Have Trouble Achieving The Goal pH or P_aCO_2
There are several situations in which it can be difficult to achieve the goal P_aCO_2 or pH

- Severe ARDS: in patients with a high dead-space fraction, it can be hard to normalize P_aCO_2 and pH despite a high minute ventilation (Most patients can tolerate a pH down to 7.15 in these situations). **Call for Help!**
- Severe metabolic acidosis: despite significant decreases in P_aCO_2, the pH may remain low. **Call for a Help!**
- Overbreathing the ventilator: decreases in the set respiratory rate will not achieve a change in minute ventilation. The patient will continue to over-breathe the ventilator

5) How Long Before I Need to Get Another Arterial Blood Gas

- After changes in F_IO_2 or PEEP: repeat ABG is not necessary. Follow S_pO_2
- After changes in the set rate: wait 15-30 minutes before the repeat ABG

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My Intubated Patient Is More Hypoxemic... Now What Do I Do?

1) **Check equipment, consider calling the respiratory therapist for help**
   Ensure the following:

   - Patient remains connected to the ventilator circuit and circuit is intact
   - No inadvertent changes F_IO_2, PEEP or other settings
   - Endotracheal tube is patent and remains in correct position
   - No pressure alarms: If the alarm is sounding, consult the respiratory therapist

2) **Examine the patient and evaluate their interaction with the ventilator**

   - Listen for bilateral breath sounds. If breath sounds are asymmetric, consider pneumothorax or lung collapse and evaluate accordingly

   - If patient is agitated and having repeated peak pressure alarms, administer intravenous fentanyl bolus and consider increasing propofol

3) **Obtain diagnostic studies**
   Arterial Blood Gas (venous blood gases cannot be used to assess oxygenation)
   Chest radiograph

4) **Adjust the ventilator to improve oxygenation**
   The two parameters on the ventilator that address oxygenation are F_IO_2 and PEEP

   - Increase F_IO_2
   - If this does not resolve the situation, increase PEEP by 5 cm H_2O

     - Expect a slow rise in oxygen saturation with increased PEEP
     - May cause paradoxical worsening of oxygenation → return to previous PEEP
     - May cause hypotension → return to previous PEEP

   - **Call for Help** if these maneuvers do not resolve the situation. Discuss other strategies with your critical care consultant

5) **Treat reversible causes of hypoxemia if present**

   - Suction the patient to clear any mucus in the endotracheal tube or central airways
   - If chest radiograph reveals lobar or whole lung collapse, start chest physiotherapy
   - If worsening edema pattern on chest radiograph, consider diuresis or new diagnosis of ARDS (see ARDS sheet)

6) **Optimize other factors that affect oxygen delivery**

   - Check hemoglobin (Hgb) and transfuse red blood cells if [Hgb] <7 g/dL
   - Check $S_{CV}O_2$ and call for help if < 60%
   - Review medications for those that can cause pulmonary vasodilation (e.g., calcium channel blockers) as this may worsen ventilation-perfusion matching

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My Patient May Be Ready to Come Off the Ventilator… Now What Do I Do?

1) **Assess Readiness for a Spontaneous Breathing Trial**

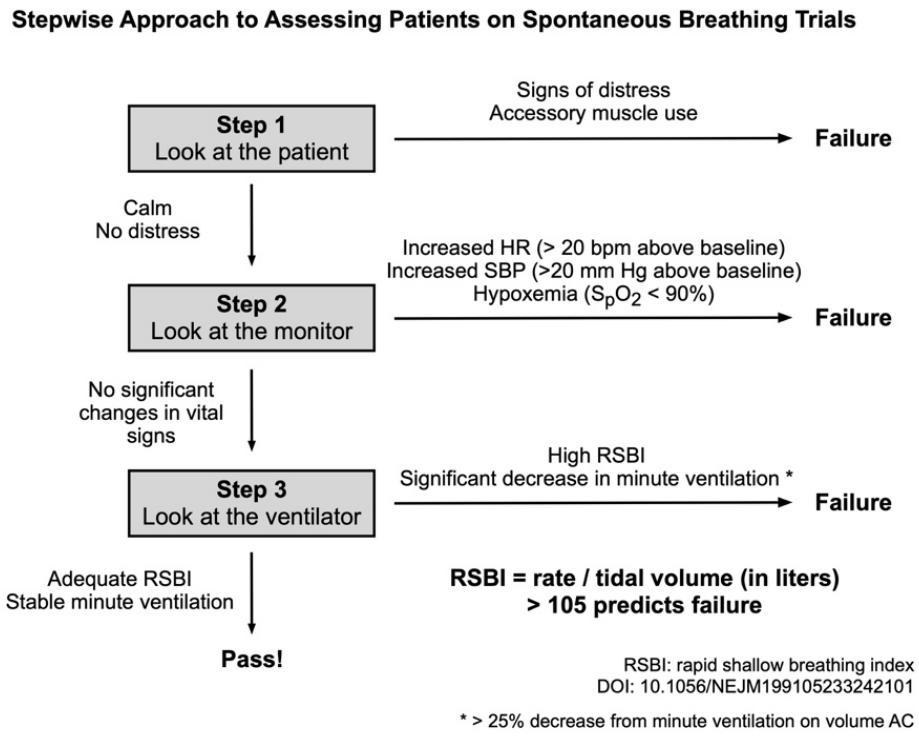
   Is the primary problem getting better?
   Are they requiring an $F_IO_2 \leq 0.4$ and a PEEP $\leq$ 8 cm H_2O?
   Is the minute ventilation $\leq$ 15 L/min?

   If the answer to all questions is "Yes," proceed to the next step. If the answer is "No," continue volume assist control

2) **Lighten Sedation (often referred to as Spontaneous Awakening Trial, SAT)**
   Turn propofol off. Some patients may require a low-dose of propofol due to anxiety around the time of the spontaneous breathing trial

3) **Start Spontaneous Breathing Trial (SBT)**
   Place the patient on Pressure Support of 5 cm H_2O with a PEEP of 5 cm H_2O for 30 minutes (local practice may vary regarding SBT ventilator settings)

4) **Assess the Spontaneous Breathing Trial**



5) **Assess Mental Status and Ability to Protect Airway**

   Normal mental status: Extubate patient

   Altered mental status: Extubate patient if they have both of the following:

   - A good cough
   - No-to-minimal airway secretions

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References

1. Halpern NA, Tan KS, DeWitt M, Pastores SM. Intensivists in U.S. Acute Care Hospitals. *Crit Care Med*. 2019;47(4):517-525. doi:10.1097/CCM.0000000000003615
2. Munster VJ, Koopmans M, van Doremalen N, van Riel D, de Wit E. A Novel Coronavirus Emerging in China — Key Questions for Impact Assessment. *N Engl J Med*. 2020;382(8):692-694. doi:10.1056/NEJMp2000929
3. Devlin JW, Skrobik Y, Gélinas C, Needham, DM. Slooter AJC, Pandharipande P et al. Clinical Practice Guidelines for the Prevention and Management of Pain, Agitation/Sedation, Delirium, Immobility, and Sleep Disruption in Adult Patients in the ICU. *Crit Care Med*. 2018;46(9):e825-e873. doi:10.1097/CCM.0000000000003299
4. Ouellette DR, Patel S, Girard TD, Morris, PE, Schmidt, GA, Truwit JD et al. Liberation From Mechanical Ventilation in Critically Ill Adults: An Official American College of Chest Physicians/American Thoracic Society Clinical Practice Guideline: Inspiratory Pressure Augmentation During Spontaneous Breathing Trials, Protocols Minimizing Sedation, and Noninvasive Ventilation Immediately After Extubation. *Chest*. 2017;151(1):166-180. doi:10.1016/j.chest.2016.10.036
5. Schmidt GA, Girard TD, Kress JP, Morris PE, Ouellette DR, Alhazzani W et al. Official executive summary of an American Thoracic Society/American College of Chest Physicians clinical practice guideline: Liberation from mechanical ventilation in critically ill adults. *Am J Respir Crit Care Med*. 2017;195(1):115-119. doi:10.1164/rccm.201610-2076ST

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