COI

None to disclose
Definition and characteristics of respiratory failure

Common causes of hypoxemic and hypercapnic respiratory failure and workup
- Acute Hypoxemic Respiratory Failure
- Chronic Hypoxemic Respiratory Failure
- Acute Hypercapnic Respiratory Failure
- Chronic Hypercapnic Respiratory Failure

Management
- HiFlow nasal cannula and Noninvasive Positive Pressure Ventilation in the acute setting
- Long-term oxygen therapy
- Long-term noninvasive ventilation

Take Home Points
J. C.

80 yo male with COPD, HFrEF (EF 40%), paroxysmal atrial fibrillation admitted with chest pain and shortness of breath x 4 days
J. C.

VS: BP 93/69 | Pulse 109 | Temp 36.1 °C (97 °F) | Resp 26 | SpO2 91% on 5L

Exam:
Alert and Oriented x3, diaphoretic, able to speak in complete sentences
rapid rate, irregularly irregular rhythm
diffuse wheezing
2+ pitting edema but extremities are well perfused
IS J.C. IN RESPIRATORY FAILURE?
RESPIRATORY FAILURE IS DEFINED BY:

An inability of the body to carry out one or both of the primary respiratory processes: oxygenation and ventilation

Hypoxemic Respiratory Failure, Hypercapnic respiratory failure, Mixed respiratory failure
Respiratory failure

Lung failure

Gas exchange failure manifested by hypoxaemia

Pump failure

Ventilatory failure manifested by hypercapnia
SIGNS OF ACUTE RESPIRATORY FAILURE

Clinical Assessment:
DiapHRaGM
- diaphoresis, hypoxia, respiratory rate, gasping, and accessory muscle contraction
Altered mental status
Asterixis
Cyanosis

Laboratory Assessment:
Arterial Blood Gas (PaO2 <60, PCO2>45)

J. C.

Given duoneb treatment and IV Lasix
EKG and CXR are ordered
Arterial Blood Gas: 7.37/50/56/28
ACUTE HYPOXEMIC RESPIRATORY FAILURE
SIX MECHANISMS OF HYPOXEMIA (PAO2 <60)

1. Decreased inhaled O2 (ie. high altitude)
2. Hypoventilation (ie. CNS depression)
3. V/Q mismatch (ie. emphysema)
4. Shunt (ie. PFO, ARDS, HPS)
5. Diffusion Limitation (ie. IPF)
6. Decreased ScVO2 (ie. low cardiac output)

Adapted from ATS Review for the Crit Care Boards
COMMON CAUSES OF ACUTE HYPOXEMIC RESPIRATORY FAILURE

Cardiac dysfunction
Pneumonia
ARDS
Pulmonary embolism
Obstructive Lung Disease
Pneumothorax
Hemothorax
Pulmonary Contusion
WORKUP FOR HYPOXEMIA

Arterial blood gas

Chest imaging

Echocardiogram with bubble study

Pulmonary Function Testing (include DLCO)
PITFALLS OF THE ARTERIAL BLOOD GAS IN THE HYPOXIC PATIENT

PaO2 is good indicator of how the lungs are working but SpO2 tells us about oxygen delivery

A−a gradient is useless if not performed on room air

ABGs could delay clinical decision–making

PaO2 can vary up to 9mmHg between ABGs

Mallat, J et al. Medicine (Baltimore) 2015 Jan;94(3)
EKG shows atrial fibrillation with RVR, HR in the 1 teens
CXR shows hyperinflation and bilateral non-specific interstitial changes
He remains on 5L NC with an SpO2 of 91%, RR 30. Now with some retractions
Given methylprednisolone 60mg x 1

How do we manage his respiratory failure?
CONVENTIONAL OXYGEN THERAPY

Capable of providing flows of 1–15L

Increase by 1L = increase by 3–4% on SpO2

Rates may be lower than inspiratory rate of patient

Oxygen is diluted because room air is entrained by patient
HIGH FLOW NASAL CANNULA

Set flow rate and FIO2

Capable of providing flow rates of 60L decreasing the risk of oxygen dilution

Humidifies secretions which can help with removal

Reduces nasopharyngeal resistance to decrease work of breathing

Washes out upper airway dead space

PEEP Effect
NONINVASIVE POSITIVE PRESSURE VENTILATION

CPAP
- Fixed positive pressure throughout the respiratory cycle
- Set PEEP and FIO2
- Patient effort determines tidal volume
- Effective for oxygenation
- Can increase pressure up 20cm H2O

Bilevel
- Different levels of pressure during inspiration and expiration
- Set IPAP (Inspiratory positive airway pressure), EPAP (expiratory positive pressure), FIO2
- S/T mode (spontaneous breaths with a backup rate). All breaths are supported
- IPAP–EPAP determines tidal volume
- EPAP determines oxygenation
- Effective for ventilation
NONINVASIVE POSITIVE PRESSURE VENTILATION: INDICATIONS

COPD exacerbation (reduces mortality and intubation rate)

Cardiogenic Pulmonary Edema (reduces intubation rate and improves dyspnea)

Obesity Hypoventilation Syndrome (reduces intubation rate)

Immunocompromised patients with bilateral infiltrates (mixed evidence)

NONINVASIVE POSITIVE PRESSURE VENTILATION: CONTRAINDICATIONS

- Cardiopulmonary arrest
- Hemodynamic instability
- Overt respiratory distress
- High aspiration risk
- GCS <10
- Facial trauma/deformity
- Severe upper GIB
- Anticipated prolonged ventilator need
High-Flow Oxygen through Nasal Cannula in Acute Hypoxemic Respiratory Failure

Jean-Pierre Frat, M.D., Arnaud W. Thille, M.D., Ph.D., Alain Mercat, M.D., Ph.D., Christophe Girault, M.D., Ph.D., Stéphanie Ragot, Pharm.D., Ph.D., Sébastien Perbet, M.D., Gwénaël Prat, M.D., Thierry Boulain, M.D., Elise Morawiec, M.D., Alice Cottereau, M.D., Jérôme Devaquet, M.D., Saad Nseir, M.D., Ph.D., Keyvan Razazi, M.D., Jean-Paul Mira, M.D., Ph.D., Laurent Argaud, M.D., Ph.D., Jean-Charles Chakarian, M.D., Jean-Damien Ricard, M.D., Ph.D., Xavier Witteboile, M.D., Stéphanie Chevalier, M.D., Alexandre Herblard, M.D., Muriel Fartoukh, M.D., Ph.D., Jean-Michel Constantin, M.D., Ph.D., Jean-Marie Tonnelier, M.D., Marc Pierrot, M.D., Armelle Mathonnet, M.D., Gaétan Béduneau, M.D., Céline Delétage-Métreau, Ph.D., Jean-Christophe M. Richard, M.D., Ph.D., Laurent Brochard, M.D., and René Robert, M.D., Ph.D., for the FLORALI Study Group and the REVA Network*
B  Patients with a PaO$_2$:FiO$_2$ $\leq$ 200 mm Hg

![Graph showing cumulative incidence of intubation over days since enrollment for patients with PaO$_2$:FiO$_2$ $\leq$ 200 mm Hg. The graph compares noninvasive ventilation, standard oxygen, and high-flow oxygen. The P-value is 0.009 by log-rank test.]

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<th>Days since Enrollment</th>
<th>High-flow oxygen</th>
<th>Standard oxygen</th>
<th>Noninvasive ventilation</th>
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Placed on HFNC 50%/40L
30 min later he continues to have increased WOB and worsening mental status
Rapid response is called and the RT draws another Arterial Blood Gas: 7.16/65/59/28
Transferred to ICU, gets intubated
ACUTE HYPERCAPNIC RESPIRATORY FAILURE
COMMON CAUSES OF ACUTE HYPERCAPNIC RESPIRATORY FAILURE

CNS Depression

Neuromuscular weakness

Mechanical load on respiratory system (i.e. airway resistance, anasarca, ascites, pleural disease, obesity)

Increased dead space (i.e. Obstructive lung disease, PE, Fibrotic lung disease)
WORK UP OF HYPERCAPNIA

Electrolyte panel to look for hyperkalemia or hypophosphatemia

CK level

Pulmonary function testing (FVC, Maximal Inspiratory Pressure, Maximal Expiratory Pressure)

Thyroid studies
BILEVEL TIPS AND TRICKS

Ensure that you have an adequate mask seal

If hypercapnia is the main issue, must optimize tidal volume (7–8cc/kg). Can titrate IPAP up to max of 20

If hypoxemia is the main issue, increase EPAP

Maintain at least 3mmHg difference between IPAP and EPAP

The lower the pH the more likely they will fail NIV
Extubated to stable condition
Transferred back to the RNF on 2L NC with BiPAP at night
Desaturation testing shows that he requires 2L at rest and 4L with exertion
CHRONIC HYPOXEMIC RESPIRATORY FAILURE
COMMON CAUSES OF CHRONIC HYPOXEMIC RESPIRATORY FAILURE

Parenchymal Disease
Obesity Hypoventilation Syndrome
Obstructive Sleep Apnea
Chronic CHF
CNS/Neuromuscular disease (ie. ALS)
Musculoskeletal disorders
LONG-TERM OXYGEN THERAPY

Supplemental O2 reduces mortality in COPD with severe resting hypoxemia (SpO2 <89%)

Recent evidence suggests in COPD, supplemental O2 for moderate exercise desaturation (SpO2 >80% and <90% on 6MWT) has no effect on mortality or time to first hospitalization

Supplemental O2 can improve exercise capacity, dyspnea, cognitive function, frequency of hospitalizations

Nocturnal Oxygen Therapy Trial Group, Ann Intern Med. 1980;93(3):391
Long-term Oxygen Treatment Trial Research Group, NEJM 2016
CHRONIC HYPERCAPNIC RESPIRATORY FAILURE
COMMON CAUSES OF CHRONIC HYPERCAPNIC RESPIRATORY FAILURE

COPD
Obesity Hypoventilation Syndrome
Chronic CHF
CNS/Neuromuscular Disease (ie. ALS, Multiple Sclerosis)
Musculoskeletal Disorders
NIPPV FOR CHRONIC HYPERCAPNIC RESPIRATORY FAILURE

Nocturnal NIPPV may improve daytime dyspnea, hypersomnience, PaCO2 levels exacerbations, and readmissions in COPD

Nocturnal NIPPV slows down progression of respiratory failure and improves survival in ALS
LONG-TERM NON-INVASIVE VENTILATION IN CHRONIC STABLE HYPERCAPNIC COPD - ATS 2020 GUIDELINES

1. Suggest NIV in patients with chronic stable hypercapnic COPD (moderate certainty)

2. Suggest screening for OSA prior to long-term NIV initiation (very low certainty)

3. Suggest not initiating long-term NIV during an admission for acute-on-chronic hypercapnic respiratory failure, favoring reassessment for NIV at 2–4 wks after resolution (low certainty)

4. Suggest not using an in-laboratory PSG to titrate NIV in patients with chronic stable hypercapnic COPD who are initiating NIV (very low certainty)

5. Suggest NIV with targeted normalization of PaCO2 (low certainty)

MEDICARE REQUIREMENTS TO QUALIFY FOR A RESPIRATORY ASSIST DEVICE

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<th>Condition</th>
<th>Requirements</th>
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<td>Noninvasive positive pressure ventilation (NIPPV) without backup rate:</td>
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</table>
Paco₂ ≥ 52 mm Hg and O₂ saturation ≤ 88% for ≥ 5 minutes (> 2 hours of recording on ambulatory nocturnal sleep oximetry) while on the higher of 2 L per minute of O₂ or prescribed FIO₂ and Obstructive sleep apnea and CPAP treatment have been considered and ruled out by facility-based nocturnal polysomnography |
| NIPPV with backup rate, any time after use without backup rate: | 
Paco₂ ≥ 7 mm Hg greater than the original qualifying result and O₂ saturation ≤ 88% for ≥ 5 minutes (> 2 hours of recording on facility-based nocturnal polysomnography) while on NIPPV without backup rate and apnea-hypopnea index < 5 and An FEV₁/FVC ratio < 70% or FEV₁ < 50% |
| NIPPV with backup rate, no sooner than 61 days after use without backup rate: | 
Paco₂ still ≥ 52 mm Hg and O₂ saturation ≤ 88% for ≥ 5 minutes (> 2 hours of recording on ambulatory nocturnal sleep oximetry) while on the higher of 2 liters per minute of O₂ or prescribed FIO₂ |
| Continuous positive airway pressure: | 
Apnea-hypopnea index/respiratory disturbance index ≥ 15 (minimum 30 events) or Apnea-hypopnea index/respiratory disturbance index 5–14 with symptoms or cardiovascular risks and NIPPV without backup rate: Above criteria and CPAP proven ineffective on polysomnography or at home |

HFNC should be #1 in pure acute hypoxemic respiratory failure (non-cardiogenic)

The ABG is not as helpful as we think for acute hypoxemic respiratory failure

For patients on NIPPV, frequent reassessment is key. Utilize your RTs

Nocturnal NIV is beneficial for hypercapnic COPD and neuromuscular patients