RESPIRATORY FAILURE BASICS

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COI

None to disclose

OUTLINE

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

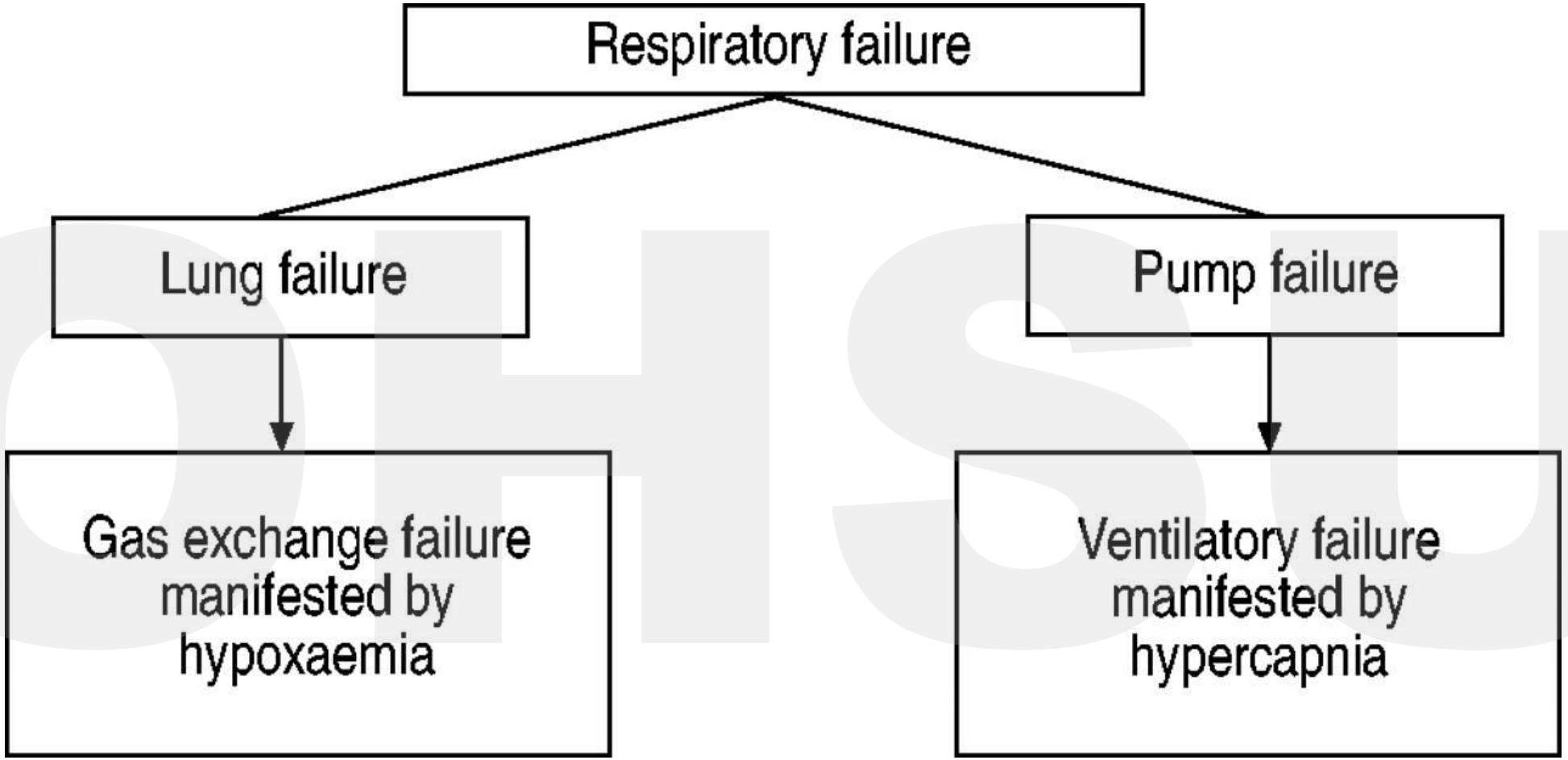
2+ pitting edema but extremities are well

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



C. Roussos, and A. Koutsoukou Eur Respir J 2003;22:3s-14s

SIGNS OF ACUTE RESPIRATORY FAILURE

Clinical Assessment:

DiapHRaGM

- **d**iaphoresis, **h**ypoxia, **r**espiratory rate, **g**asping, and **a**ccessory muscle contraction

Altered mental status

Asterixis

Cyanosis

Laboratory Assessment:

Arterial Blood Gas ($PaO_2 < 60$, $PCO_2 > 45$)

Tulaimat, A et al. PLoS One, 2017 Jul 3;1

J.C.

Given duoneb treatment and IV Lasix

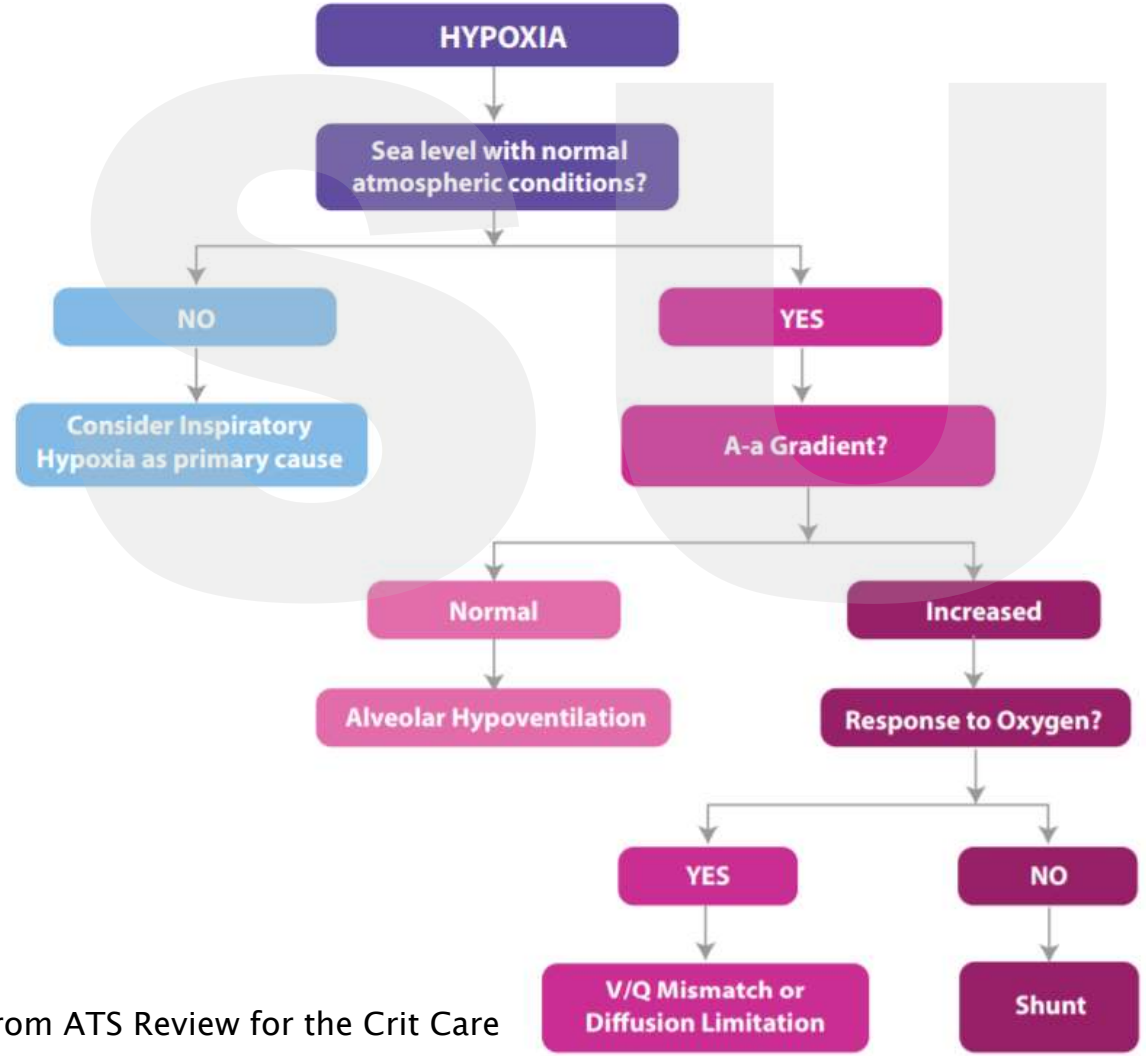
EKG and CXR are ordered

Arterial Blood Gas: 7.37/50/56/28

ACUTE HYPOXEMIC RESPIRATORY FAILURE

SIX MECHANISMS OF HYPOXEMIA (PAO2 <60)

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



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)

J.C.

EKG shows atrial fibrillation with RVR, HR in the 1teens

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 H20

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)

Brochard L et al. N Engl J Med 1995; 333:817
Masip J et al. Lancet 2000;356:2126-32
Gray A, et al. N Engl J Med 2008;359:142-51

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

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High-Flow Oxygen through Nasal Cannula in Acute Hypoxemic Respiratory Failure

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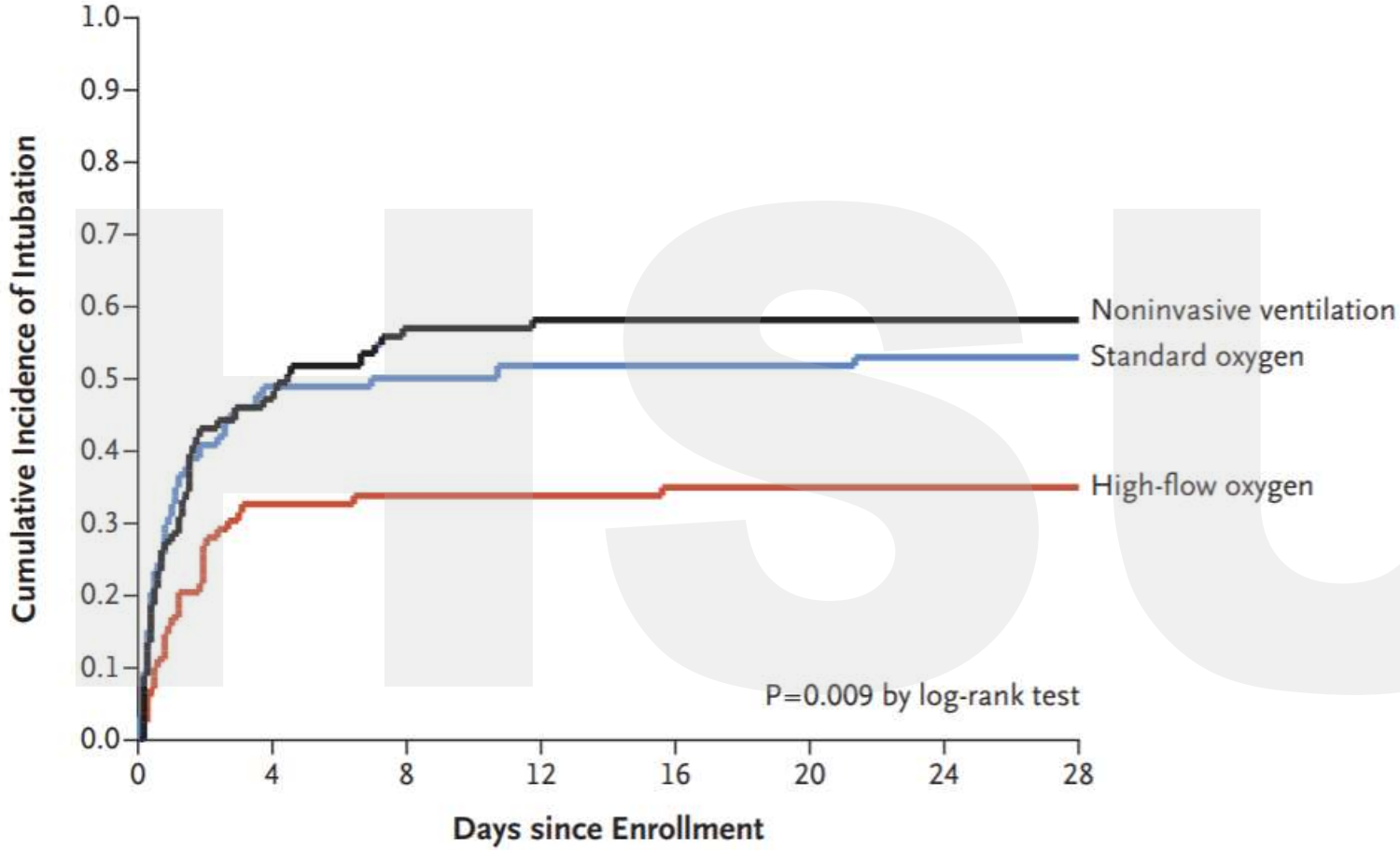
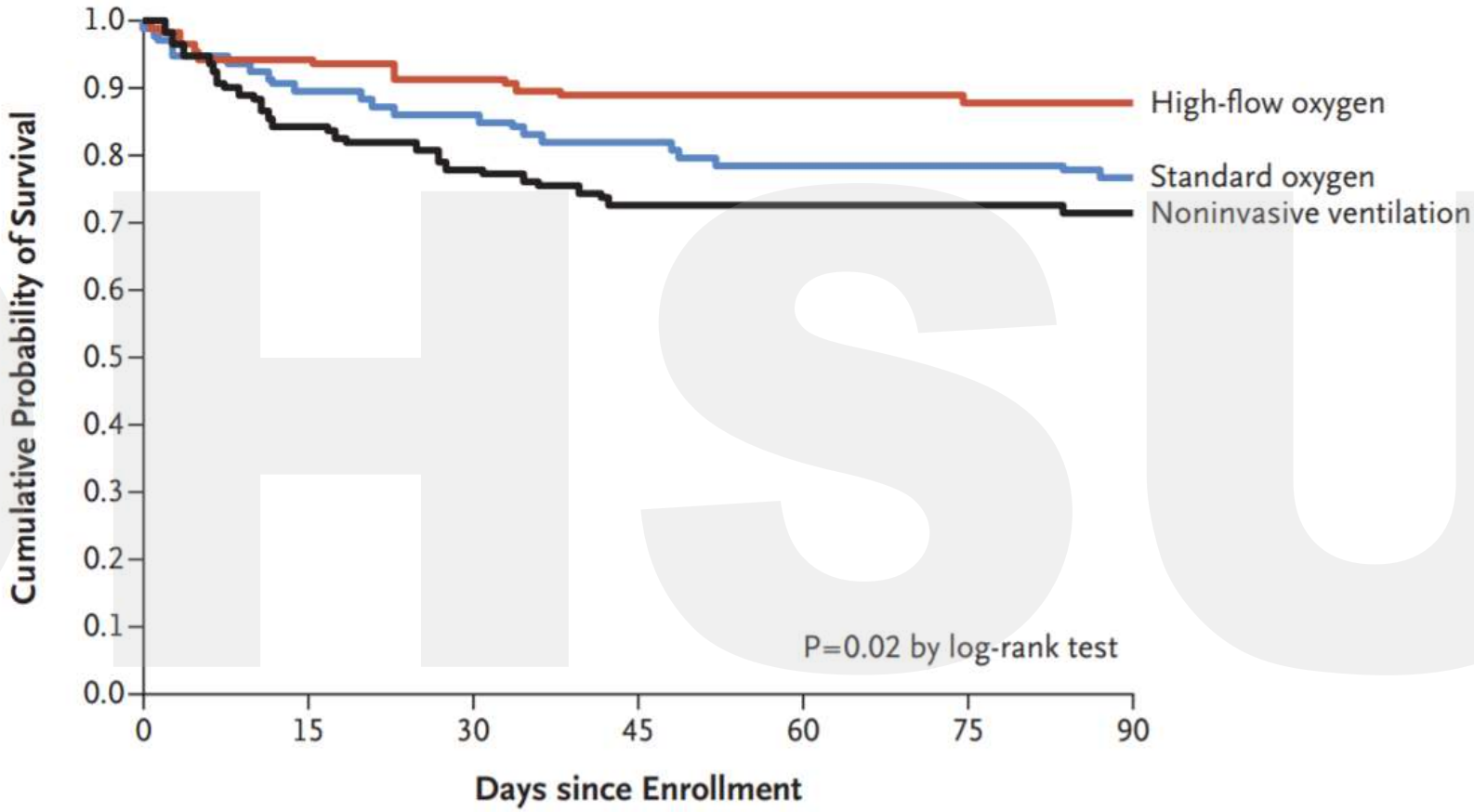
B Patients with a Pao_2:FIO_2 ≤200 mm Hg



No. at Risk								
High-flow oxygen	83	55	54	54	53	53	53	53
Standard oxygen	74	37	35	34	34	34	33	33
Noninvasive ventilation	81	41	34	32	32	32	32	32



No. at Risk

High-flow oxygen	106	100	97	94	94	93	93
Standard oxygen	94	84	81	77	74	73	72
Noninvasive ventilation	110	93	86	80	79	78	77

J.C.

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 (ie. airway resistance, anasarca, ascites, pleural disease, obesity)

Increased dead space (ie. 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

J.C.

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

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, hypersomnlence, 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)

Macrea et al. Am J Respir Crit Care Med. 2020 Aug 15; 202(4): e74-e87

MEDICARE REQUIREMENTS TO QUALIFY FOR A RESPIRATORY ASSIST DEVICE

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)

Noninvasive positive pressure ventilation (NIPPV) without backup rate:
$PaCO_2$ ≥ 52 mm Hg[a]
and
O_2 saturation ≤ 88% for ≥ 5 minutes (≥ 2 hours of recording on ambulatory nocturnal sleep oximetry) while on the higher of 2 L per minute of O_2 or prescribed FiO_2
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:
$PaCO_2$ ≥ 7 mm Hg greater than the original qualifying result
and
O_2 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 FEV_1/FVC ratio < 70% or FEV_1 < 50%

NIPPV with backup rate, no sooner than 61 days after use without backup rate:
$PaCO_2$ still ≥ 52 mm Hg
and
O_2 saturation ≤ 88% for ≥ 5 minutes (≥ 2 hours of recording on ambulatory nocturnal sleep oximetry) while on the higher of 2 liters per minute of O_2 or prescribed FiO_2

RESTRICTIVE THORACIC DISORDERS: PROGRESSIVE NEUROMUSCULAR DISEASE OR SEVERE THORACIC CAGE ABNORMALITIES

NIPPV with or without backup rate:
$PaCO_2$ ≥ 45 mm Hg
or
O_2 saturation ≤ 88% for ≥ 5 minutes (≥ 2 hours of recording on ambulatory nocturnal sleep oximetry) while on prescribed FiO_2
or (for neuromuscular diseases only):
Minimum inspiratory pressure < 60 cm H_2O
or
FVC < 50% of predicted; COPD not contributing to the limitation

CENTRAL SLEEP APNEA OR COMPLEX SLEEP APNEA SYNDROME

NIPPV with or without backup rate:
All of the following on facility-based nocturnal polysomnography: apnea-hypopnea index > 5, central events > 50% of total, central events ≥ 5 per hour, excessive daytime sleepiness or disrupted sleep
and
Significant improvement on NIPPV and prescribed FiO_2

OBSTRUCTIVE SLEEP APNEA

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[b]

NIPPV without backup rate:
Above criteria and CPAP proven ineffective on polysomography or at home

HYPOVENTILATION SYNDROME

NIPPV without backup rate:
Awake $PaCO_2$ ≥ 45 mm Hg
and
$PaCO_2$ ≥ 7 mm Hg greater during sleep or upon awakening (on prescribed FiO_2)
or
O_2 saturation ≤ 88% for ≥ 5 minutes (≥ 2 hours of recording on facility-based nocturnal polysomonography) with an apnea-hypopnea index < 5

NIPPV with backup rate:
Awake $PaCO_2$ on prescribed FiO_2 up ≥ 7 mm Hg from initial qualifying $PaCO_2$, despite using NIPPV without backup rate
or
O_2 saturation ≤ 88% for ≥ 5 minutes (≥ 2 hours of recording on facility-based nocturnal polysomnography), while on NIPPV without backup, and an apnea-hypopnea index < 5
and
An FEV_1/FVC ratio ≥ 70% and an FEV_1 ≥ 50% of predicted

Theerakittikul T et al. Cleve Clin J Med. 2010 Oct;77(10): 14

TAKE HOME POINTS

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

THANK YOU

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