CRITCARE BITES

NON-INVASIVE MODES OF VENTILATION: NIV, HFNC

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MAD FOR MEDICINE

INTRODUCTION

NON-INVASIVE MODES OF VENTILATION

- CPAP
- BiPAP 'NIV'
- HFNC

RESPIRATORY FAILURE

- AHRF
  Acute hypoxemic respiratory failure
- HYPERCAPNIC

BENEFITS OF NON-INVASIVE MODES

- Spontaneous ventilation is maintained
- Preserves physiological pathways of airway protection
- Reduces complications related to endotracheal intubation and IMV
  - VILI
  - VAP
  - Sedation, neuromuscular blockade
- Prevents diaphragmatic atrophy
- Maintains normal heart-lung interactions

POTENTIAL HARMS

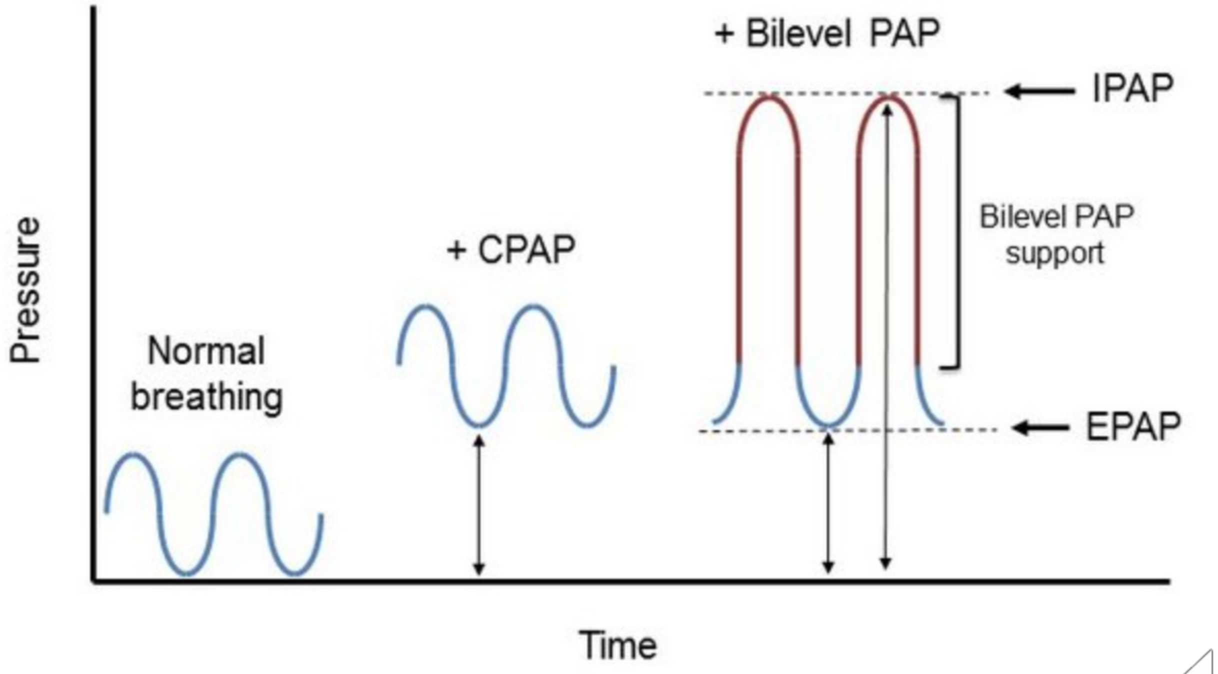
- Hypoxemia, dysregulated inspiratory effort, altered respiratory mechanics and inhomogeneous lung inflation → vicious cycle
- Intense inspiratory effort results in high tidal volumes and tachypnea
- Injured lungs are exposed to a higher risk of volutrauma and barotrauma
  - P-SILI
  - Large swings in transpulmonary pressure
  - Pendelluft phenomenon
- May account for increased mortality when NIV or HFNC fails
- Delay in endotracheal intubation

NIV

- Patient triggered, pressure-targeted mode of ventilation
- Positive inspiratory pressure is delivered above a PEEP
- Reduces work of breathing, improves V/Q matching
- Beneficial effects on the left heart
- Hypoventilation and respiratory acidosis best treated with NIV
- For pure AHRF, effect of positive inspiratory pressure needs to be monitored to ensure that it does not lead to excessive tidal volumes: predicts subsequent failure

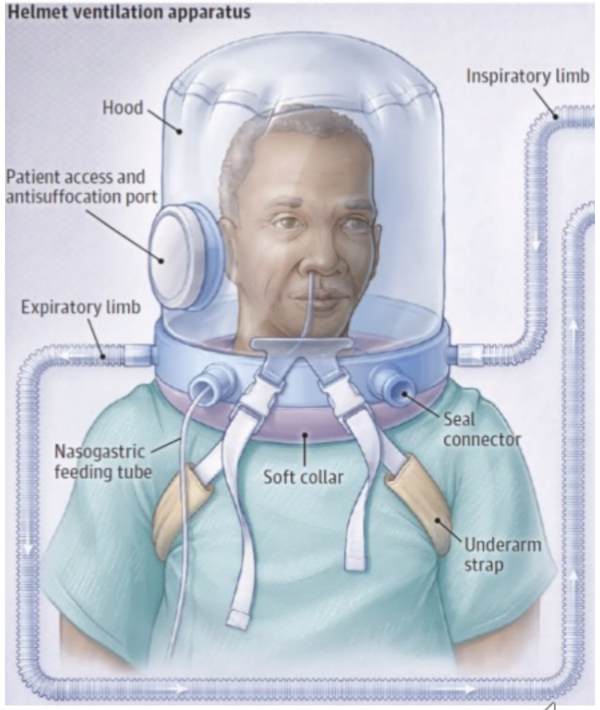
BIPAP VS CPAP

- BIPAP
  - IPAP ≈ PIP on the ventilator
  - EPAP ≈ PEEP
    - Affects oxygenation
  - ‘Driving pressure’ = IPAP – PEEP
    - Influences VT and thus ventilation
- CPAP
  - ≈ PEEP
    - Affects oxygenation
- Titrate FiO2 according to need



INTERFACE

- Oronasal face mask
  - Problems: leak, pressure sores and discomfort
- Helmet
  - No pressure on skin, allowing for more prolonged use of NIV
  - Problems: claustrophobia, higher levels of PEEP to avoid collapse of the hood in patients with large tidal volumes, high gas flows necessary to avoid CO2 re-breathing
  - Meta-analysis, helmet NIV > face mask and HFNC in reducing risk of endotracheal intubation and mortality (Ferreyro et al, JAMA 2020)



Images: www.draeger.com Grieco et al, JAMA 2021

INDICATIONS: PREVENTING INTUBATION

Strong	Moderate, 'think twice'	Avoid, insufficient evidence
COPD exacerbation Reduces intubation and mortality	Neuromuscular weakness *Ability to protect airway, bulbar weakness*	Asthma
APO Reduces intubation, maybe CPAP > NIV	Chest wall deformity and kyphoscoliosis	ARDS
OSA/OHS	Post-operative respiratory failure *Post-abdominal surgery, post-CABG* Reduces intubation	Pneumonia
Bronchiectasis	Extubation failure only COPD Does not prevent intubation, increased mortality	Upper airway obstruction
Mild-moderate AHRF *PF ratio >150* *Including immunocompromised* Reduces intubation vs conventional O2	Bronchoscopy	All other extubation failure
	Palliation	

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- Consider closer monitoring in ICU/ HD especially when initiating NIV in patients for indications with only moderate level of support and in patients with mild-moderate AHRF
- Low threshold to declare NIV failure and proceed to intubation

INDICATIONS: PRE-OXYGENATION

- Strongly consider in the **obese** and those with **AHRF**

ORIGINAL ARTICLE

Noninvasive Ventilation for Preoxygenation during Emergency Intubation

Authors: Kevin W. Gibbs, M.D., Matthew W. Semler, M.D., Brian E. Driver, M.D., Kevin P. Seitz, M.D., Susan B. Stempek, P.A., Caleb Taylor, M.D., M.P.H., Daniel Resnick-Ault, M.D., +51, for the PREOXI Investigators and the Pragmatic Critical Care Research Group* Author Info & Affiliations

Published June 13, 2024 | N Engl J Med 2024;390:2165-2177 | DOI: 10.1056/NEJMoa2313680 | VOL. 390 NO. 23

- Critically ill adults (age ≥18 years) undergoing tracheal intubation: preoxygenation with either noninvasive ventilation or an oxygen mask
- Primary outcome: hypoxemia – SpO2 <85% between induction of anesthesia and 2 minutes after tracheal intubation
- Hypoxemia 9.1% in the noninvasive-ventilation group vs 18.5% in oxygen-mask group

INDICATIONS: WEANING

- **Hasten extubation in COPD patients**
  - Failed SBT but otherwise ready to be weaned
- **Post-extubation to prevent re-intubation**
  - High risk patients (varies between studies)
    - **COPD**
    - **Heart failure**
    - **Age >65**
    - Previous extubation failure
    - Hypercapnia ($PaCO_2$ >45mmHg before or after SBT)
    - Obesity, OHS

CONTRAINDICATIONS

- Cardiac/ respiratory arrest
- Severe hemodynamic instability
- Severe metabolic acidosis
- Severe respiratory acidosis e.g. pH <7.20 (can still consider in COPD)
- Multi-organ failure
- Active hemoptysis/ hematemesis
- Facial surgery or trauma
- Depressed GCS <8
- Inability to protect airway

INITIAL SETTINGS AND ADJUSTMENTS

- Spontaneous/ timed mode
- IPAP: start at 10cmH2O, titrate in increments of 2, maximum of 24cmH2O
  - COPD ~16-18cmH2O
  - Neuromuscular weakness ~10-12cmH2O
  - AHRF most <16cmH2O
  - IPAP rise time: 0.1s
- EPAP: start at 5cmH2O, titrate in increments of 2, maximum of 10-12cmH2O
- Monitor the 'driving pressure' (IPAP – EPAP)/ tidal volumes as settings are adjusted:
- Titrate FiO2 to target SpO2 (usually 88-92%)
- Set RR at 12 breaths/min (usually as a 'back up' as patients are spontaneously breathing)
- Monitor ABG for changes in pH, pCO2 and pO2

WHERE TO SITE PATIENT?

- Intensive care unit (ICU)
  - High risk of failure and subsequent intubation: non-COPD indication or pH <7.20
- High dependency unit (HD)
  - NIV likely to be successful: COPD patient with pH ≥7.20 and comfortable
- Respiratory General Ward
  - DNR patients
  - Sustained improvement on NIV

PREDICTING NIV FAILURE

- ABG 1 hour after initiation
  - No improvement or decrease in pH
  - Minimal or no improvement in PF ratio: <200 after 1h increased risk of intubation, <150 increased risk of death
- Persistent tachypnea
- High tidal volumes
  - Tidal volume of >9-9.5ml/kg of predicted body weight 1h after NIV initiation associated with increased risk of intubation and death
- HACOR score
  - Components: pH, HR, RR, P/F ratio, GCS
  - Score of >5 predicts failure
  - At 1 hour of NIV, odds ratio of NIV failure is 1.73 for every 1-point increase in HACOR score
- Consider the original indication for NIV
  - NIV failure rates in COPD ~15-20%
  - NIV failure rates for AHRF ~40-60% → lower threshold to abandon NIV and proceed for intubation
    - NIV failure independent predictor for death in such patients

HFNC

- Generates a flow-dependent FiO2
- Delivers flow higher or equal to inspiratory requirement and thereby, diminishes air entrainment

- Gas goes through an air-oxygen blender that can generate a total flow of up to 60L/min is heated and humidified with an active humidifier

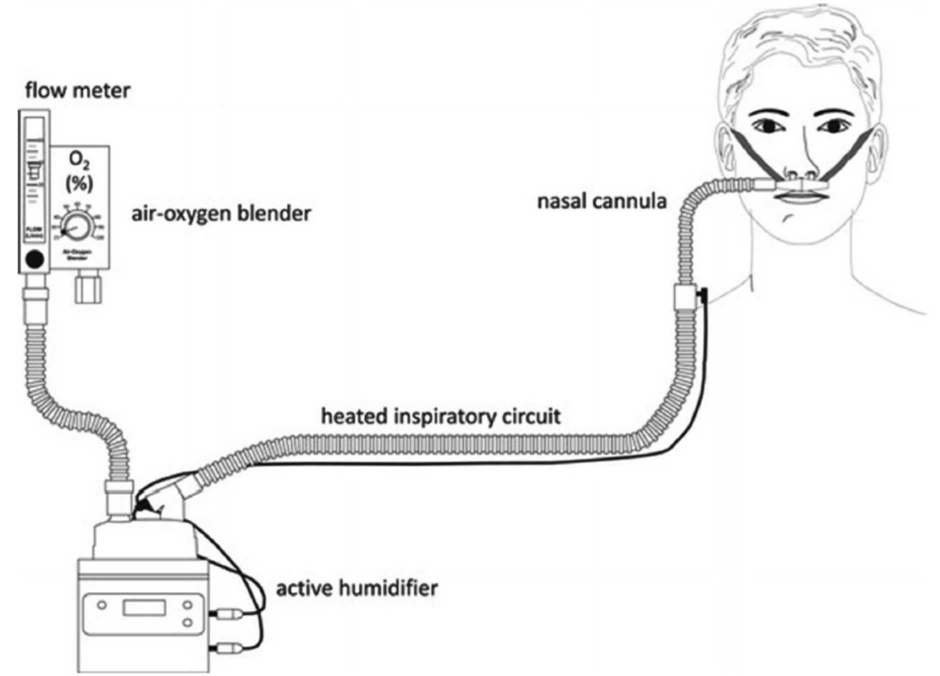
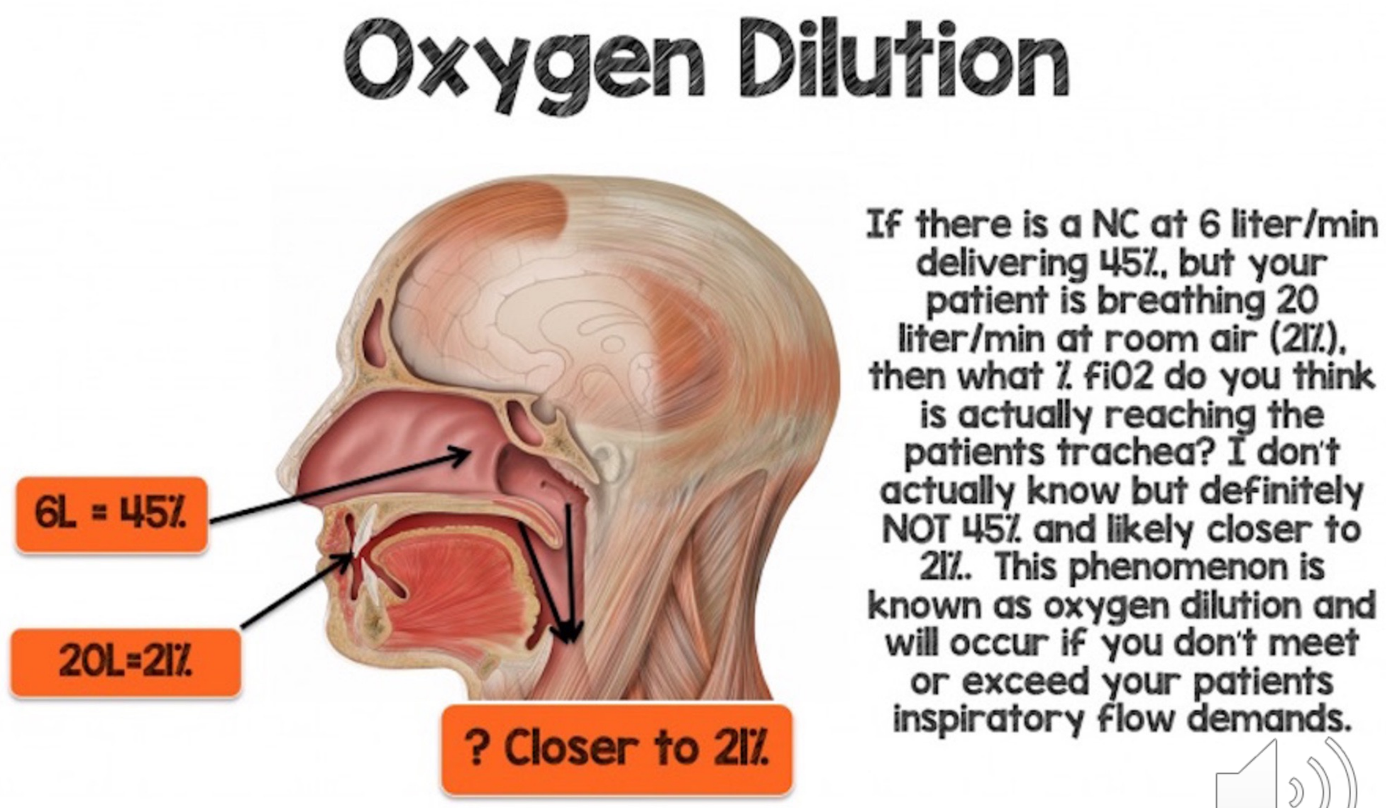


Fig. 1 High-flow nasal cannula oxygenation (HFNCO) device. An air/oxygen blender, allowing FiO_2 ranging from 0.21 to 1.0, generates flows of up to 60 L/min. The gas is heated and humidified by an active heated humidifier and delivered via a single limb

Intensive Care Med (2016) 42:1336–1349

AIR ENTRAINMENT

- FiO2 = 0.21 + 0.04 x L/min of oxygen
  - FiO2 on 4LNP: 0.21 + 0.04 x 4 = 0.37
- NOT TRUE
- Concentration of oxygen that patients inspire depends on the ventilatory minute volume (MV) and the flow rate of oxygen



PHYSIOLOGY

- Reduces entrainment of air by utilizing high flow
  - Air entrainment occurs when patient's intrinsic flow rate exceeds that of O2 flow rate
  - Heated and humidified air allows patients to tolerate high flow rates
- High flow washes out CO2 in anatomical dead space
- PEEP
  - Low levels 5-8cmH2O at higher flows
  - Mechanical splinting of nasopharynx

→

- FIO2 levels higher and more stable than conventional O2
- Reduction in dead space → reduction in work of breathing
- Better V/Q matching as PEEP allows for alveolar recruitment

INDICATIONS

- Acute hypoxemic respiratory failure with PF ratio ≤200
  - Consider especially in immunocompromised patients
- To prevent re-intubation in certain circumstances
  - Select patients who passed SBT but PF ratio <200 mmHg
  - High risk patients
    - Elderly, heart failure, COPD
  - Post-cardiac surgery (to prevent re-intubation)

INDICATIONS: AHRF

Table 2 Main clinical studies on HFNCO in adults with hypoxemic acute respiratory failure

References	Study design	Population	Patients (*N*)	Main results
Hypoxemic ARF in the ICU				
[7]	Cohort, unselected patients. HFNCO 50 L/min vs face mask oxygen	Hypoxemic ARF	38	Improved oxygenation Decreased respiratory rate
[20]	Cohort, unselected patients. HFNCO 20–30 L/min vs face mask oxygen	Hypoxemic ARF	20	Improved oxygenation Decrease in respiratory/heart rates, dyspnea, respiratory distress, and thoracoabdominal asynchrony
[12]	HFNCO vs face mask oxygen	Hypoxemic ARF	60	Decreased treatment failure (defined as need for non-invasive ventilation) from 30 to 10 %. Fewer desaturation episodes
[6]	Cohort study, HFNCO 20–30 L/min vs face mask oxygen	Hypoxemic ARF	20	Improved comfort; improved oxygenation
[26]	Cohort study (post hoc)	Hypoxemic ARF (2009 A/H1N1v outbreak)	20	9/20 (45 %) success (no intubation). All 8 patients on vasopressors required intubation within 24 h. After 6 h of HFNCO, non-responders had lower PaO_2/FiO_2 values
[24]	Observational, single-center study	ARDS	45	40 % intubation rate. HFNCO failure associated with higher SAPS II, development of additional organ failure, and trends toward lower PaO_2/FiO_2 values and higher respiratory rate
FLORALI [22]	Multicenter, open-label RCT with 3 groups: HFNCO, usual oxygen therapy (face mask), or non-invasive ventilation	Hypoxemic ARF, $PaO_2/FiO_2 \leq 300$	310	Intubation rate was 38 % with HFNCO, 47 % with standard oxygen, and 50 % with non-invasive ventilation. Decreased 90-day mortality with HFNCO
[83]	Retrospective before/after study of HFNCO	Hypoxemic ARF	172	Reduced need for intubation (100 vs 63 %, $p < 0.01$)
[28]	Patients intubated after HFNCO	Hypoxemic ARF	175	In patients intubated early, lower mortality (39.2 vs 66.7 %), higher extubation success (37.7 vs 15.6 %), and more ventilator-free days. Early intubation was associated with decreased ICU mortality
Hypoxemic ARF in the emergency department				
[21]	Patients with ARF (>9 L/min oxygen or clinical signs of respiratory distress)	Hypoxemic ARF	17	Decreased dyspnea and respiratory rate and improved oxygenation
[84]	RCT of HFNCO vs standard oxygen for 1 h	Hypoxemic ARF	40	Decreased dyspnea and improved comfort

ARF acute respiratory failure, *HFNCO* high-flow nasal cannula oxygenation, *RCT* randomized controlled trial

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ARF acute respiratory failure, *HFNCO* high-flow nasal cannula oxygenation, *RCT* randomized controlled trial

- Reduces endotracheal intubation compared to conventional O2
- Reduces intubation over NIV in moderate-severe AHRF where PF ratio <200
- FLORALI and subsequent meta-analysis in JAMA 2020: reduced mortality compared to conventional O2
- Immunocompromised patients
  - Post-hoc analysis of FLORALI
  - Included patients: hematological or solid organ cancer, drug-induced, steroids, HIV
  - Intubation rates higher in patients with NIV vs HFNC

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INDICATIONS: POST-EXTUBATION

- Reduces re-intubation rates post-extubation in respiratory failure
  - Compared to conventional O2
- Both high and low risk patients
- Non-inferior to NIV
- Alternating between NIV and HFNC may better than HFNC alone

Effect of Postextubation High-Flow Nasal Cannula vs Conventional Oxygen Therapy on Reintubation in Low-Risk Patients
A Randomized Clinical Trial

Gonzalo Hernández, MD, PhD; Concepción Vaquero, MD; Paloma González, MD; Carles Subira, MD; Fernando Frutos-Vivar, MD; Gemma Rialp, MD; Cesar Laborda, MD; Laura Colinas, MD; Rafael Cuena, MD; Rafael Fernández, MD, PhD

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Effect of Postextubation High-Flow Nasal Cannula vs Noninvasive Ventilation on Reintubation and Postextubation Respiratory Failure in High-Risk Patients
A Randomized Clinical Trial

Gonzalo Hernández, MD, PhD; Concepción Vaquero, MD; Laura Colinas, MD; Rafael Cuena, MD; Paloma González, MD; Alfonso Canabal, MD, PhD; Susana Sanchez, MD; Maria Luisa Rodriguez, MD; Ana Villasclaras, MD; Rafael Fernández, MD, PhD

CONTRAINDICATIONS

- Cardiac/ respiratory arrest
- Severe hemodynamic instability
- Severe metabolic acidosis
- Multi-organ failure
- Hypercapnic respiratory failure
- Active hemoptysis/ hematemesis/ epistaxis
- Severe encephalopathy
- Base of skull fracture or recent surgery to the nose

PREDICTING HFNC FAILURE

- SpO2 <90% or RR ≥30 on >70/70
- Development of copious tracheal secretions
- Lack of improvement in signs of high respiratory-muscle workload
- **ROX index**
  - SpO2/FiO2 to RR
    - ROX score ≥4.88 at 2/6/12 hours: lower risk of progressing to mechanical ventilation
    - ROX score <3.85: risk of HFNC failure is high and should consider intubating
    - ROX score 3.85 to <4.88: repeat scoring 1-2 hours later
- Acidosis with pH <7.35
- Hemodynamic instability
- Neurological deterioration

AHRF: NIV VERSUS HFNC?

- Mild-to-moderate AHRF (PF >150): either HFNC/ NIV/ CPAP
  - Reduces risk of endotracheal intubation compared to conventional O2 therapy
  - In the absence of shock, other contraindications
  - Helmet NIV may be superior to HFNC in COVID-19 respiratory failure (HENIVOT trial)
- Moderate-severe AHRF
  - Intubate the patient or choose HFNC over NIV (preference will still be for intubation)
  - FLORALI trial: HFNC reduced intubation and mortality over NIV in patients with PF ratio <200
  - Risk of NIV failure higher when PF ratio <150 and NIV failure independent risk factor for mortality
- Patients
  - Immunocompromised
    - Do not need to adopt a strategy that is different for immunocompetent patients
    - Based on post-hoc analysis of FLORALI trial, HFNC had mortality benefit
  - COPD, OHS, heart failure: NIV/ CPAP

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