Nasal High Flow Therapy: An Evidence-Based Approach

Utah Society for Respiratory Care Conference

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Fisher & Paykel HEALTHCARE

Disclosures

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Avid supporter of New Zealand All Blacks Rugby Team

Learning Objectives

An evidence-based approach to the use of Nasal High Flow across adult and pediatric care settings (with ED focus). At completion attendees will be able to:

- Understand the origins and mechanisms of action for Nasal High Flow
- Review **updated** clinical evidence and **new** Clinical Practice Guidelines
- Review treatment algorithms and guidance for adult and pediatric patients
- Evaluate and apply knowledge to patient care and practice change

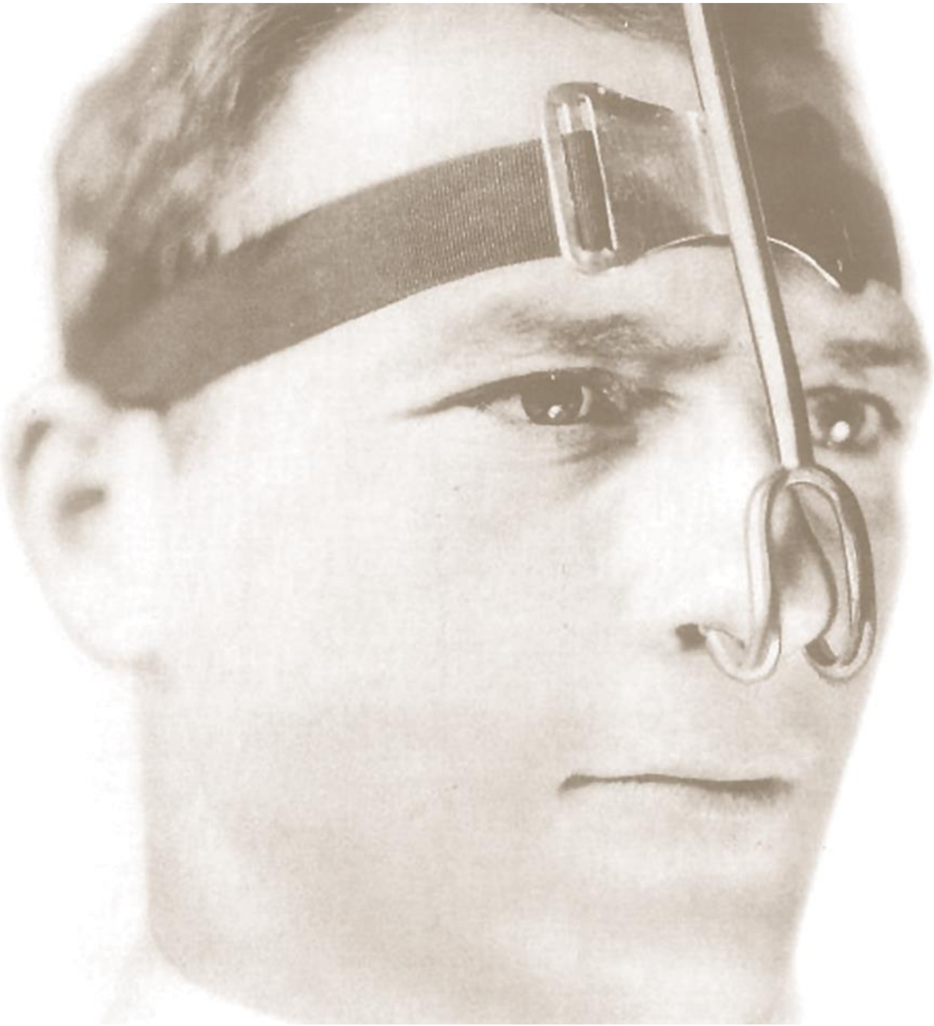
Outline

1. Quick recap: mechanisms of action for NHF
2. How has clinical evidence lead to Clinical Practice Guidelines?
3. Hot topic questions: Pediatrics? Therapy success?
4. Q&A

Who routinely used HFNC ***before*** *COVID-19?*

*Can HFNC be used as **first-line** therapy for patients who present with undifferentiated respiratory distress?*

History & background



c. 1920’s

History & background

tests demonstrated severe delayed hypersensitivity reaction, maximal at 48–72 hours. This response was to the first application after transplant and approximately 3 months after previous tests. It is probable that small amounts of the chemicals remained in the tissues and when thymic function was established, sensitisation occurred. Biopsy of a lymph-node 8 months after implantation of thymic tissue was normal for an infant of this age (fig. 4b). This finding, coupled with normal numbers of circulating lymphocytes, indicated repopulation of peripheral lymphoid tissue with small lymphocytes. After operation

CONTINUOUS CONTROLLED HUMIDIFICATION OF INSPIRED AIR

Summary It has been observed that gases can be administered through the nose at high flow-rates provided that they are at body-temperature and fully saturated with water-vapour. A simple and easily portable system has been devised for delivering gases in this way, and has been shown to be effective in volunteers. It is now proving satisfactory in clinical use, both for continuous humidification and for administration of oxygen.

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M.D. Copenhagen

History & background

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Most of the problems of humidification could be solved by the use of water-vapour instead of aerosols. This would more nearly reproduce the physiological mechanism of humidification in the respiratory tract. Such a method became practicable when the author discovered that gases could be blown into one nostril at 20–30 litres per minute without discomfort, and even without perception, provided that the gas was at body-temperature and 100% saturated with water-vapour. (The highest tolerable flow of dry, cool gas is normally regarded as 6–8 litres per minute.)

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LOMHOLT
Copenhagen

High flow terminology

Interface

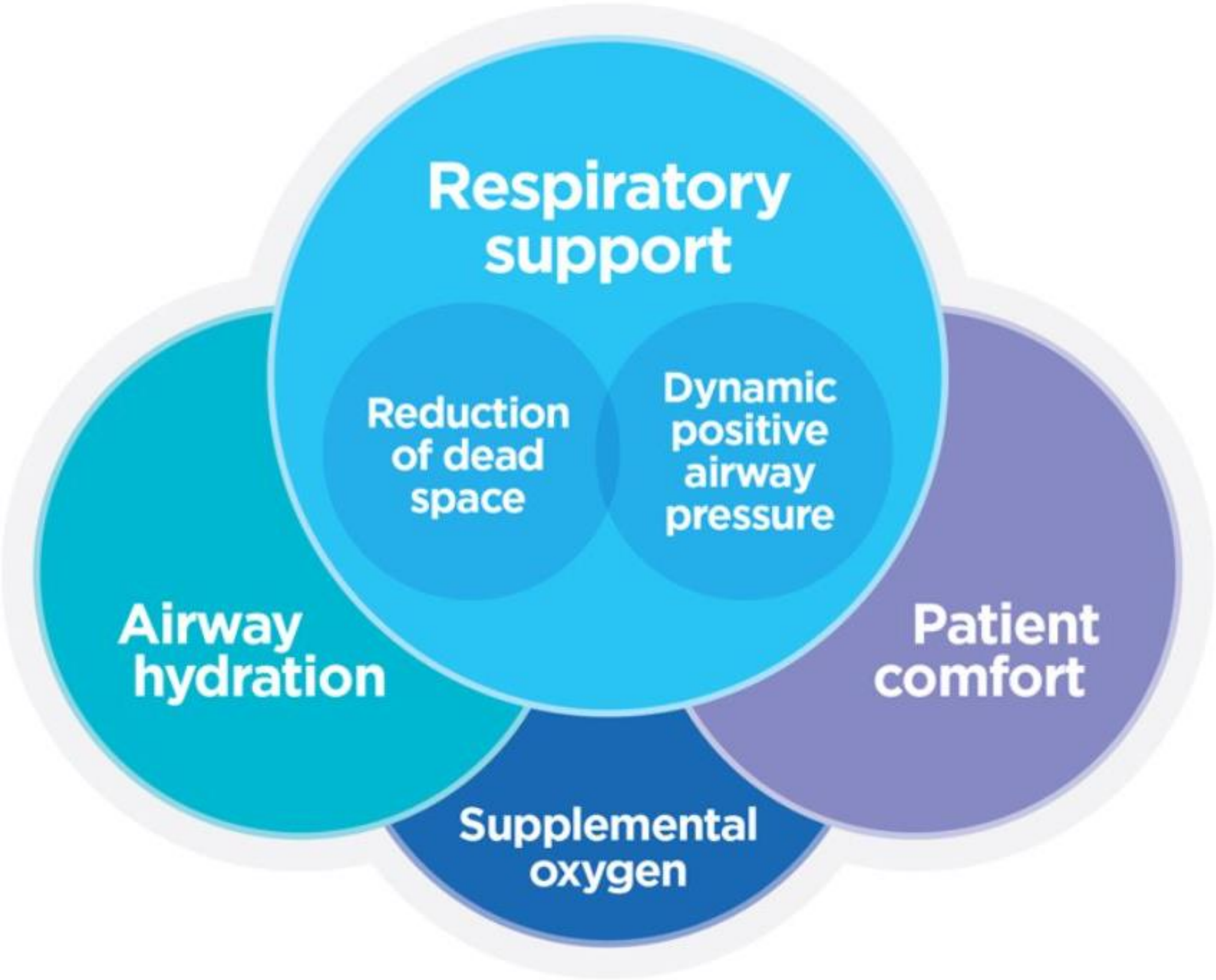
High flow nasal cannula (HFNC)
High flow nasal prongs (HFNP)
High flow oxygen (HFO)
Humidified high flow nasal cannula (HHFNC)

Therapy

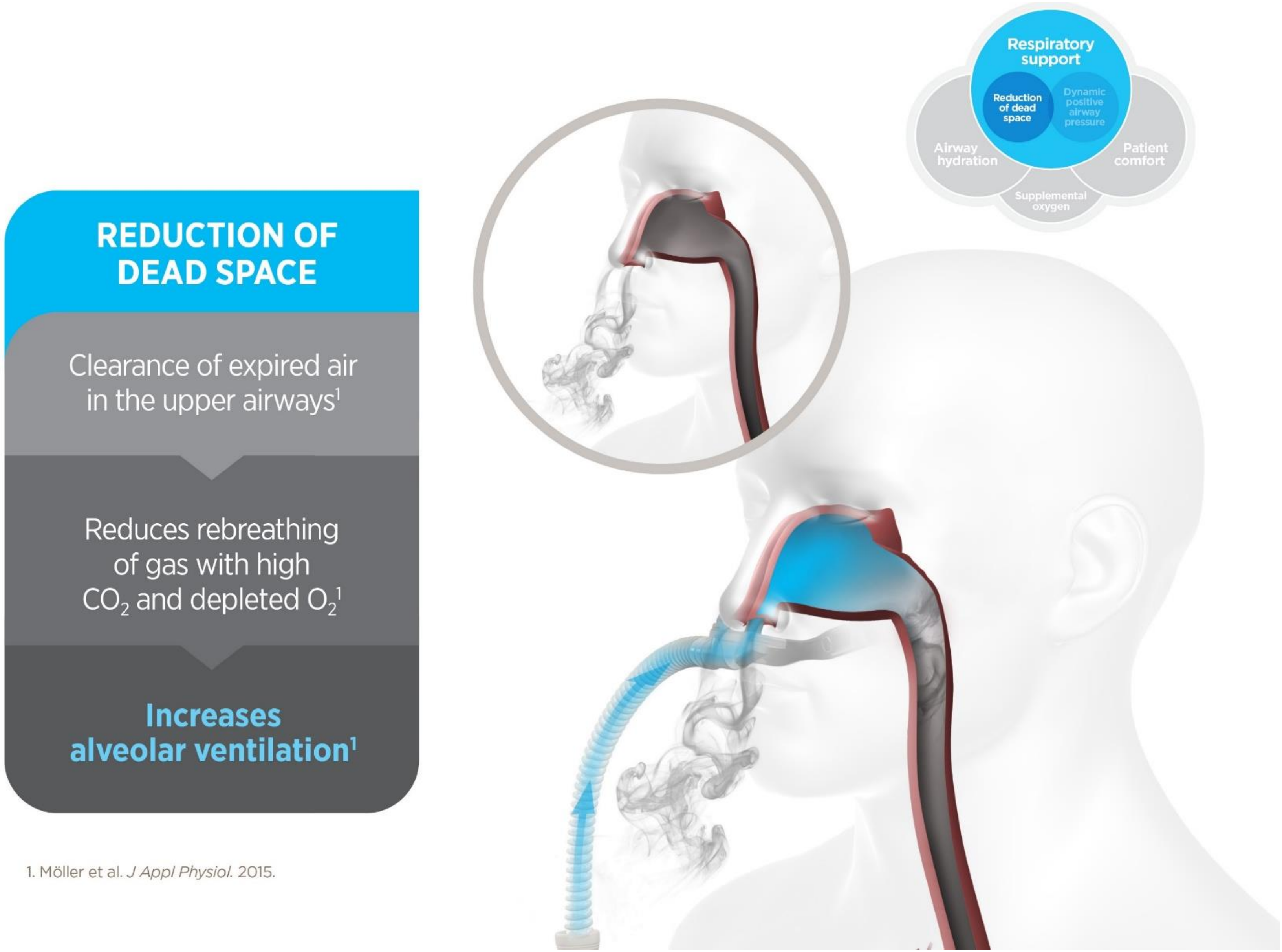
High flow therapy (HFT)
Humidified high flow therapy (HHFT)
Nasal high flow (NHF)
High flow oxygen/therapy (HFO/T)

Optiflow™
High velocity nasal insufflation (HVNI™)
Comfort Flo™

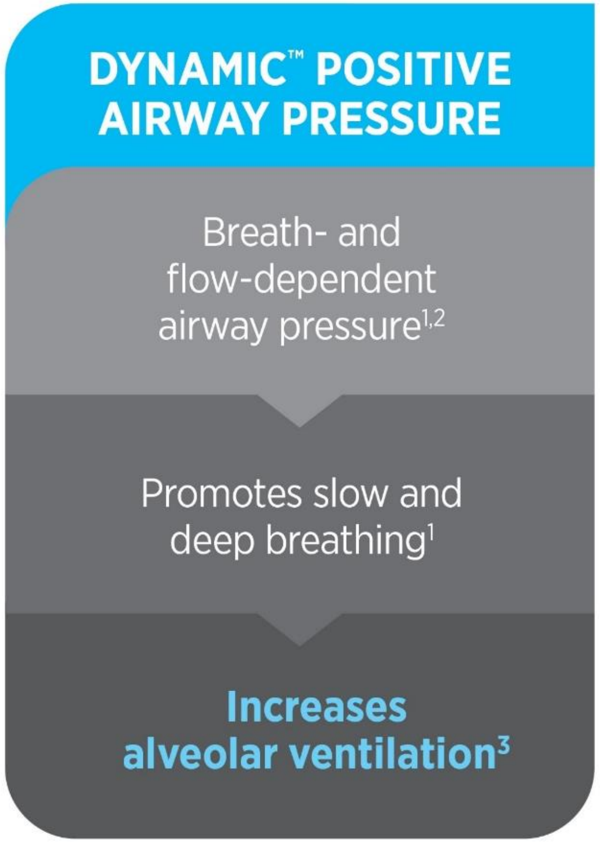
Mechanisms of action

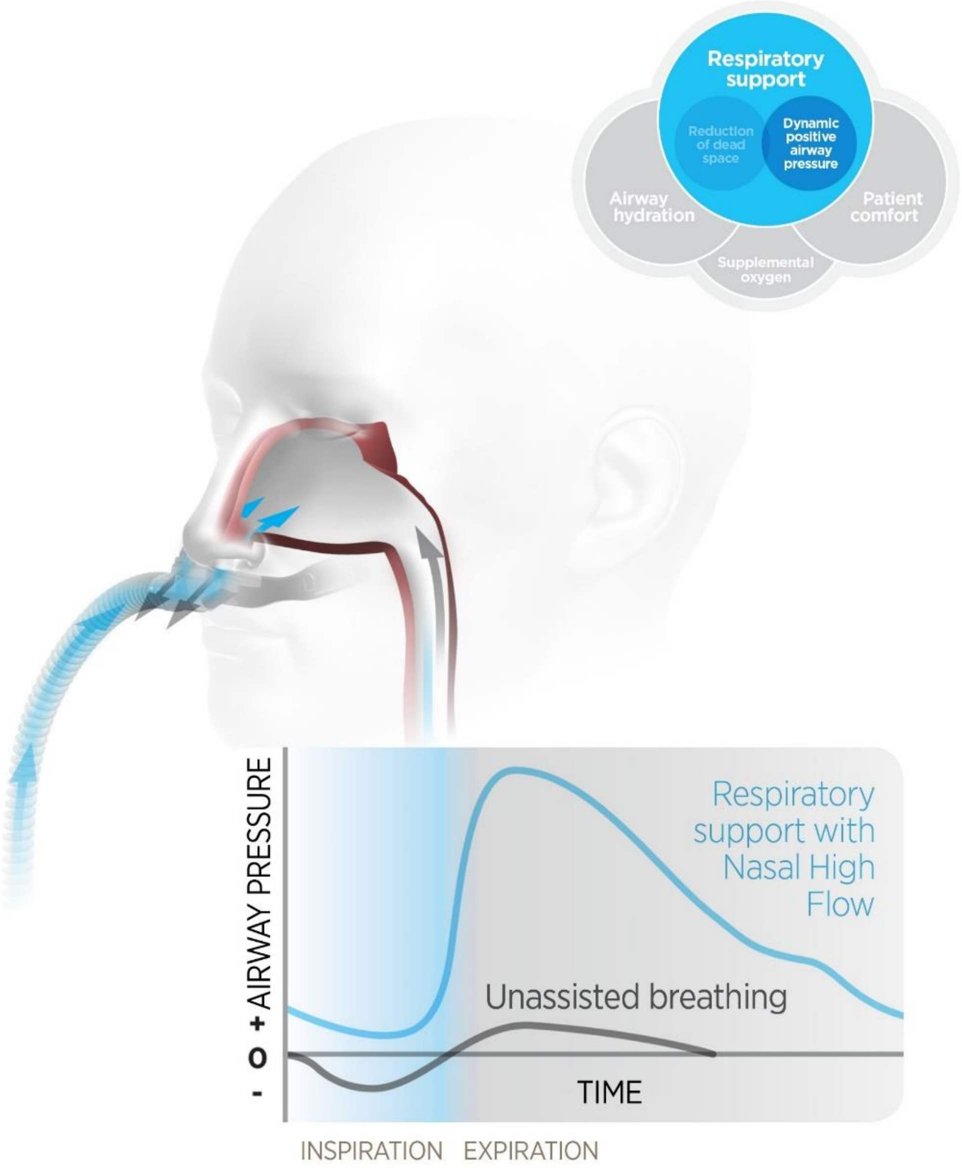


Reduction of dead space



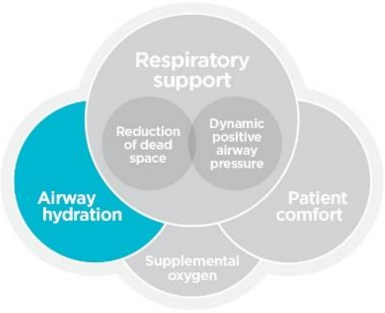
Dynamic positive airway pressure





1. Mündel et al. *J Appl Physiol.* 2013.
2. Parke et al. *Respir Care.* (Aug) 2011.
3. Parke et al. *Respir Care.* (Mar) 2011.

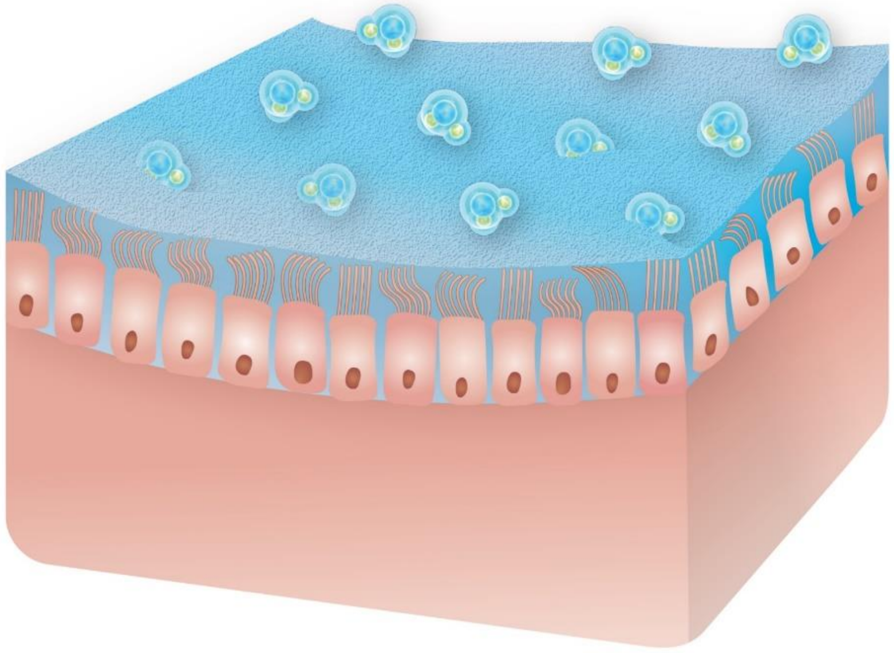
Airway hydration



OPTIMAL HUMIDITY

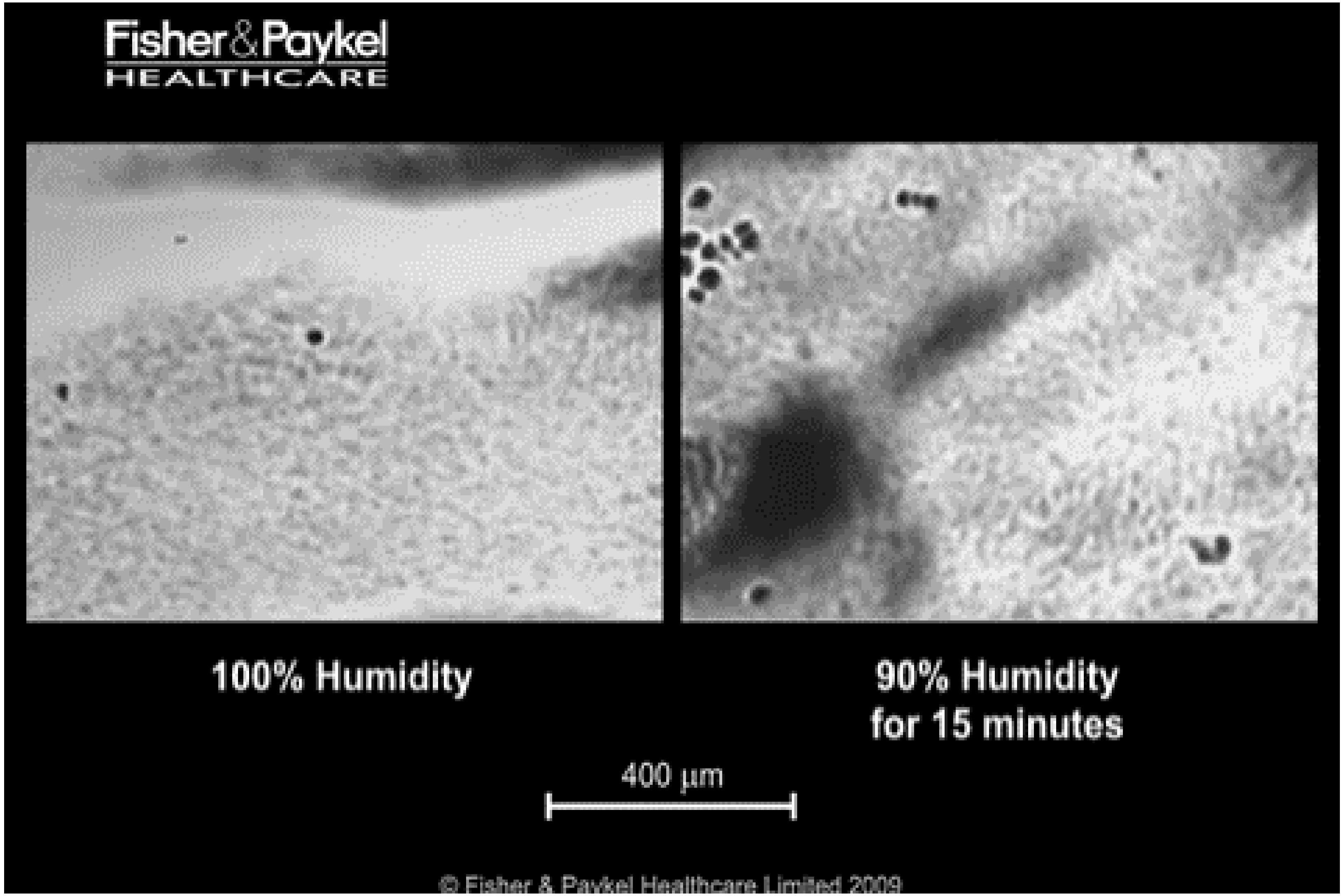
Prevents desiccation of the airway epithelium[1]

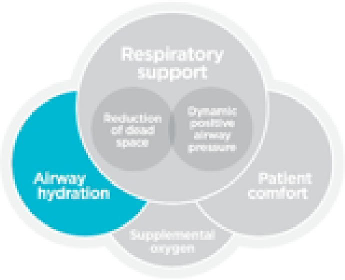
Improves mucus clearance[1,2]



1. Williams et al. *Crit Care Med*. 1996.
2. Hasani et al. *Chron Respir Dis*. 2008.

Airway hydration





In vitro model of
the effects of
high flows of warm,
humidified air
on mucociliary
transport

Patient comfort

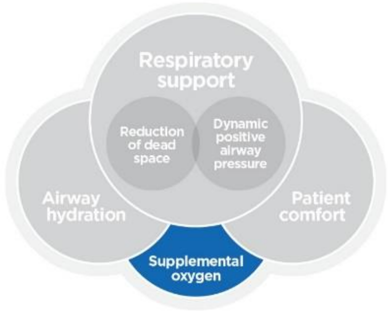
COMFORTABLE[1,2] AND EASY TO USE

OPEN SYSTEM
No seal required

Patient tolerance[1,3]

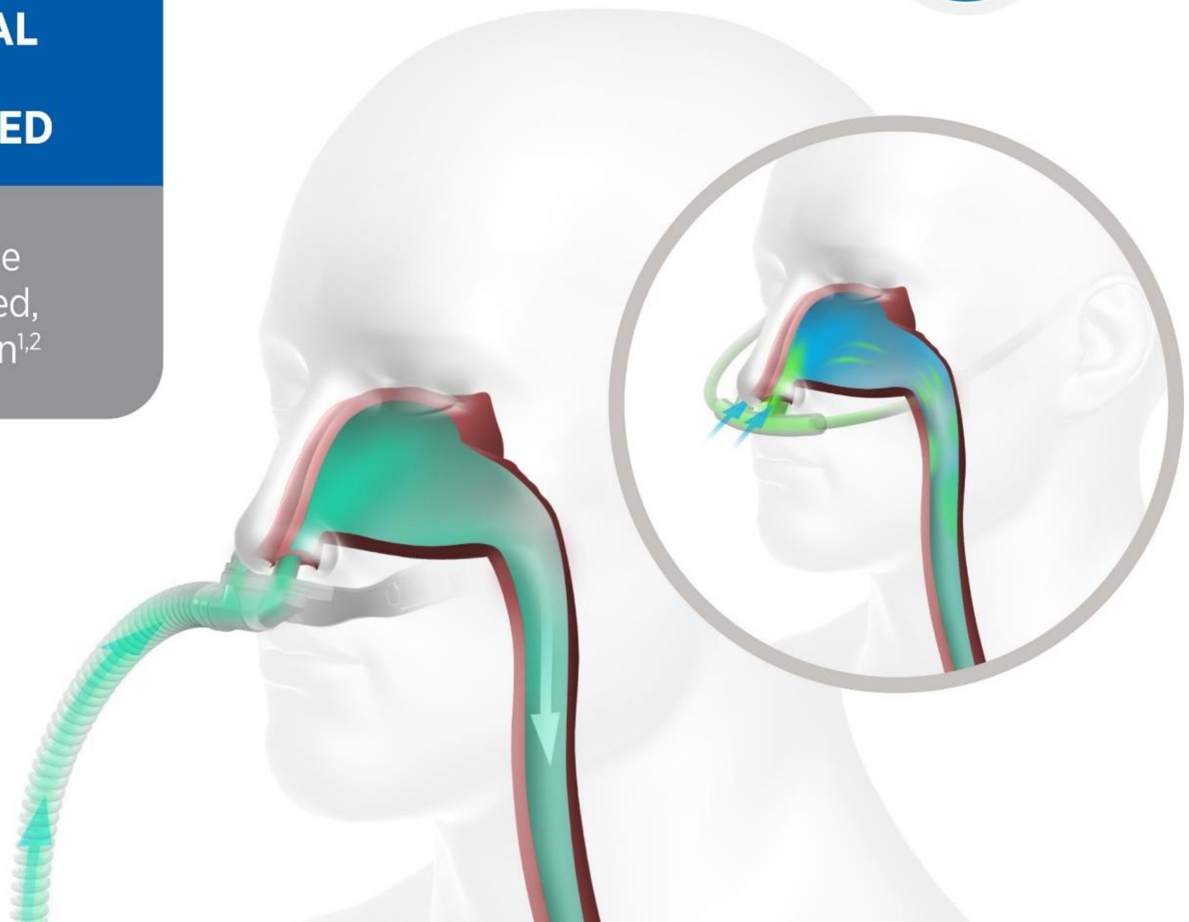
1. Roca et al. *Respir Care.* 2010.
2. Maggiore et al. *Am J Respir Crit Care Med.* 2014.
3. Frat et al. *N Engl J Med.* 2015.

Supplemental oxygen



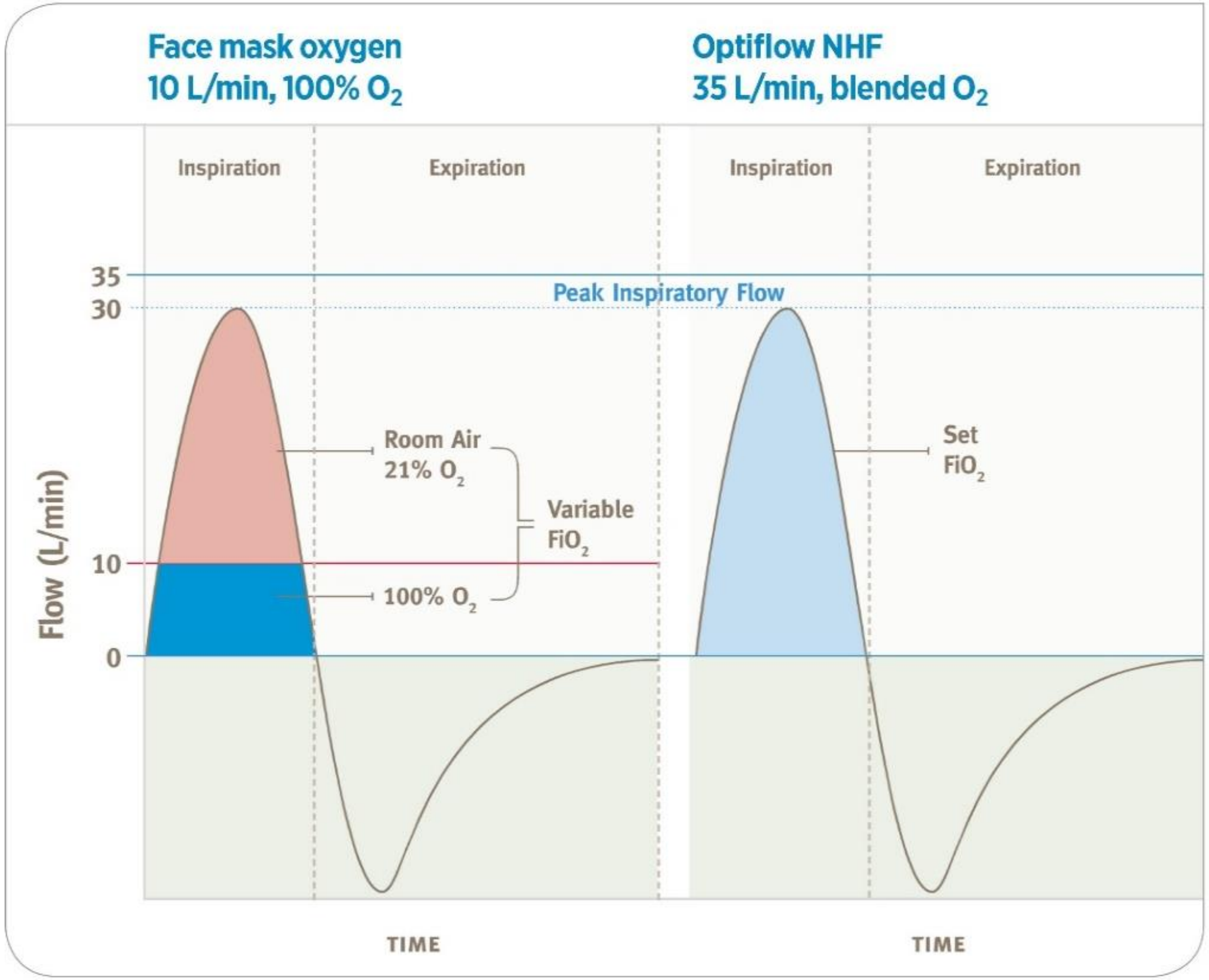
SUPPLEMENTAL OXYGEN WHEN REQUIRED

Confidence in the delivery of blended, humidified oxygen[1,2]

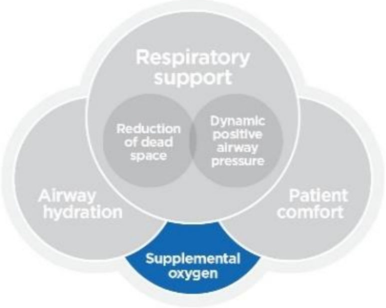


1. Ritchie et al. *Anaesth Intensive Care.* 2011.
2. Masclans et al. *Clin Pulm Med.* 2011.

Supplemental oxygen



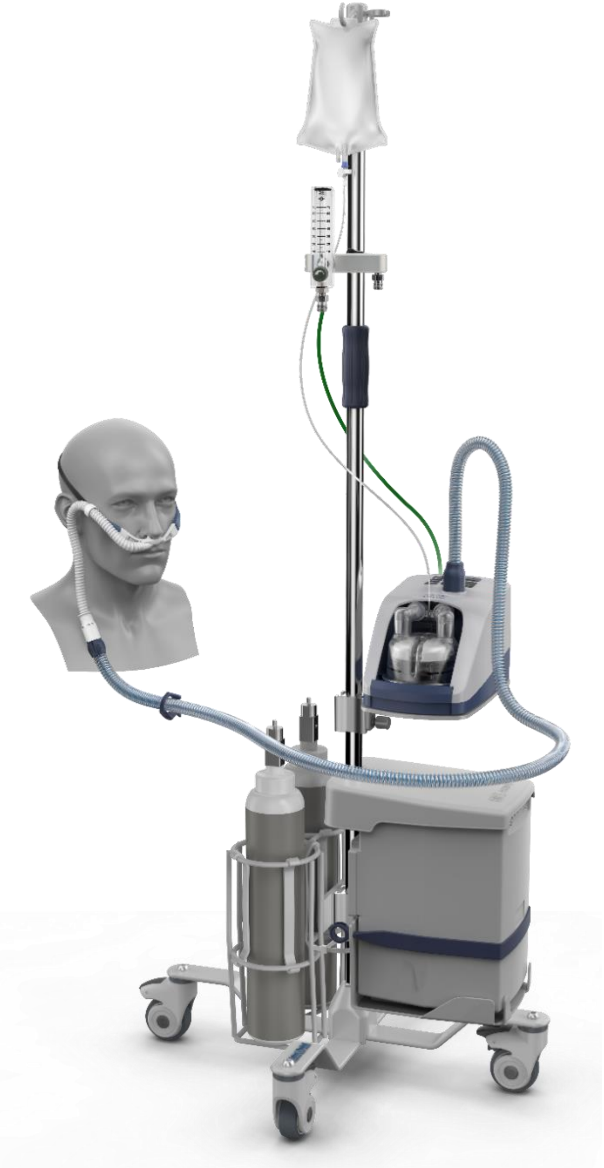
Adapted from Masclans et al.



Confidence in the delivery of blended humidified oxygen[1,2]

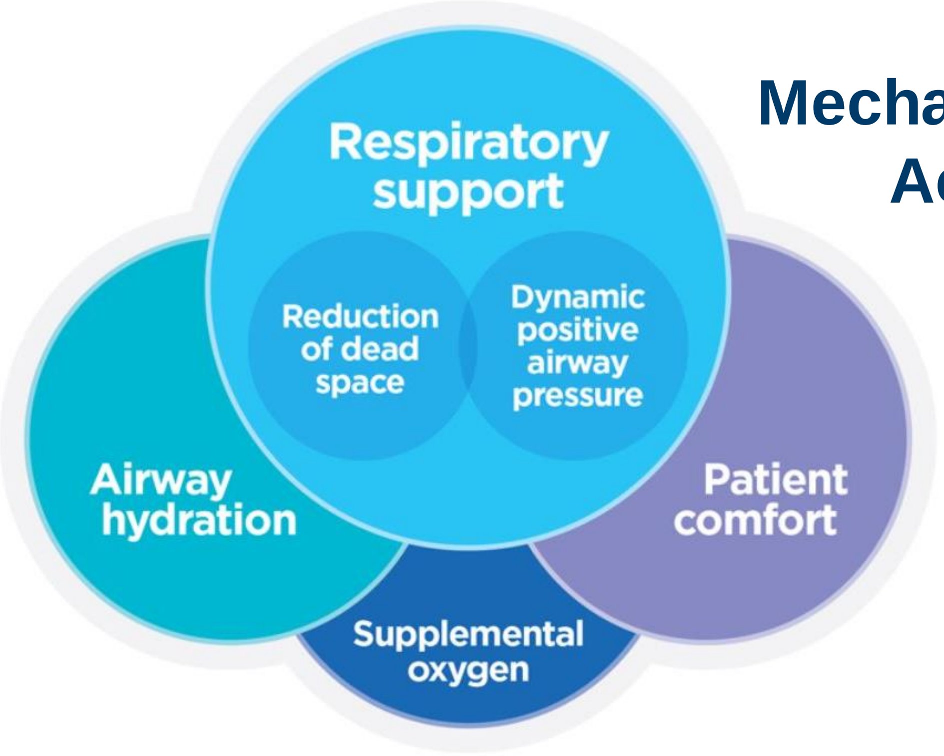
1. Ritchie et al. *Anaesth Intensive Care.* 2011.
2. Masclans et al. *Clin Pulm Med.* 2012.

Nasal High Flow



Nasal High Flow therapy is the delivery of heated and humidified air (w/ or w/o supplemental oxygen), up to 60 L/min, to a patient using a high flow nasal cannula (HFNC).

Mechanisms of Action



Outline

1 Quick recap: mechanisms of action for NHF

2 How has clinical evidence lead to Clinical Practice Guidelines?

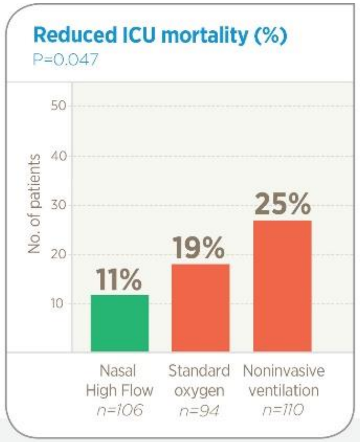
3 Hot topic questions: Pediatrics? Therapy success?

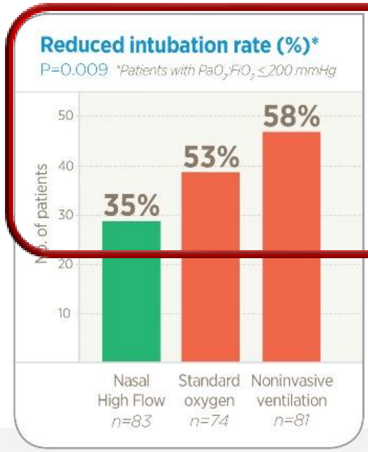
4 Q&A

Can the early use of NHF reduce the rate of intubation?

Frat et al. 2015 NEJM

FLORALI Study





39% fewer intubations between NIV and NHF

REDUCES mortality rate

REDUCES escalation of care

STUDY

A 23-center study compared nasal high flow (NHF) therapy to use of a non-rebreather mask and NIV as a primary treatment (pre-intubation).

METHOD

- 310 patients in acute hypoxemic respiratory failure (PaO_2:FiO_2 ≤ 300 mmHg) were randomized to receive NHF, non-rebreather mask or NIV.
- Primary outcome: number of patients intubated at day 28 - not attained.

RESULTS

- NHF significantly reduced ICU mortality: NHF 11%, standard O_2 therapy 19%, NIV 25% and 90-day mortality: NHF 12%, standard O_2 therapy 23%, NIV 28%
- NHF significantly reduced need for intubation in more acute patients (PaO_2:FiO_2 ≤ 200 mmHg)
- Significant increase in ventilator-free days on NHF
- NHF significantly reduced intensity of respiratory discomfort and dyspnea

Frat et al. *N Engl J Med.* 2015.

Can NHF support acute undifferentiated SOB ED patients?

Bell et al. 2015 Emerg Med Australas

REDUCED respiratory rate

REDUCED escalation

IMPROVED patient comfort

Bell. EMA. 2015.

STUDY

A comparison of NHF with conventional oxygen therapy (COT) in patients with acute undifferentiated shortness of breath in the ED

METHOD

- **Randomized controlled trial** in two Australian EDs
- 100 patients with undifferentiated shortness of breath
- NHF flow rate was commenced at 50 L/min with FiO_2 at 30%
- Primary outcomes: The need to escalate ventilation therapy or a reduction in respiratory rate of 20% or more within 2 hours

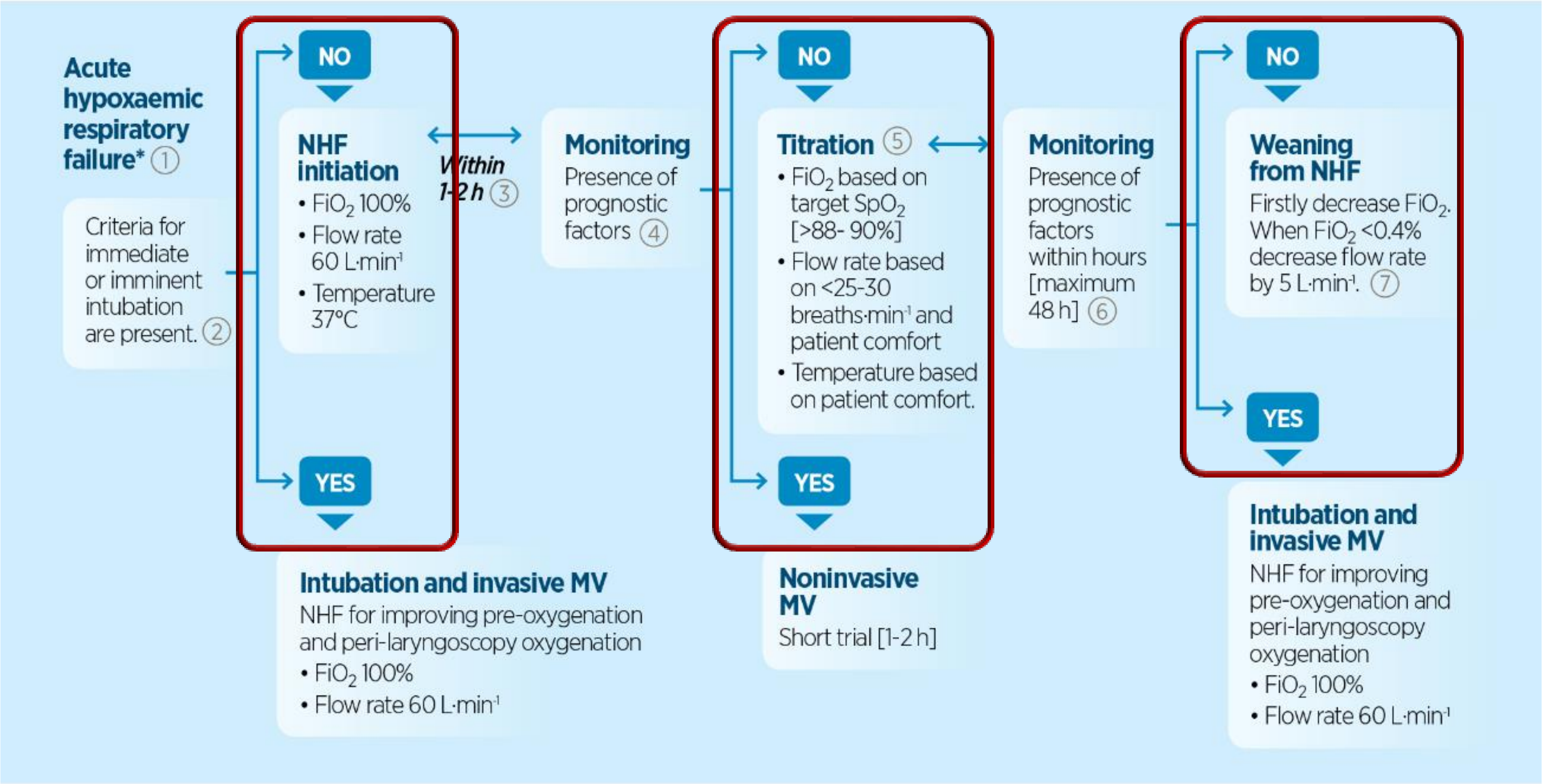
RESULTS

- **Significantly reduced escalation in ventilatory support using NHF**
  4.2% (NHF) vs. 19% (COT), $p = 0.02$
- Higher proportion of patients had > 20% reduction in respiratory rate using NHF
  66.7% (NHF) vs. 38.5% (COT), $p = 0.005$
- More patients demonstrated a reduction in dyspnea
  Modified Borg score: 75% (NHF) vs. 55.8% (COT), $p = 0.044$
- Significant increase in patient comfort with NHF
  Numerical scale out of 5 (very comfortable): 4 (NHF) vs. 3 (COT), $p = 0.035$

Literature review of AHRF studies

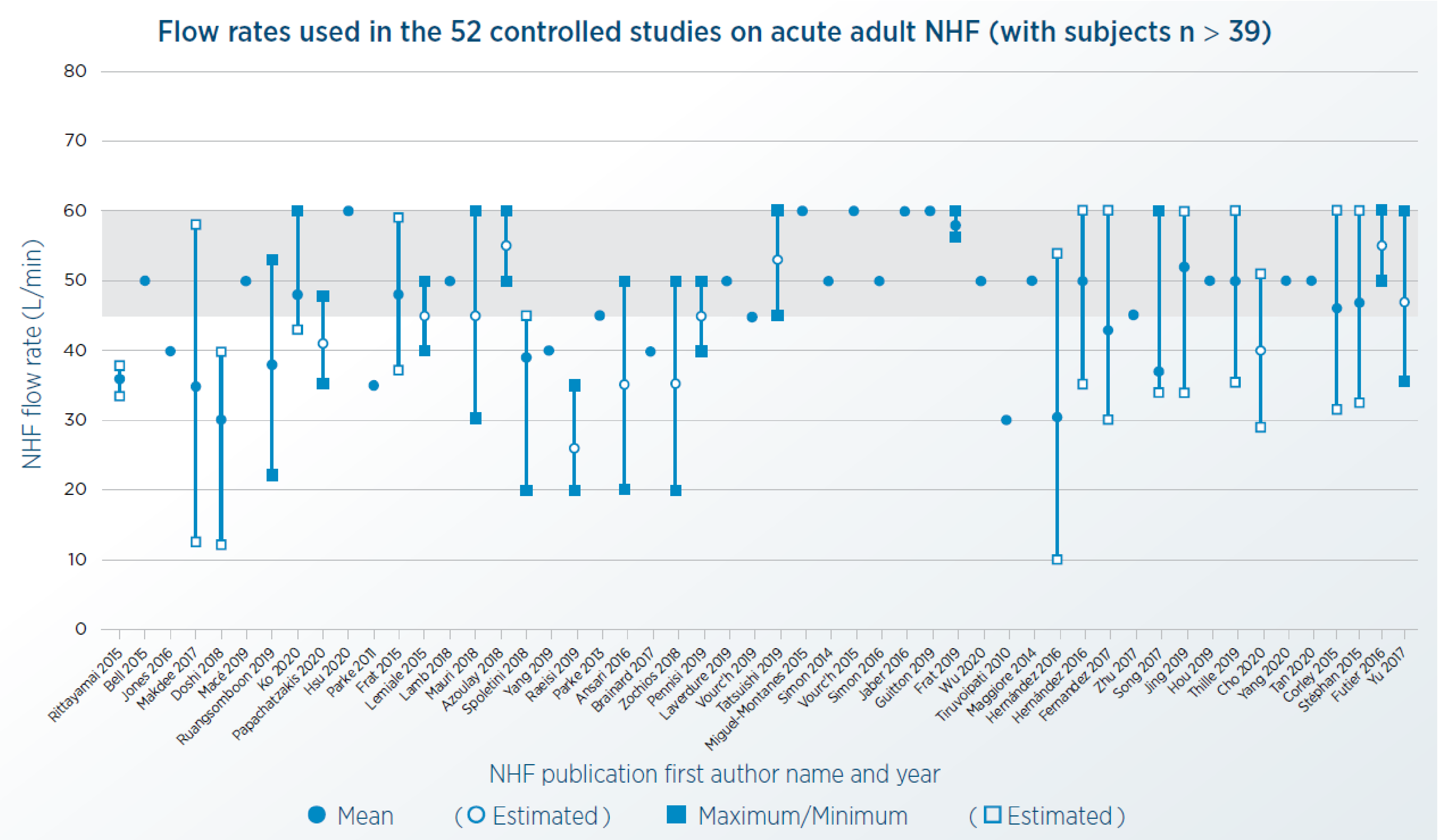
Ischaki et al. 2017

Ischaki. Eur Respir Rev. 2017.



MV = mechanical ventilation; SOT = standard oxygen treatment *Adapted from original paper

Wide body of evidence supporting Nasal High Flow



A recent systematic search of the PubMed database found 52 acute adult NHF controlled studies.

- 85% reported flow rates above 45 L/min

SOCIETY RECOMMENDATIONS AND CLINICAL APPLICATIONS	ESICM	ERS	SSC	AARC	ACP
Avoid intubation	✓	✓	✓[1]	✓	✓
Peri-intubation	✓[2]				
Post-extubation	✓[3]	✓[4]		✓[5]	✓[6]
Rest breaks from NIV		✓			
Avoid escalation				✓	

AARC: American Association for Respiratory Care. ACP: American College of Physicians. SSC: Surviving Sepsis Campaign; ARDS: Acute respiratory distress syndrome; AHRF: Acute hypoxemic respiratory failure. 1. Sepsis-induced hypoxemic respiratory failure; 2. Continuous use of NHF; 3. Following extubation for patients intubated >24hrs and have any high-risk feature; 4. Non-surgical patients; 5. Immediately post-extubation to avoid re-intubation; 6. For post-extubation acute hypoxemic respiratory failure.

AARC CLINICAL PRACTICE GUIDELINES

Piraino T, et al. Respiratory Care. 2021.

General recommendations for the delivery of supplemental oxygen for patients who require oxygen

Aim for SpO_2 range of 94–98% for most of hospitalized patients (included critically ill patients).

Aim for 88–92% for patients with COPD.

Aim for 88–95% for patients with ARDS.

Consider early initiation of NHF.

RECOMMENDATION based on the collective experience

Post-extubation

NHF is preferred to COT immediately post-extubation in patients who require supplemental oxygen.

RECOMMENDATION based on scientific experience

Avoid escalation

NHF is preferred to COT to avoid escalation to NIV or IV in patients who require supplemental oxygen.

RECOMMENDATION based on scientific experience

Immuno-compromised

Either NHF or COT may be used in patients who require supplemental oxygen.

RECOMMENDATION based on scientific experience

Can NHF support hypercapnic patients in the ED?

Jeong et al. 2015 AJEM

REDUCED respiratory rate

REDUCED $PaCO_2$

IMPROVES oxygenation

STUDY

A retrospective analysis of arterial blood gases (ABG) of patients treated with NHF with respiratory failure, with and without hypercapnia in the ED

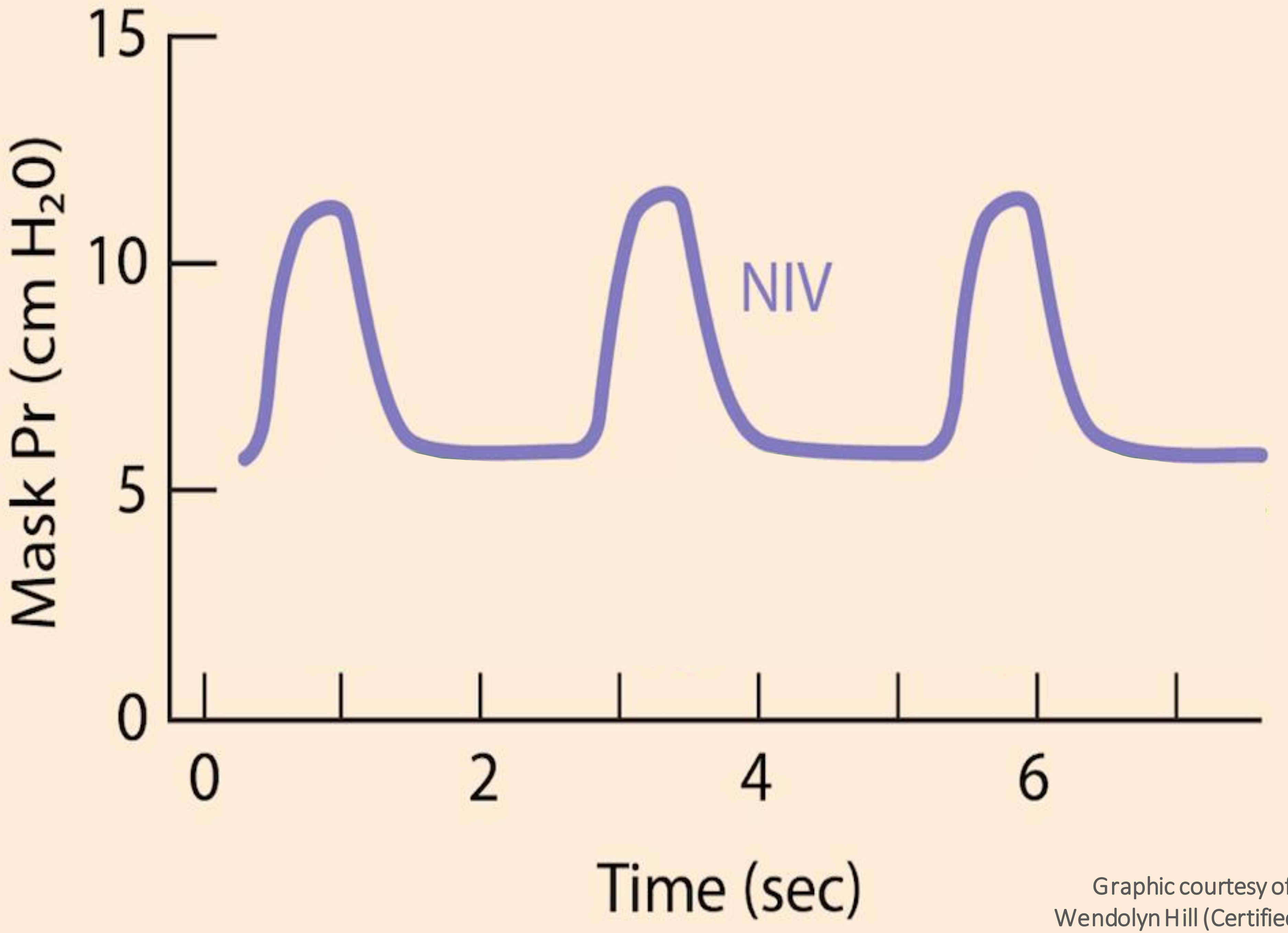
METHOD

- 81 (46 hypercapnic) patients with acute respiratory failure
- NHF flow rate and FiO_2 determined at physician's discretion
- Primary outcome: change in Arterial Blood Gas (ABG)

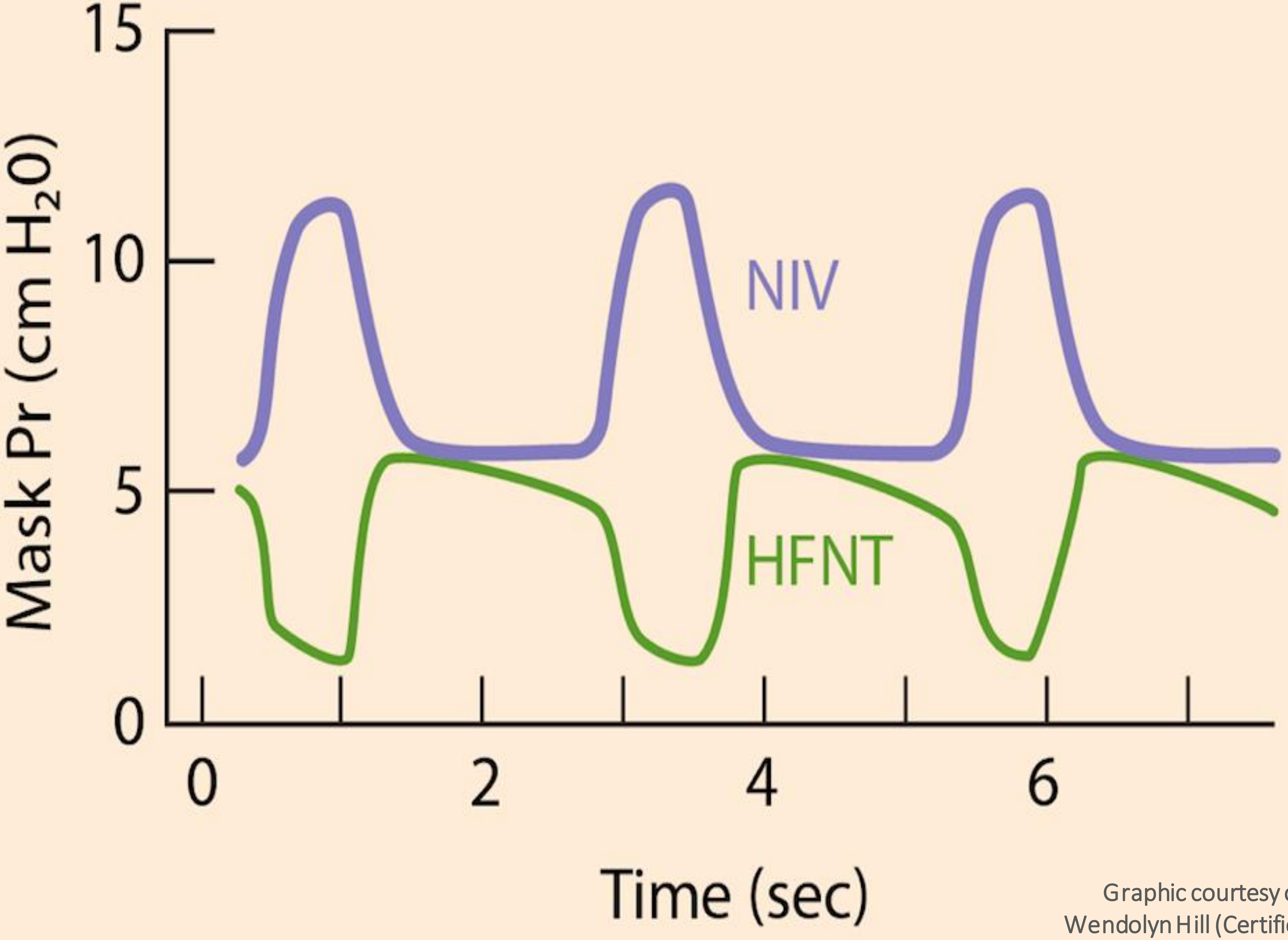
RESULTS

- **Significant reduction in $PaCO_2$ in the hypercapnic group**
  73.2 mmHg ± 20.0 to 67.2 mmHg ± 23.4, $p = 0.02$
- Significant increase in PaO_2 and SpO_2 for hypercapnic and nonhypercapnic patients
  overall 64.7 mmHg ± 33.3 to 80.0 mmHg ± 31.4, $p < 0.01$
  overall 83.5% ± 14.4 to 92.0% ± 7.3, $p < 0.01$
- Significant reduction in respiratory rate for patients with hypercapnia
  24.7 breaths per minute ± 5.8 to 23.6 ± 5.2, $p = 0.03$

Jeong. AJEM. 2015.



Graphic courtesy of Dr Nicholas Hill and Wendolyn Hill (Certified Medical Illustrator)



Graphic courtesy of Dr Nicholas Hill and Wendolyn Hill (Certified Medical Illustrator)

Cortegiani et al. 2020

Critical Care

High flow nasal therapy versus noninvasive ventilation as initial ventilatory strategy in COPD exacerbation: a multicenter non-inferiority randomized trial.

NHF VS NIV

Design

9 centered RCT

Patients

n = 79

Mild-to-moderate AECOPD (pH 7.25–7.35, $PaCO_2 \geq 55$ mmHg before ventilator support)

Intervention	Control
NHF	NIV

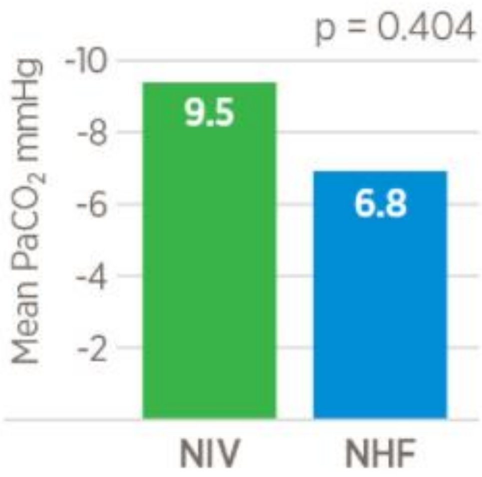
Outcome

Primary: $PaCO_2$ from baseline to 2 h (non-inferiority margin 10 mmHg)

Secondary: non-inferiority of NHF to NIV in reducing $PaCO_2$ at 6 h rate of treatment changes, dyspnea, discomfort, RR, ABG, hospital LoS, mortality

Results

Mean $PaCO_2$ reduction from baseline at 2 hours



- NHF was non-inferior to NIV in reduction of $PaCO_2$ ($p = 0.0003$).
- Both treatments had a significant effect on $PaCO_2$ reductions over time, and trends were similar between groups.
- 32% of NHF patients required NIV by 6 h.

Pantazopoulos et al. 2020 COPD: Journal of Chronic Obstructive Pulmonary Disease

Nasal high flow use in COPD patients with hypercapnic respiratory failure: treatment algorithm & literature review

Design

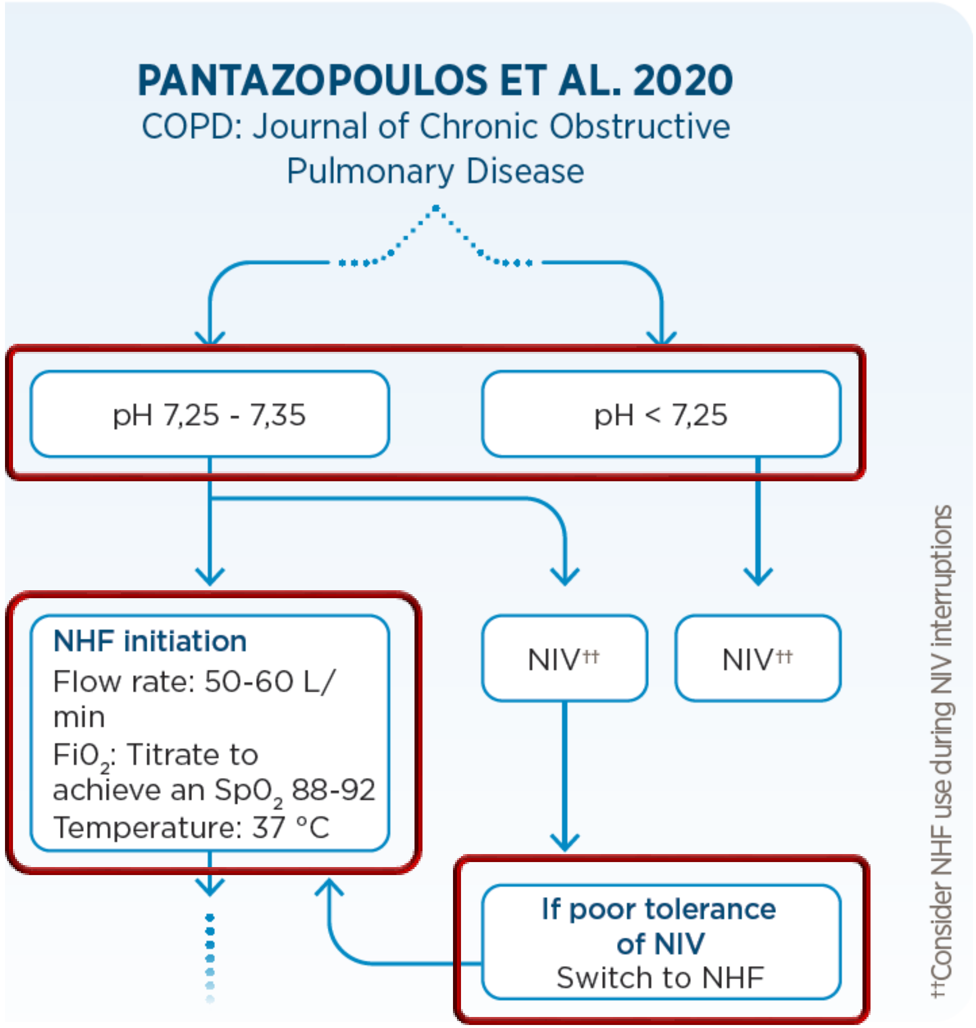
Literature review

Aim

Discuss suitability of NHF therapy for COPD patients who cannot tolerate NIV and propose a therapy algorithm for patients with AECOPD based on current literature.

Search result

AECOPD (9 studies)



Conclusions

NHF may be used in place of NIV in least tolerate and compliant patients, or in association with NIV to reduce mask-related side effects.

Takeaway

NHF recommended as initial ventilatory support for patients with:

- pH between 7.25 – 7.35
- $PaCO_2 \geq 45$ mmHg
- Escalate to NIV for pH < 7.25

Outline

1 Quick recap: mechanisms of action for NHF

2 How has clinical evidence lead to Clinical Practice Guidelines?

3 **Hot topic questions: Pediatrics? Therapy success?**

4 Q&A

Hot topic questions

Question 1: How can we utilize NHF with pediatric patients?

Question 2: How can we determine NHF therapy success or failure?

Landmark Study: The PARIS Trial

The largest NHF RCT was conducted by Franklin et al.[1] This multi-center RCT supports the use of NHF in the ED and general care areas in young infants with bronchiolitis

1,472 patients (< 12 months) with bronchiolitis

17 Emergency Departments and Wards

The primary outcome of the study was that the use of NHF at 2 L/kg/min as a primary treatment in the ED and general care areas resulted in a significantly lower rate of therapy failure compared with standard oxygen therapy (12 vs. 23%, $p < 0.001$). Therapy failure was defined as an escalation of therapy or PICU admission.

Reduced patient escalation

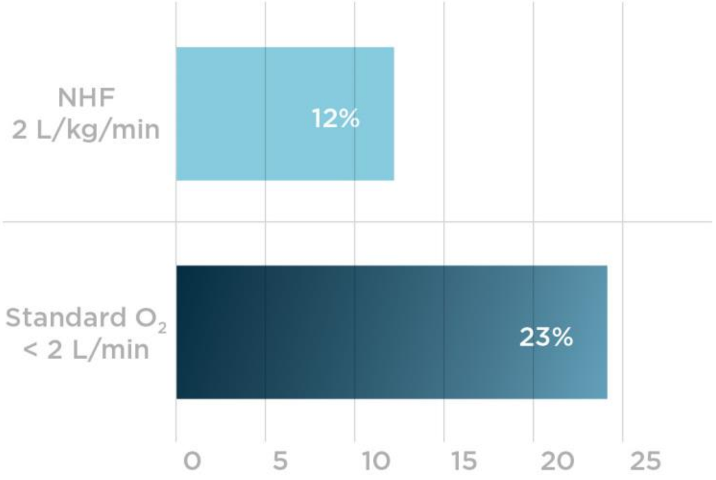
Q1: NHF with pediatrics?

Franklin 2018, N Engl J Med[1]

- Patients receiving NHF at 2 L/kg/min are half as likely to fail vs. standard O_2 < 2 L/min.
- All patients who failed standard O_2 received rescue NHF.
  - 61% of them responded to NHF and avoided PICU.

Note: Standard O_2 = 100% O_2 NHF at 2 L/kg/min = Total flow/kg/min; FiO_2 titrated

Therapy failure



Those who received NHF had significantly lower rates of escalation of care due to therapy failure than those receiving standard O_2 ($p < 0.001$).[1]

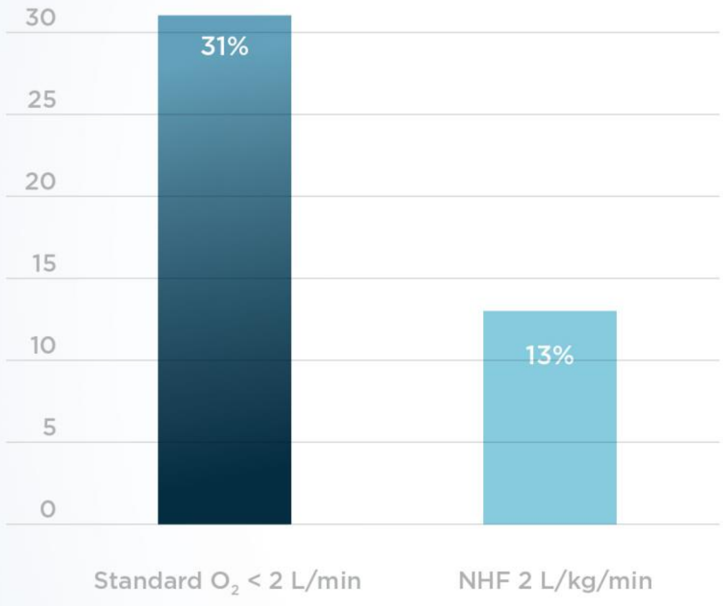
1. Franklin et al. *N Engl J Med* 378, 1121–1131 (2018).

Optimizing NHF in the ED

Q1: NHF with pediatrics?

Introducing NHF in the ED

PICU Admissions (Mayfield 2014)[1]

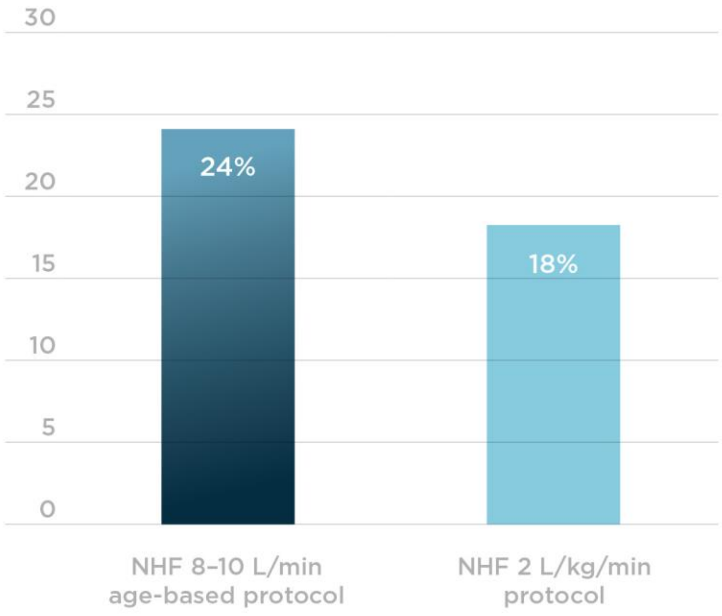


- → PICU admissions reduced by 18%.
- → Estimated US$850K savings per year by avoiding PICU (for a 19-bed PICU).

Note: Standard O_2= 100% O_2
NHF at 2 L/kg/min = Total flow/kg/min; FiO_2 titrated

Age-based vs. weight-based NHF

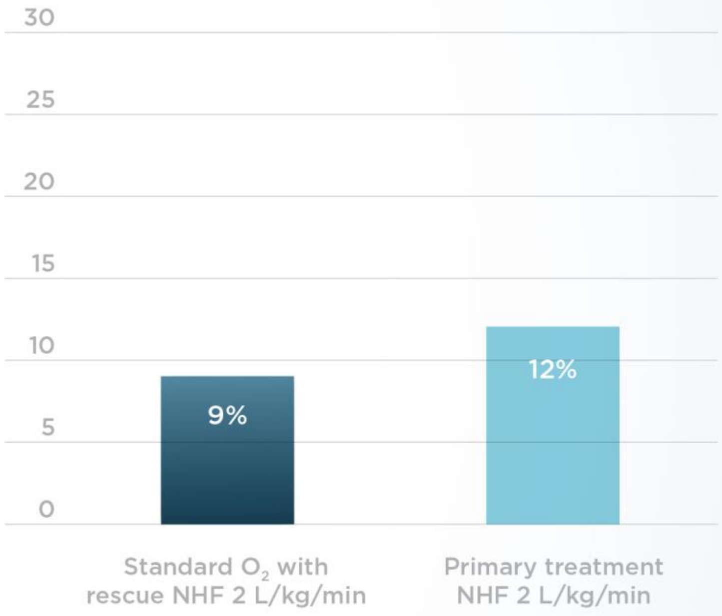
PICU Admissions (Willer 2021)[2]



- → PICU admissions reduced by 6.2%.
- → US$661 savings per bronchiolitis patient by avoiding PICU.

Primary NHF vs. Early rescue NHF

PICU Admissions (Vijay 2020)[3]



- → No statistically significant difference in PICU admissions due to use of rescue NHF.
- → Cost neutral.

Note: Cost analysis of the Franklin study.[4]

1. Mayfield et al. *J Pediatric Child Health* 50, 373–378 (2014). 2. Willer et al. *Hosp Pediatr* 11, 891–895 (2021).
3. Vijay et al. *Arch Dis Child* 105, 975–980 (2020). 4. Franklin et al. N Engl J Med 378, 1121–1131 (2018).

Q1: NHF with pediatrics?

Landmark Study: The FIRST-ABC Trial

First-line Support for Assistance in Breathing in Children (FIRST-ABC) was designed as a master protocol of two pragmatic noninferiority RCTs by Ramnarayan et al.[13] These RCTs investigated the safety and efficacy of NHF and CPAP when used as:

- → Post-extubation support in critically ill children (Step down)
- → First-line support in acutely ill children (Step up)

Treatment Algorithm. A standardized treatment protocol was used to ensure the consistency of treatment across the multiple centers involved in the study.

CPAP (7 – 8 cmH_2O) or NHF starting at 2 L/kg/min → Weaning therapy → Stopping therapy → Success: ≥ 48 hours free from respiratory support | Primary Outcome: Time to liberation from respiratory support

Q1: NHF with pediatrics?

Reduced length of stay and sedation

Ramnarayan 2022 JAMA[1]

PICU

NHF as primary treatment was non-inferior to CPAP for time on respiratory support.

Therapy failure was less likely in the NHF group compared with the CPAP group.

31% of patients switched to NHF

Predominantly due to discomfort

20% of patients switched to CPAP

Predominantly due to clinical deterioration

Of the secondary outcomes, the NHF group had significantly:

Step up

- **9.3%** Lower use of sedation
  NHF 27.7% vs. CPAP 37.0%
- **3.1** Less days in PICU
- **7.6** Less days in hospital
- Fewer occurrences of nasal trauma
  NHF 2.0% vs. CPAP 6.5%

1. Ramnarayan et al. *JAMA* 328(2), 162-172 (2022).

Pediatric weight vs flow rate

Q1: NHF with pediatrics?

Recent evidence supports flow of ≥ 2 L/kg/min for infants up to 12 kg.[1-5]

Flow rates for those over 12 kg have been protocolized by the PARIS 1 and 2 research group.[5]

Weight	Flow Rate
Up to 12 kg	2 L/kg/min
13–15 kg	30 L/min
16–30 kg	35 L/min
31–50 kg	40 L/min
>50 kg	50 L/min

† Systematic research of the available literature conducted on July 21 2021 using predefined search terms, with data extraction and screening performed via DistillerSR (Evidence Based Partners, Ottawa, Ontario) by internal clinical researchers. An F&P Optiflow system is defined as a flow source (either independent or integrated) with an F&P humidifier and an F&P Optiflow interface.

1. Brink et al. *Pediatr Crit Care Med* 14, 326–331 (2013). **2.** *Milési et al. Intensive Care Med* 39, 1088–1094 (2013).
3. *Pham et al. Pediatr Pulmonol* 50, 713–720 (2014) **4.** *Schlapbach et al. Intensive Care Med* 40, 592–599 (2014).
5. Franklin et al. *BMJ Open*. 9, e030516. (2019). **6.** Franklin et.al. *N Engl J Med* 378, 1121–1131 (2018)

Q2: Determining NHF therapy success

Sztrymf et al, 2011 associates nasal high flow (NHF) with sustained beneficial effects on oxygenation and clinical parameters in patients with acute respiratory failure[1]

Respiratory rate reduction appears to be a predictor of therapy success[1]

↓ **Respiratory rate**
5 minutes[2] – 15 minutes[1]

↑ **Oxygenation**
10 minutes[2] – 15 minutes[3]

↓ **Dyspnea**
5 minutes[4] – 30 minutes[1]

↓ **Supraclavicular retraction**
30 minutes[1]

↓ **Thoracoabdominal asynchrony**
30 minutes[1]

1. Sztrymf et al. *Intensive Care Med.* 2011.
2. Rittayamai et al. *Respir Care*, 2014.
3. Lenglet et al. *Respir Care*, 2015.
4. Rittayamai et al. *Respir Care*, 2015.

Q2: Determining NHF therapy success

- Roca & colleagues conducted derivation (2016) and validation (2019) studies of an index to predict the success of HFNC in pneumonia patients with AHRF

- First look at the ROX index: defined by three common noninvasive measurements:

$$\frac{SpO_2 / FiO_2}{RR} = \text{ROX index}$$

- Oxygen saturation measured by SpO_2 / FiO_2 had a greater weight than RR

$$\frac{SpO_2/FiO_2}{\text{Respiratory rate}} = \text{ROX index}$$

'Healthy' example

$$\frac{95/0.21}{15} = 30.2$$

'Patient' example

$$\frac{95/0.85}{37} = 3.0$$

"The authors confirmed that a ROX value of ≥ 4.88 predicted the success of NHF"

Roca et al. 2016

Q2: Determining NHF therapy success

Roca et al. 2019

When an adult respiratory compromised patient presents …

If hypoxemic:

Low levels of blood oxygen

- SpO_2 < 92%, ABG: PaO_2 < 75mm Hg

Frat. NEJM. 2015.

- 23 ctr RCT, 310 pts AHRF, NHF vs COT vs NIV
- NHF reduced mortality and need for intubation

Bell. Emerg Med Aust. 2015.

- 2 ctr RCT, 100 ED pts with acute undifferentiated shortness of breath, NHF vs COT
- NHF reduced escalation in ventilatory support

Ischaki. Eur Resp Rev. 2017.

- Literature review (99 papers) and treatment algorithm

Clinical Practice Guidelines

- ESICM, 2020 – **recommend HFNC over COT**
- AARC, 2021 – **recommend HFNC over COT**
- ACP, 2021 – **use HFNC over NIV**
- SCCM, 2021 – **suggest HFNC over NIV**

If hypercapnic:

High partial pressure of blood carbon dioxide

- $PaCO_2$ > 45 mmHg, pH < 7.35

Jeong. Am J Emerg Med. 2015.

- Retrospective ABG analysis of 81 ED pts with ARF
- Reduced $PaCO_2$ and RR in hypercapnic group
- Increased PaO_2 and SpO_2 for hypercapnic and non-hypercapnic groups

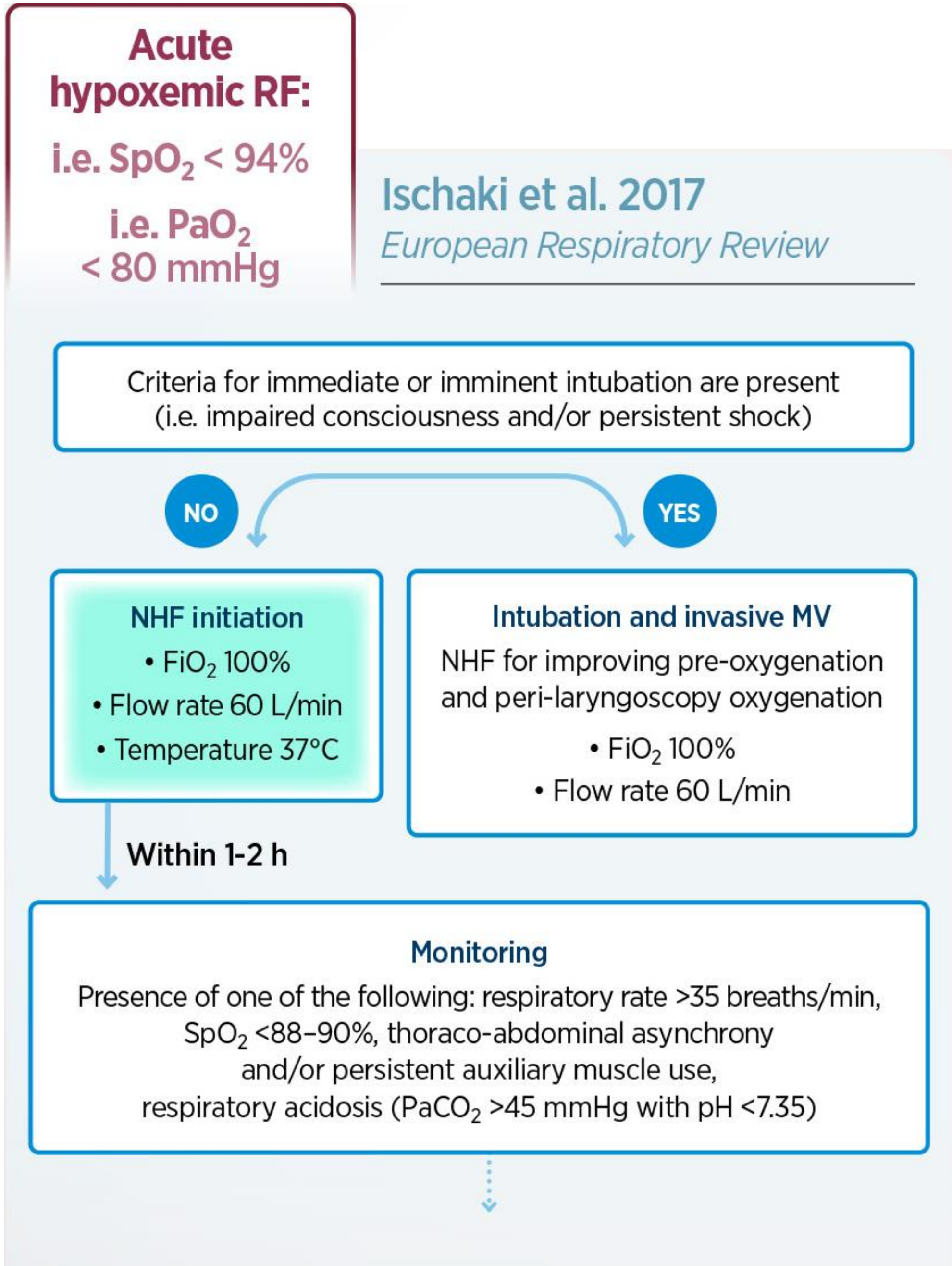
Cortegiani. Crit Care. 2020.

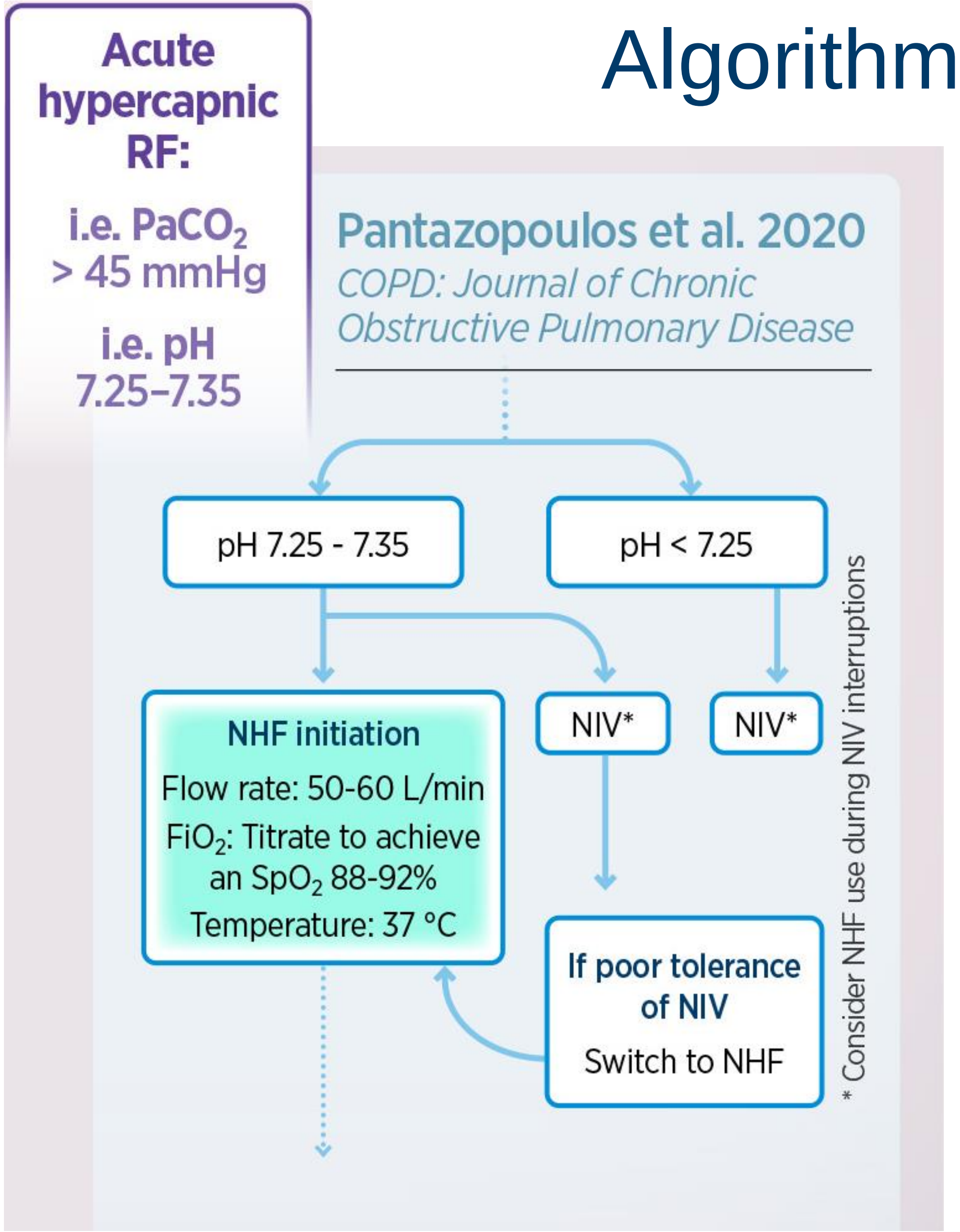
- 9 ctr RCT, 79 pts AECOPD, NHF vs NIV
- NHF non-inferior to NIV as initial ventilatory support
- 32% of pts receiving NHF required NIV by 6h

Guidance

- Pantazopoulos. COPD. 2020.
  Literature review (9 RCTs) and treatment algorithm
  NHF recommended for patients with
    - pH between 7.25 – 7.35
    - escalate to NIV for pH < 7.25

Algorithms


Acute hypoxemic RF:
i.e. SpO_2 < 94%
i.e. PaO_2 < 80 mmHg
Ischaki et al. 2017
European Respiratory Review
Criteria for immediate or imminent intubation are present (i.e. impaired consciousness and/or persistent shock)
NO
YES
NHF initiation
• FiO_2 100%
• Flow rate 60 L/min
• Temperature 37°C
Intubation and invasive MV
NHF for improving pre-oxygenation and peri-laryngoscopy oxygenation
• FiO_2 100%
• Flow rate 60 L/min
Within 1-2 h
Monitoring
Presence of one of the following: respiratory rate >35 breaths/min, SpO_2 <88–90%, thoraco-abdominal asynchrony and/or persistent auxiliary muscle use, respiratory acidosis ($PaCO_2$ >45 mmHg with pH <7.35)


Acute hypercapnic RF:
i.e. $PaCO_2$ > 45 mmHg
i.e. pH 7.25–7.35
Pantazopoulos et al. 2020
COPD: Journal of Chronic Obstructive Pulmonary Disease
pH 7.25 - 7.35
pH < 7.25
NHF initiation
Flow rate: 50-60 L/min
FiO_2: Titrate to achieve an SpO_2 88-92%
Temperature: 37 °C
NIV*
NIV*
If poor tolerance of NIV
Switch to NHF
* Consider NHF use during NIV interruptions

Can HFNC be used as ***first-line*** *therapy for patients who present with undifferentiated respiratory distress?*

Review

1 Quick recap: mechanisms of action for NHF

2 How has clinical evidence lead to Clinical Practice Guidelines?

3 Hot topic questions: Pediatrics? Therapy success?

4 Q&A

Thank you from Fisher & Paykel Healthcare

Open for any questions

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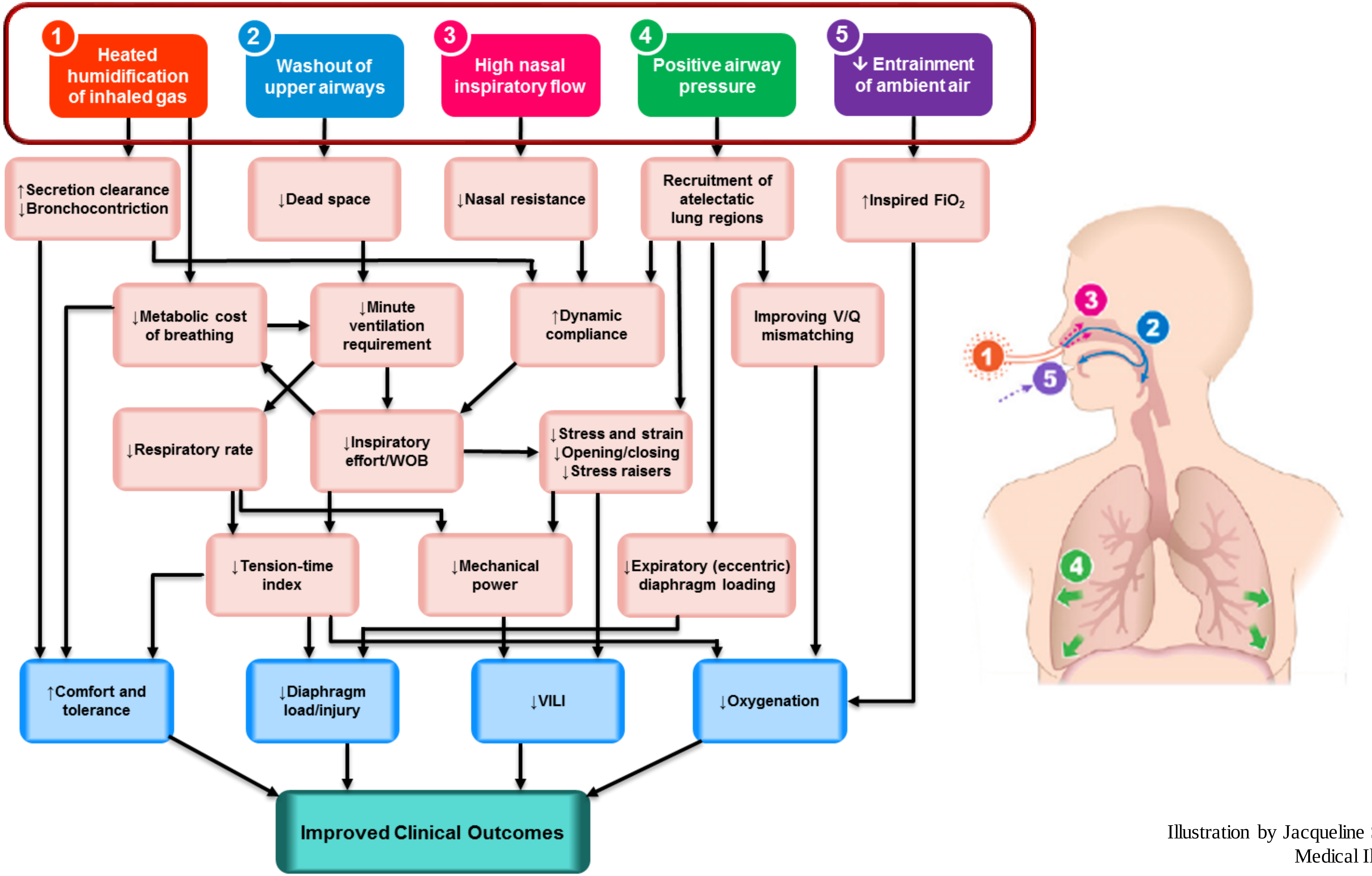
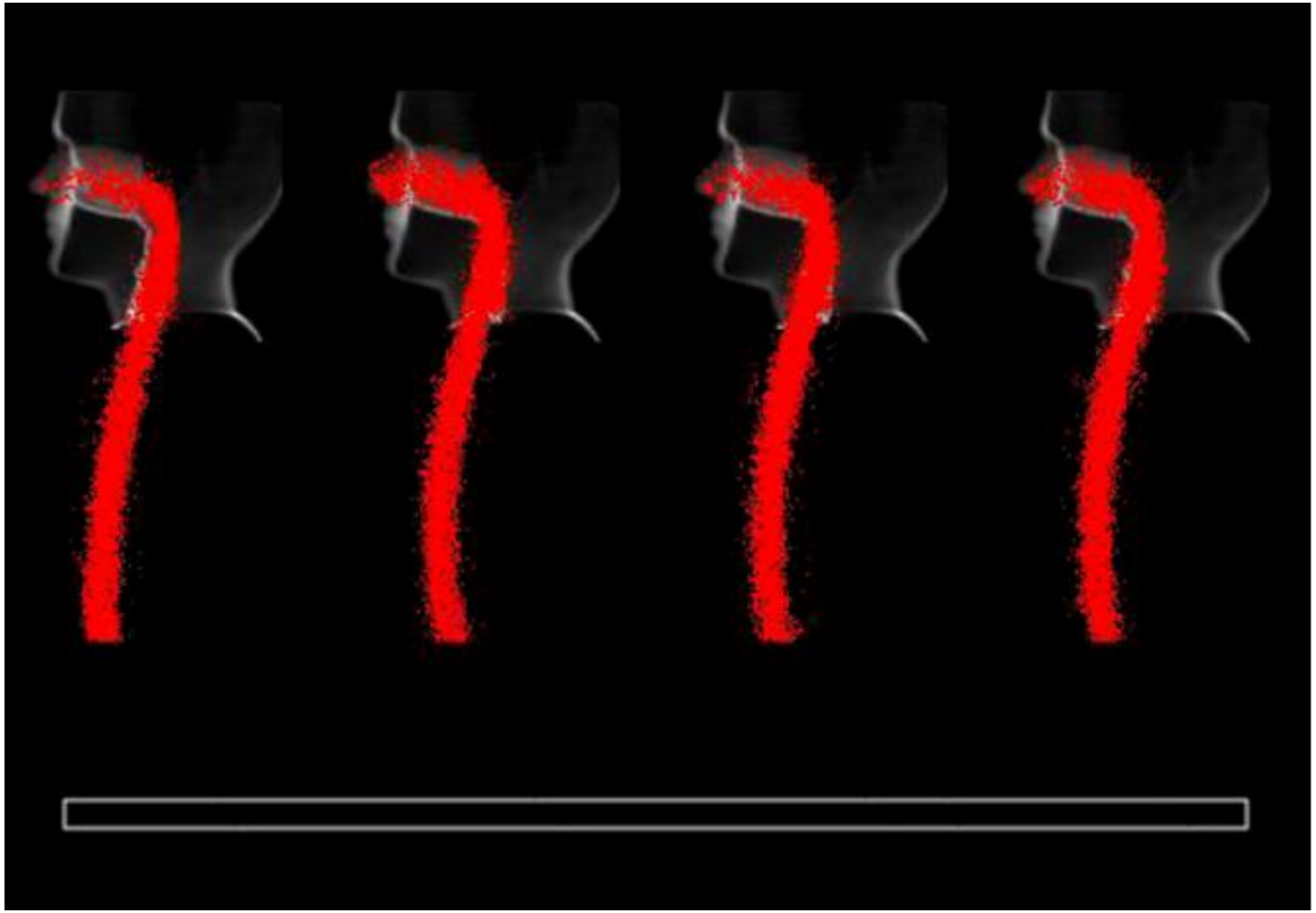
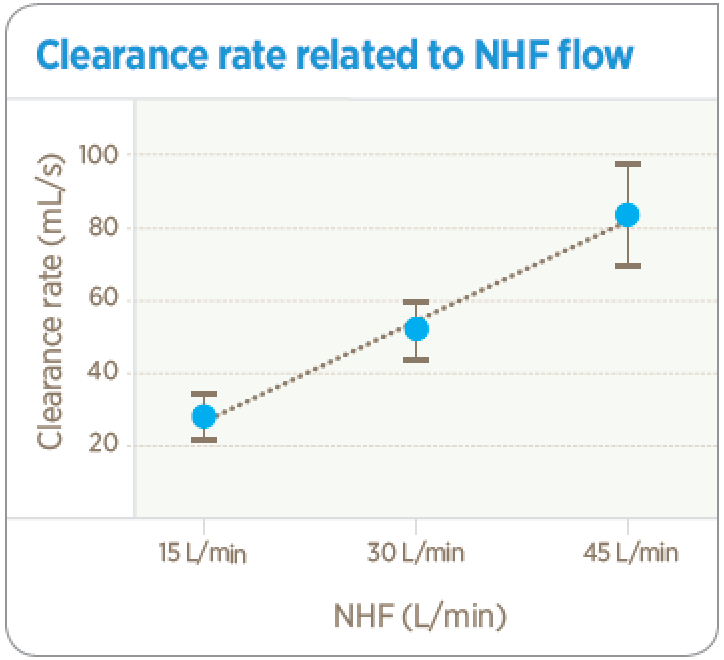


Illustration by Jacqueline Schaffer
Medical Illustrator

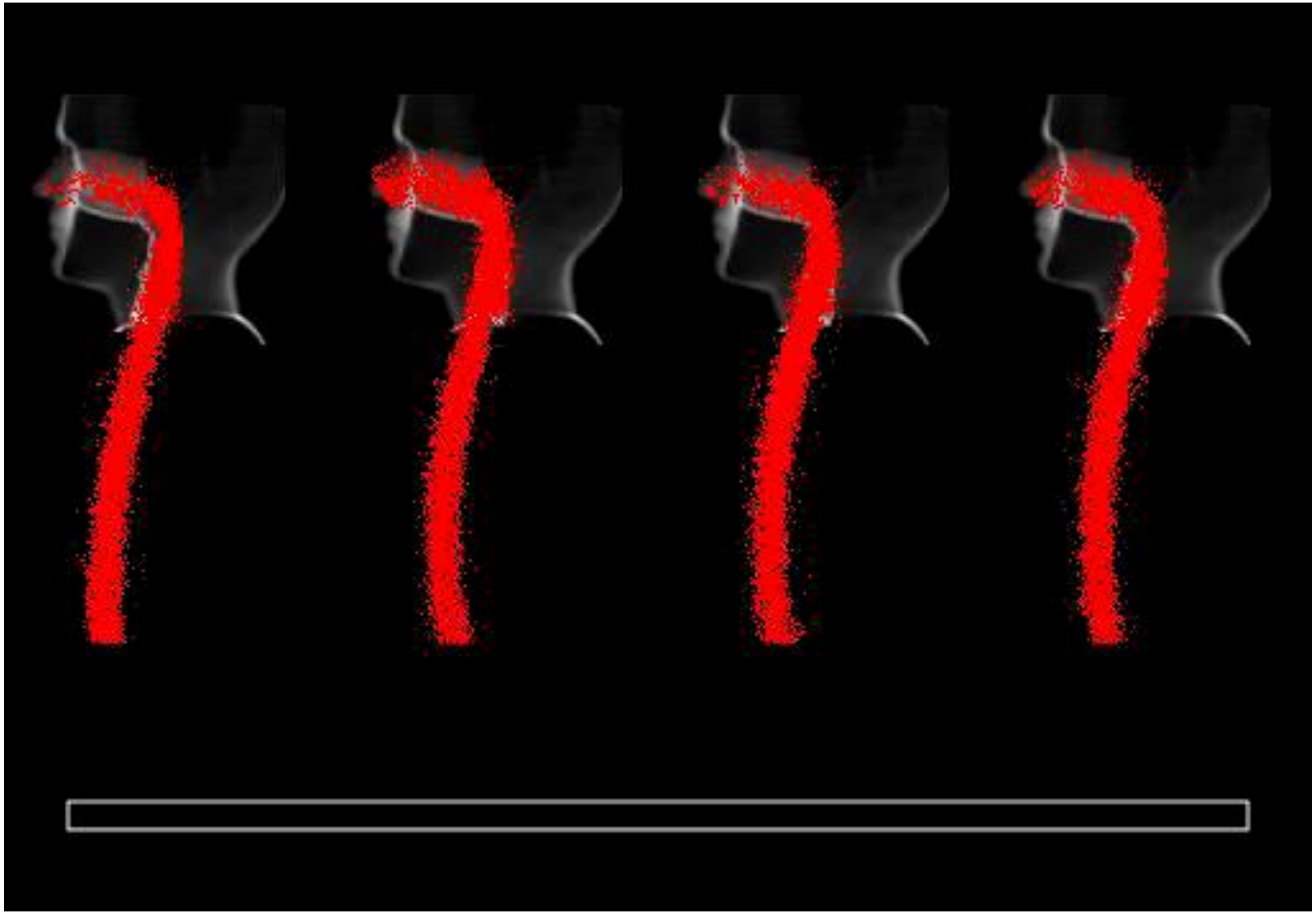
Reduction of dead space: Moller





Adapted from Möller et al. J Appl Physiol. 2015.

Reduction of dead space: Moller



What changes are seen in patients using NHF?

NHF increases airway pressure, end-expiratory lung volume and tidal volume.[1]

ESICM CLINICAL PRACTICE GUIDELINES

Rochwerg B, et al. Intensive Care Medicine. 2020.

Acute hypoxemic respiratory failure

NHF is preferred to conventional oxygen therapy (COT) for patients with hypoxemic respiratory failure.

STRONG RECOMMENDATION

Peri-intubation

No recommendation is made regarding use of NHF in the peri-intubation period.

NHF during intubation should be continued for patients who are already receiving NHF.

CONTINUE NHF

Post-extubation respiratory failure

NHF is preferred to COT following extubation in patients with any high-risk feature who were intubated for >24 hours.

NIPPV is preferred to NHF in patients who would normally be extubated to NIPPV.

CONDITIONAL RECOMMENDATION

Post-operative

NHF is preferred to COT in high risk and/or obese patients undergoing cardiac or thoracic surgery to prevent respiratory failure in the immediate postoperative period.

Prophylactic NHF to prevent respiratory failure in other postoperative patients is not recommended.

CONDITIONAL RECOMMENDATION

ERS CLINICAL PRACTICE GUIDELINES

Oczkowski S, et al. European Respiratory Journal. 2021.

Acute hypoxemic respiratory failure

NHF is preferred to COT or NIV in patients with acute hypoxemic respiratory failure.

CONDITIONAL RECOMMENDATION

Acute hypercapnic respiratory failure

Trialling NIV prior to use of NHF in patients with COPD or acute hypercapnic respiratory failure.

CONDITIONAL RECOMMENDATION

Post-extubation

NHF is preferred to COT in non-surgical patients.

NIV is preferred to NHF in non-surgical patients at high risk of extubation failure, unless NIV is contra-indicated.

CONDITIONAL RECOMMENDATION

Post-operative

Either NHF or COT can be used in post-operative patients at low risk of respiratory complications.

Either NHF or NIV can be used in post-operative patients at high risk of respiratory complications.

CONDITIONAL RECOMMENDATION

Breaks from NIV

NHF is preferred to COT during breaks from NIV in patients with acute hypoxemic respiratory failure.

CONDITIONAL RECOMMENDATION

Hypoxemic patients

icm INTENSIVE CARE MEDICINE · ESICM

The role for high flow nasal cannula as a respiratory support strategy in adults: a clinical practice guideline.
Rochwerg B, et al. 2020

“We **recommend** using HFNC compared to COT for patients with acute hypoxemic respiratory failure.”

ACP American College of Physicians — Leading Internal Medicine, Improving Lives

Appropriate use of high flow nasal oxygen in hospitalized patients for initial or postextubation management of acute respiratory failure: A clinical guideline.
Qaseem A, et al 2021

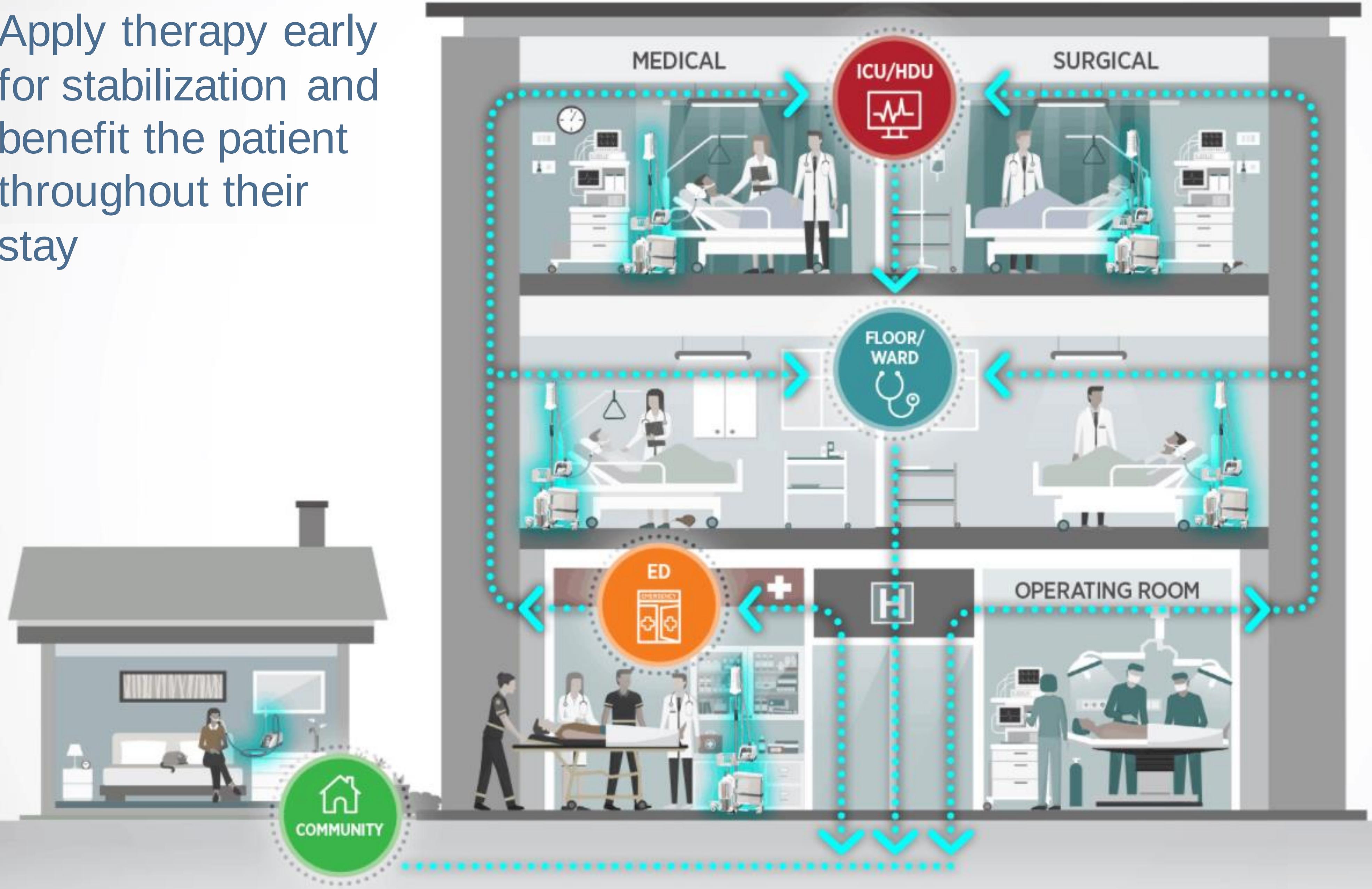
“Use high-flow nasal oxygen rather than noninvasive ventilation in hospitalized adults for the management of acute hypoxemic respiratory failure.”

Society of Critical Care Medicine — The Intensive Care Professionals

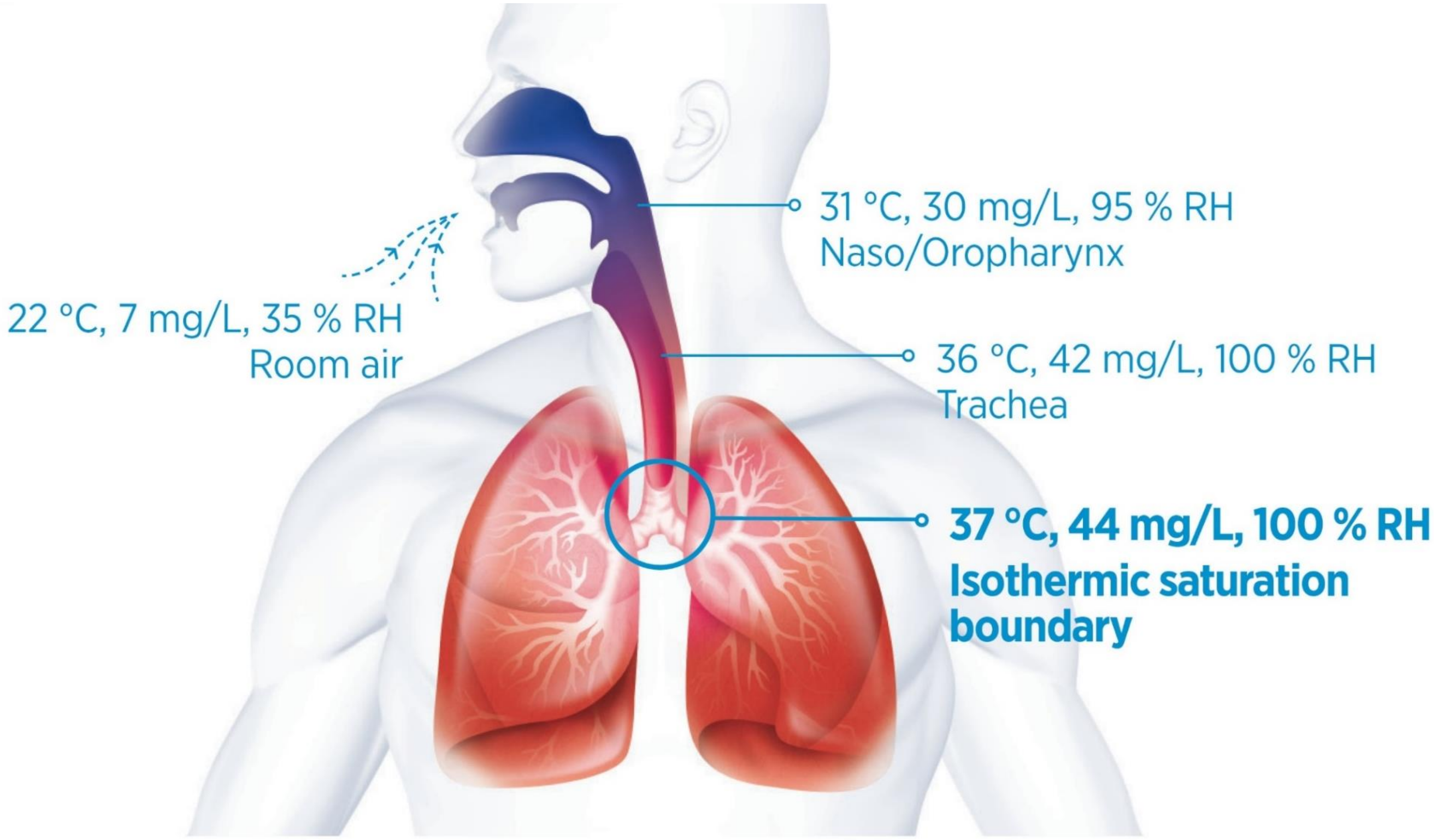
Surviving Sepsis Campaign, 2021: international guidelines for management of sepsis and septic shock
Evans L, et al. 2021

“For adults with sepsis-induced hypoxemic respiratory failure, we **suggest** the use of high flow nasal oxygen over noninvasive ventilation.”

Apply therapy early for stabilization and benefit the patient throughout their stay



Optimal humidity



Multi-disciplinary implementation

Jackson et al. 2021

Respiratory Care

Implementation of high-flow nasal cannula therapy outside the intensive care setting.

Design

Single center cohort observational study (pre and post NHF implementation)

Patients

n = 346

Initiation or discontinuation of therapy outside the ICU

Intervention

18-month after implementing NHF therapy

Control

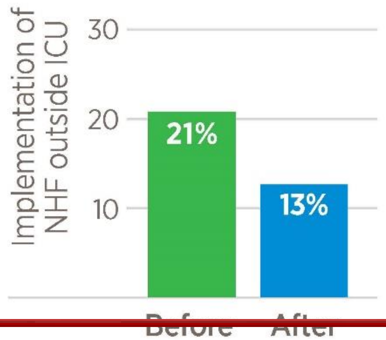
Prior to NHF implementation

Outcome

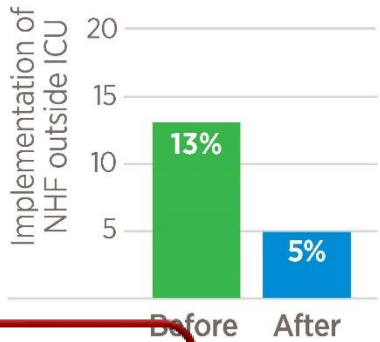
Share education and implementation process. Report patient outcomes

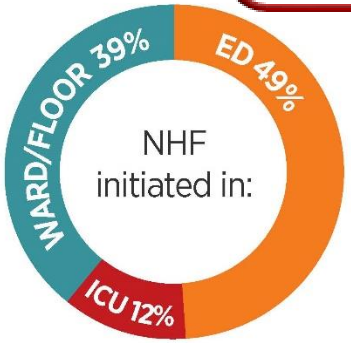
Results

Mortality



Escalation to MV





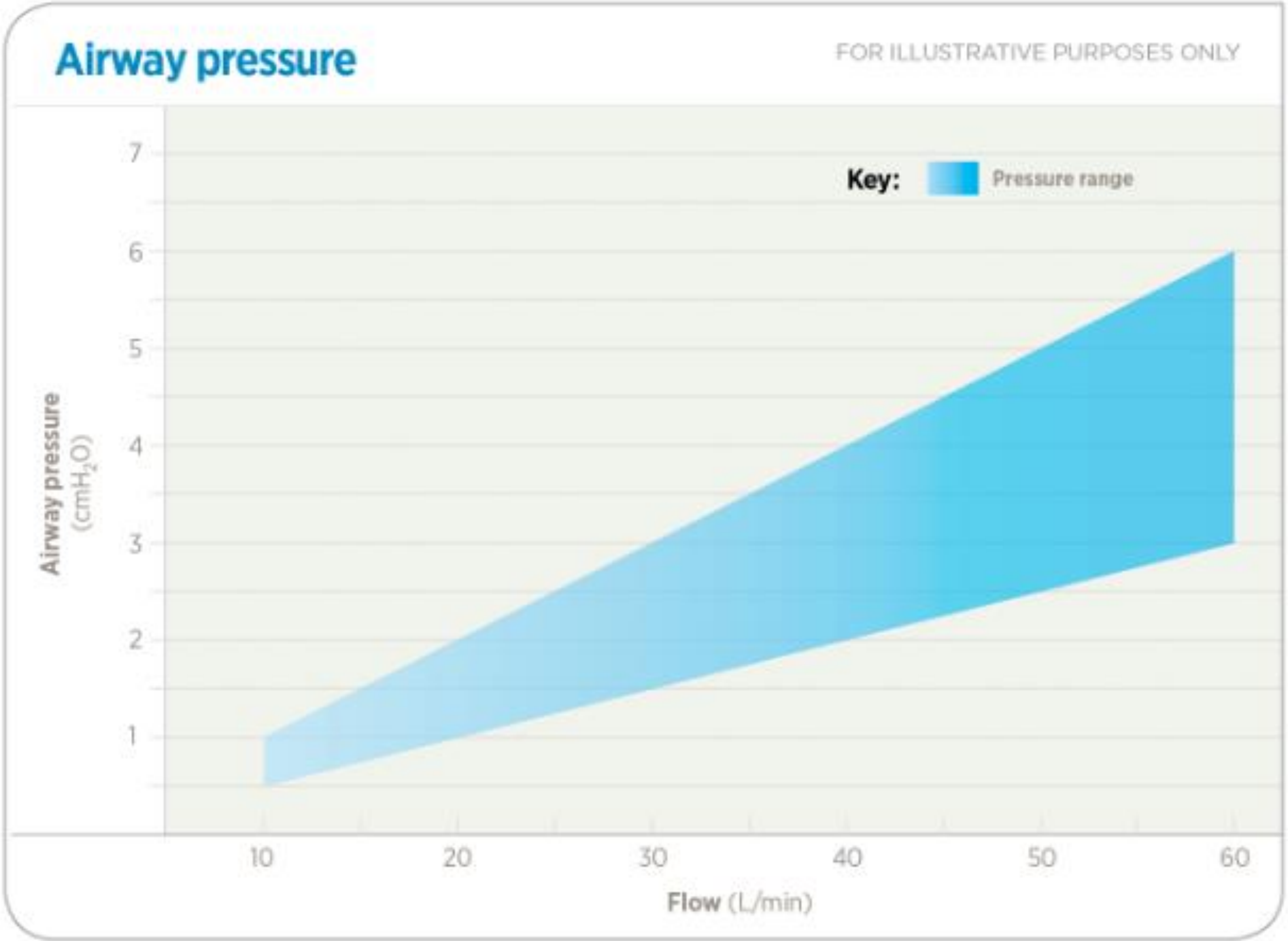
After implementation:

- **53% (n = 184) of NHF patients avoided the ICU completely**
- **486 ICU days were avoided**

What flow rates should be used for AHRF patients?

*at 12 hours post extubation

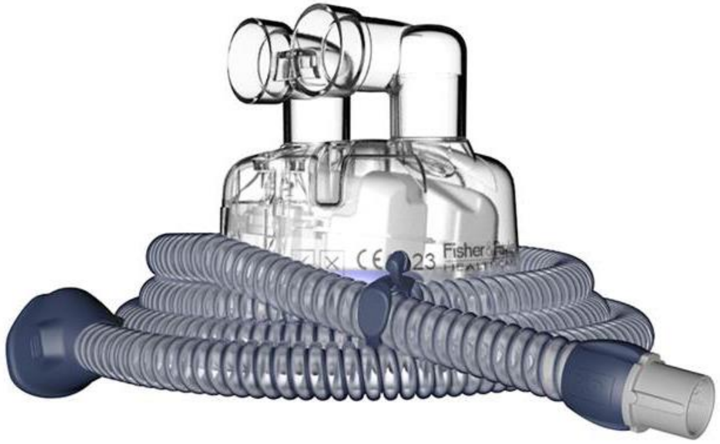
How much pressure is generated?



Pressure increases approximately 0.5 - 1 cmH_2O per 10 L/min[1-3]

1. Parke et al. *Respir Care.* (Aug) 2011.
2. Groves et al. *Aust Crit Care.* 2007.
3. Ritchie et al. *Anaesth Intensive Care.* 2011.

900PT563 Airvo Tube & Chamber Kit w/ Nebulizer Adaptor



900PT561

Airvo Neb adapter

900PT563

Fisher&Paykel HEALTHCARE

What are the delivered & respirable dose?

Albuterol sulfate (1 mg/mL, 2.5 mL)	10 L/min	20 L/min	30 L/min
Delivered dose (µg)*	1,362.9 – 2,087.7	548.6 – 1,938.0	383.3 – 1,461.80
Delivered %	**55 – 84**	**22 – 78**	**15 – 58**
Respirable dose (µg, 1-5 µm)*	1,035.9 – 1,550.3	470.7 – 1,428.2	387.9 – 837.3
Respirable %	**41 – 62**	**19 – 57**	**16 – 33**

Testing completed with one Aerogen Solo nebulizer, three sets of Airvo 2, 900PT563 Airvo Tube & Chamber Kit with Nebulizer Adapter, OPT970 tracheostomy interface and three tests per set. * 95% confidence intervals

Fisher&Paykel HEALTHCARE

What is the inhaled dose using Airvo and Aerogen Solo?

Firstly, a quick reminder that the FDA does not approve the nasal delivery of aerosolized drugs or medications for lung deposition.

- *Alolaiwat (2021) demonstrated that the inhaled dose of albuterol was higher with vibrating mesh nebulizer (VMN) via Airvo 2 than Vapotherm Precision Flow at flows of 20 L/min **(~10 times higher with Airvo 2**) and 40 L/min (**~6 times higher with Airvo 2**).*

Assessment of Aerosol Delivery and Fugitive Aerosol Particle Concentrations During Aerosol Delivery via Two High Flow Devices: A RCT in Healthy Volunteers

Alolaiwat A, Harnois L, Li J, Fink JB. Rush University. *Poster 2021*

- Two HFNC devices (Airvo 2 and Vapotherm Precision Flow) were utilized with vibrating mesh nebulizer at inlet of the humidifier
- Aerosol particle concentrations were compared between the two devices in random order of setup
- Two aerosol particle sizers measured the fugitive aerosol concentrations at sizes of 0.3 to 10 µm at baseline, before, during and after each experiment
- In-vitro study conducted to evaluate inhaled dose with albuterol at three flow settings (20, 40, 60 L/min for Airvo 2 and 20, 30, 40 L/min for Vapotherm).

What is the inhaled dose using Airvo and Aerogen Solo?

Flow, L/min	Inhaled dose (%)		p
	Vapotherm	Airvo2	
20	1.3 ± 0.1	12.9 ± 0.9	0.05
40	0.8 ± 0.1	5.0 ± 0.2	0.05
60	NA	3.4 ± 0.1	NA

Table1. Inhaled dose of VMN via Vapotherm and Airvo2 at different flow settings.

Fisher&Paykel HEALTHCARE

Assessment of Aerosol Delivery and Fugitive Aerosol Particle Concentrations Generated During Aerosol Delivery via Two High Flow Devices; A Randomized Crossover Study in Healthy Volunteers

RUSH UNIVERSITY

Amnah Alolaiwat[1]; Lauren Harnois[1]; Jie Li [1] James B Fink[1,2]

1 Department of Respiratory Care, College of Health Science, Rush University, Chicago, IL, USA; 2 Aerogen Pharma Corp, San Mateo, CA, USA

Introduction

- Aerosol delivery via high-flow nasal cannula (HFNC) has attracted clinical interests in recent years.
- Both HFNC and aerosol therapy have been considered as aerosol generating procedure (AGP) during COVID-19 pandemic.
- Little is known about the fugitive aerosol concentrations during trans-nasal aerosol delivery and the effective method to reduce the fugitive aerosol concentrations.

figure1. Experiment set up

Methods

- Two HFNC devices (Airvo2 and Vapotherm) were utilized with a vibrating mesh nebulizer (VMN) placed at the inlet of humidifier.
- Aerosol particle concentrations were compared between the two devices, in a random order of:
  - HFNC alone, HFNC with a surgical mask over nasal cannula, HFNC with a scavenger face tent , HFNC with VMN, HFNC with VMN and a surgical mask, and HFNC with VMN and a scavenger face tent.
- Two aerosol particle sizers placed at 1 and 3 feet away from subjects to measure the fugitive aerosol concentrations at sizes of 0.3 to 10 µm at baseline, before, during and after each experiment
- small in-vitro study was conducted to evaluate inhaled dose with albuterol (2.5mg in 3mL) delivered using VMN via the two HFNC devices, three flow settings (20L, 40L, 60L for Airvo2 and 20L, 30L, 40L for Vapotherm) were used. Figure 1.

Disclosures

- Conflict of interest: Dr. Li declares to receive research funding from Fisher & Paykel Healthcare Ltd, Aerogen Ltd, and Rice Foundation, lecture honorarium from AARC and Fisher & Paykel Healthcare Ltd. Also, Dr. Fink is Chief Science Officer for Aerogen Pharma Corp. Other authors have no conflict of interests.
- Research Funding: Study was funded byFisher & Paykel Healthcare Ltd, Aerogen Ltd, and Rice Foundation

Result

- Compared to HFNC alone, nebulization via VMN with Vapotherm device did not generate higher fugitive aerosol concentrations (p>0.05 for all particle sizes). Figure 2.
- Nebulization via VMN with Airvo2 device generated higher fugitive aerosol concentrations at sizes 0.3 to 1.0 µm
- Placing a surgical mask over HFNC or using a scavenger face tent were similar effective in reducing the fugitive aerosol concentrations

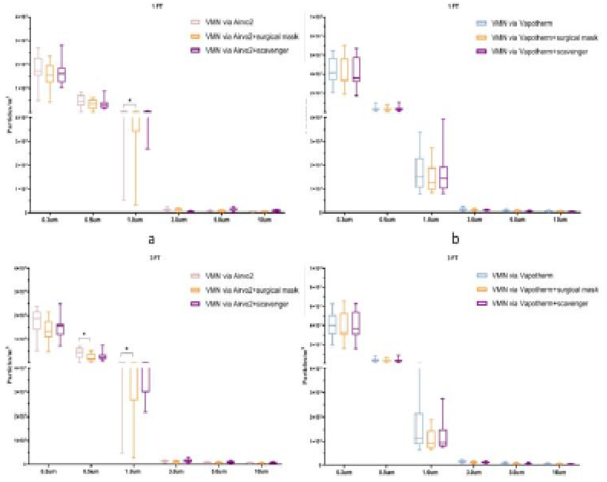


Figure 2. Fugitive aerosol concentrations with Airvo2 vs Vapotherm.

- In the in-vitro study :
  - The inhaled dose of albuterol was higher with VMN via Airvo2 than Vapotherm with HFNC flow of 20 L/min [12.9 ± .9]% vs [1.3 ± .1]%, p=.05) and 40 L/min ([5.0 ± .2]% vs [.8 ± .1]%, p=.05)].

Flow, L/min	Inhaled dose (%)		p
	Vapotherm	Airvo2	
20	1.3 ± 0.1	12.9 ± 0.9	0.05
40	0.8 ± 0.1	5.0 ± 0.2	0.05
60	NA	3.4 ± 0.1	NA

Table1. Inhaled dose of VMN via Vapotherm and Airvo2 at different flow settings.

Conclusion

- Airvo2 generated higher inhaled dose and fugitive aerosol particle concentrations than Vapotherm
- Placing a surgical mask or a scavenger face tent could reduce fugitive aerosol concentrations.

References

- Li J. Narrative review of practical aspects of aerosol delivery via high-flow nasal cannula. Ann Transl Med. 2021 Apr;9(7):590.
- Li J. The Ratio of Nasal Cannula Gas Flow to Patient Inspiratory Flow on Trans-nasal Pulmonary Aerosol Delivery for Adults: An in Vitro Study. Pharmaceutics. 2019 May 10;11(5):225.
- Dhand R,. Coughs and Sneezes: Their Role in Transmission of Respiratory Viral Infections, Including SARS-CoV-2. *American Journal of Respiratory and Critical Care Medicine, 202*(5).
- Ari A. Aerosol Drug Delivery Through High Flow Nasal Cannula. Curr Pharm Biotechnol. 2017;18(11):877-882.
- Bem RA. Risk of Aerosol Formation During High-Flow Nasal Cannula Treatment in Critically Ill Subjects. Respir Care. 2021 Jun;66(6):891-896.