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**Disclosures**

Senior Product Manager (Nasal High Flow) for Fisher & Paykel Healthcare

Crazy about my sons, Alex (11) & Matthew (9), and the New Zealand All Blacks Rugby Team

Pittsburgh Steelers supporter



Fisher & Paykel Healthcare logo

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**Learning Objectives**

Attendees will be familiar with the application of Nasal High Flow in the pediatric and adult population and the literature supporting its use.

- Identify the four mechanisms of action for Nasal High Flow
- Understand the physiological effects of Nasal High Flow
- Describe the clinical outcomes of implementing Nasal High Flow

Fisher & Paykel Healthcare logo

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Outline

History & background

Mechanisms of action to physiological effects to clinical outcomes

Pediatric to adult



Implementation to usage

Horizontal lines for notes

History & background

1214 DECEMBER 7, 1968 PRELIMINARY COMMUNICATIONS THE LANCET

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.

Department of Anaesthesia, Rigshospitalet, Copenhagen, Denmark. NIELS LOMHOLT M.D. Copenhagen

Horizontal lines for notes

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.)

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.

Department of Anaesthesia, Rigshospitalet, Copenhagen, Denmark. NIELS LOMHOLT M.D. Copenhagen

Horizontal lines for notes

**History & background**

- HFO High flow oxygen
- HFOT High flow oxygen therapy
- HFNC High flow nasal cannula
- HFNP High flow nasal prongs
- NHFO<sub>2</sub> Nasal high flow oxygen
- HHFO Heated high flow oxygen
- HHFNC Humidified high flow nasal cannula
- HHHFO<sub>2</sub> Heated & humidified high flow oxygen
- HHHFNC Heated & humidified high flow nasal cannula

**NHF Nasal High Flow**

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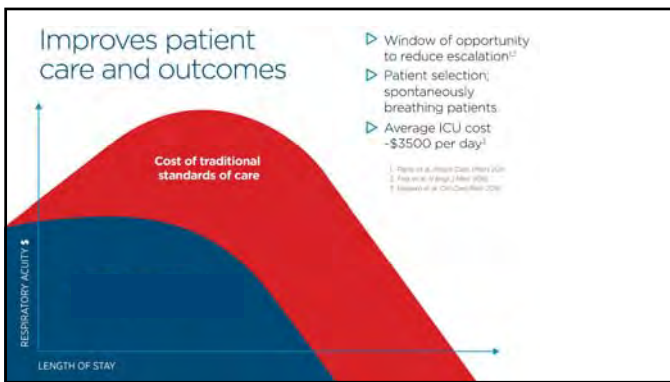
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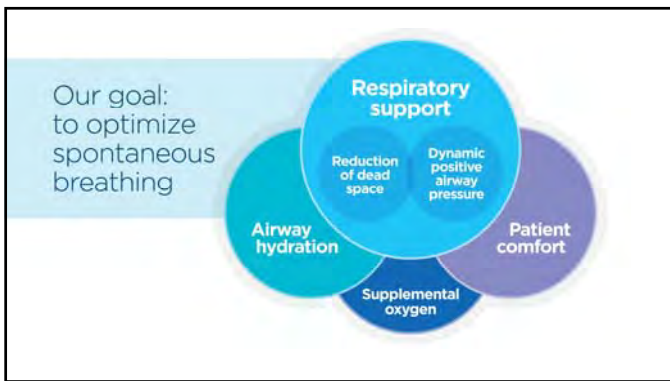
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### Reduction of dead space

**REDUCTION OF DEAD SPACE**

Clearance of expired air in the upper airways

Reduces re-breathing of gas with high CO<sub>2</sub> and depleted O<sub>2</sub>

Increases alveolar ventilation

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### Reduction of dead space

Modelling of CO<sub>2</sub> in patient airways during nasal high flow therapy with computational fluid dynamics<sup>12</sup>

**Airway Modelling**

Obtained from CT scan 480 images 5.0x100 volume

Model with a volume of 0.2 litres

**Full Version (10 mins)**

**End Expiration**

Computational modelling of CO<sub>2</sub> concentration

**Comparison (10 mins)**

© Cambridge University Press 2012  
© Cambridge University Press 2012

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### Reduction of dead space - Spence

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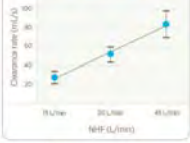
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### Reduction of dead space - Moller

Clearance rate related to NHF flow



Adapted from Moller et al. J Appl Physiol 2005



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### Reduction of dead space - Moller



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### Reduction of dead space

Reduces rebreathing of gas with high CO<sub>2</sub> and depleted O<sub>2</sub>

NORMAL TIDAL VOLUME AND DEADSPACE:



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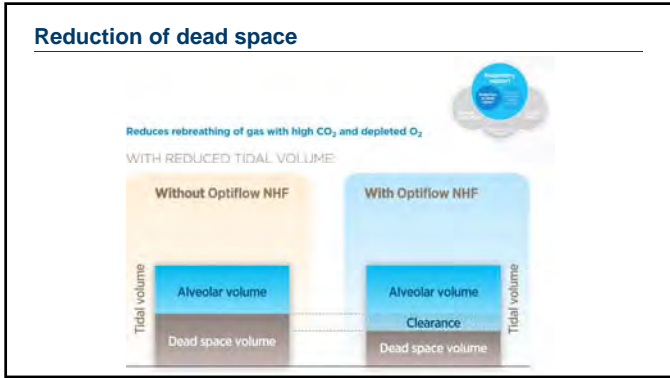
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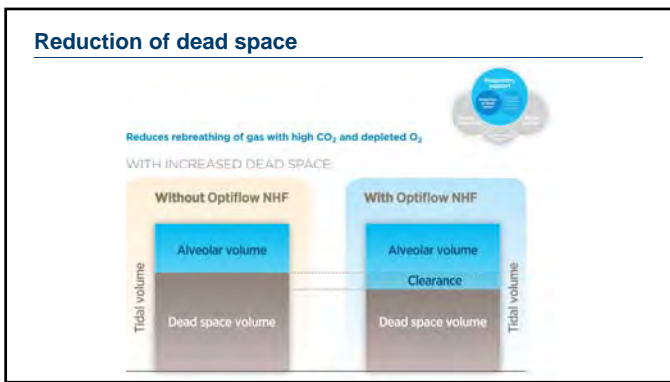
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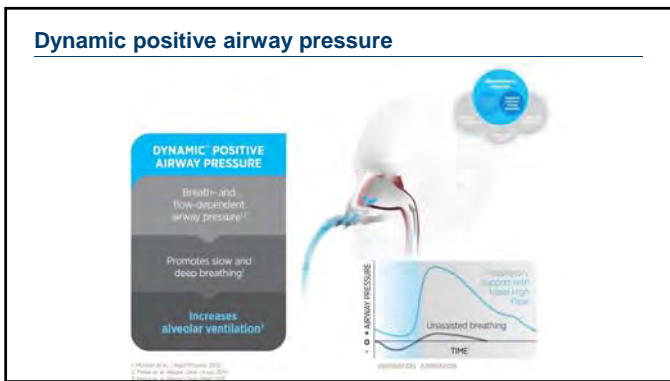
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### Dynamic positive airway pressure

The slide contains two graphs. The left graph, titled 'Unassisted breathing', shows airway pressure (cmH2O) on the y-axis and time on the x-axis. It depicts a normal tidal volume and a pressure curve that rises during inspiration and falls during expiration. The right graph, titled 'Promotes slow, deep breathing', shows a significantly larger tidal volume and a higher, more sustained airway pressure during inspiration. A small circular icon with 'NHF' is positioned above the graphs.

- Pressure dynamically changes depending on breath and flow
- Inspiratory resistance decreases, making inspiration easier
- Expiratory resistance increases, leading to prolonged expiration

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### What changes are seen in patients using NHF?

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

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### Supplemental oxygen

**SUPPLEMENTAL OXYGEN WHEN REQUIRED**  
Confidence in the delivery of warmed, humidified oxygen?

The diagram shows a human head in profile with a nasal cannula. A circular inset provides a magnified view of the nasal passage and the cannula's placement. A text box on the left asks about confidence in the delivery of warmed, humidified oxygen.

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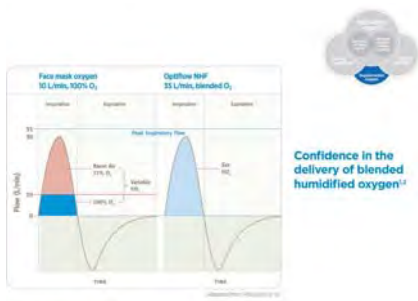
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### Supplemental oxygen



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### Airway hydration



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### Airway hydration



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### Airway hydration

**Fisher & Paykel HEALTHCARE**

100% Humidity

90% Humidity for 15 minutes

400 µm

*© Fisher & Paykel Healthcare Limited 2015*

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

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### Patient comfort

**COMFORTABLE AND EASY TO USE**

OPEN SYSTEM  
No seal required

Patient tolerance

*© Fisher & Paykel Healthcare Limited 2015*

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### Patient comfort

**IMPROVES comfort & patient compliance**

**KEY CLINICAL STUDY**

- ▷ Well tolerated
- ▷ Greater overall comfort than face mask
- ▷ Heating and humidification of gas improves patient comfort and tolerance of therapy
- ▷ Significantly less skin breakdown than BPAP therapy
- ▷ Lower nurse workload noted, compared with BPAP

*© Fisher & Paykel Healthcare Limited 2015*

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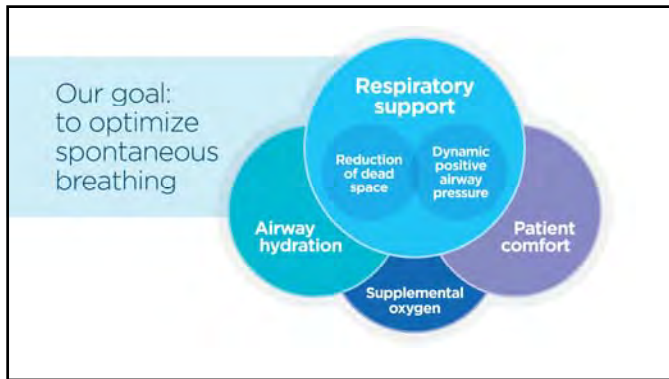
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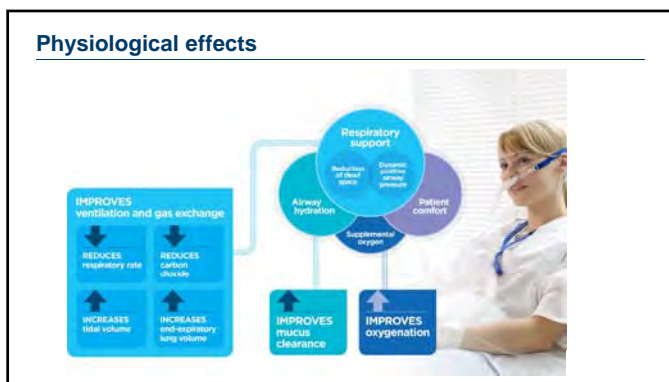
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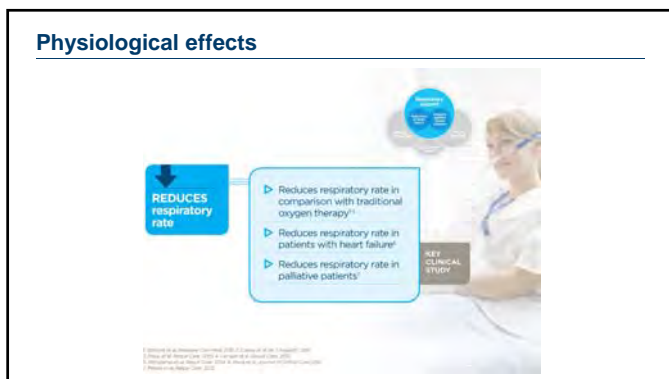
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**Sztrymf et al. 2011** Intensive Care Medicine

**↓**  
**REDUCES**  
respiratory rate

**STUDY**  
Sztrymf et al. investigated the efficacy and outcome of nasal high flow therapy (NHFT) compared with use of conventional high-flow face masks

**METHOD**

- 38 ICU patients in acute respiratory failure
- All patients were switched from nonbreathing face mask to NHFT

**RESULTS**

- ▶  $F_{iO_2}$  was significantly higher 1 hour after commencing NHFT
- ▶  $P_{aO_2}/F_{iO_2}$  was improved on NHFT at both the 1-hour and 24-hour time points
- ▶ Significant reductions in respiratory rate, heart rate, dyspnea score, jugular-ocular reflexion and thoracoabdominal asynchrony were shown on NHFT
- ▶ NHFT was well tolerated

Sztrymf et al. Intensive Care Medicine 2011

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**Corley et al. 2011** British Journal of Anaesthesia

**↑**  
**INCREASES**  
end-expiratory lung volume

**STUDY**  
Corley et al. compared the differences between low flow oxygen therapy and nasal high flow (NHFT) therapy on alveolar pressure and end-expiratory lung volume (EELV).

**METHOD**

- 20 post-cardiac surgery patients
- Low flow oxygen therapy via face mask
- NHFT via nasal cannula
- NHFT was delivered at 35 - 50 L/min



**RESULTS**

On NHFT:

- ▶ A significant increase in mean airway pressure, end-expiratory pressure, and flow oxygen
- ▶ An increase in end-expiratory lung volume (EELV) of 25.6% was achieved (increased from 1.0 to 1.256 L)
- ▶ Respiratory rate was significantly reduced
- ▶  $P_{aO_2}/F_{iO_2}$  also improved significantly compared to low flow oxygen

Corley et al. British Journal of Anaesthesia 2011

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**Physiological effects**

**↓**  
**REDUCES**  
carbon dioxide

- ▶ Reduces rebreathing of  $CO_2$
- ▶ Reduces dead space ventilation
- ▶ Reduces arterial  $CO_2$



Wright et al. Anaesthesia 2011

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### Physiological effects

IMPROVES mucus clearance

Humidification therapy improves mucociliary clearance

KEY CLINICAL STUDY

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### Hasani et al. 2008 Chronic Respiratory Disease

IMPROVES mucus clearance

**STUDY**  
Hasani et al. examined the impact of humidification on mucociliary clearance

**METHOD**

- 10 patients with bronchiectasis.
- Delivered warmed, humidified air at a flow of 20 - 25 L/min through nasal cannula for 7 days, 3 hours per day.

**RESULTS**

- ▶ Following humidification, mucociliary clearance was significantly improved
- ▶ Improved mucociliary clearance may slow the rate of disease progression.

**Optiflow mucociliary clearance**

■ No treatment  
■ Air treatment

Residual volume of sputum (mL)

Time (days)

Hasani et al. *Respir Med* 2008

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### Physiological effects

IMPROVES oxygenation

- ▶ Delivers a prescribed  $FiO_2$
- ▶ Improves oxygenation in patients in respiratory distress<sup>1,2</sup>
- ▶ Improves oxygenation compared with traditional oxygen therapy<sup>3,4</sup>
- ▶ Improves oxygenation during bronchoscopy<sup>5</sup>

1. Hackett P. *J Intensive Care Med* 2012; 27: 10-16.  
2. De Groot LJM, et al. *Respir Med* 2011; 105: 10-16.  
3. Hackett P, et al. *Respir Med* 2011; 105: 10-16.  
4. Hackett P, et al. *Respir Med* 2011; 105: 10-16.  
5. Hackett P, et al. *Respir Med* 2011; 105: 10-16.

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### Clinical outcomes

↓ REDUCES mortality rate  
 ↓ REDUCES escalation of care  
 ↑ IMPROVES comfort & patient compliance  
 ↑ IMPROVES symptomatic relief

SUMMARY HEALTH ECONOMICS  
 BEYOND ICU REFERENCES

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### Clinical outcomes

↓ REDUCES escalation of care

USED AS FIRST-LINE RESPIRATORY SUPPORT

↓ REDUCES INTUBATION RATE vs. non-invasive or NIV  
 Frat et al. NEJM. 2015.

↓ REDUCES REINTUBATION RATE vs. standard O<sub>2</sub> via cannula, non-invasive  
 Hernández et al. JAMA. Apr 2016.

POST-EXTUBATION

↓ REDUCES REINTUBATION RATE vs. Venturi mask  
 Maggione et al. AJRCCM. 2014.

NON-INFERIOR vs. BiPAP  
 Stéphan et al. JAMA. 2015.

↓ REDUCES REINTUBATION RATE vs. BiPAP  
 Hernández et al. JAMA. Oct 2016.

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### Frat et al. 2015 The New England Journal of Medicine

↓ REDUCES mortality rate  
 ↓ REDUCES escalation of care

**STUDY**  
 A 23-center study compared nasal High Flow (NHFF) therapy to use of a non-rebreather mask and NIV as a primary treatment (pre-intubation).

**METHOD**

- 810 patients in acute hypoxemic respiratory failure (PACO<sub>2</sub> > 50 mmHg) were randomized to receive NHFF, non-rebreather mask or NIV.
- Primary outcome: number of patients intubated at day 28 (not defined).

**RESULTS**

- NHFF significantly reduced the need for intubation in these acute patients (study P < 0.001).
- Significant increase in mortality-free days.
- NHFF significantly reduced the number of respiratory system-related adverse events.

Reduced intubation rate (%)  
 17% 19% 23%

Reduced reintubation rate (%)  
 23% 33% 50%

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**Hernández et al. 2016** Journal of the American Medical Association

**REDUCES escalation of care**

**STUDY**  
A 7-center study compared the efficacy of nasal high flow (NHF) to use of conventional oxygen therapy (COT) post-extubation.

**METHOD**

- 537 patients at low risk of reintubation (defined as age < 65, APACHE score < 12, BMI < 30 etc.) were randomized to receive NHF or COT (via nasal cannula or airway retractor).
- Primary outcome: reintubation within 72 hours.

**RESULTS**

- ▶ NHF significantly reduced reintubation: 4.9% (2/40) NHF patients vs 12.2% (10/82) COT patients.
- ▶ NHF significantly reduced post-extubation respiratory failure: 8.5% (34/40) NHF patients vs 14.4% (118/82) COT patients.
- ▶ Successfully reintubated patients had a median duration of mechanical ventilation (IQR, 7 days) vs 10 days (IQR, 9 vs 13 days).
- ▶ NHF did not delay reintubation compared to COT.

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**Hernández et al. 2016** Journal of the American Medical Association

**REDUCES escalation of care**

**STUDY**  
A 3-center non-inferiority study compared use of nasal high flow (NHF) to bi-level positive airway pressure (BPAP) post-extubation.

**METHOD**

- 624 patients at high risk of reintubation (defined as age > 65, APACHE score > 12, BMI > 30 etc.) were randomized to receive NHF or BPAP.
- Non-inferiority margin: 10%.
- Primary outcomes:
  - Reintubation within 72 hours.
  - Post-extubation respiratory failure within 72 hours.

**RESULTS**

- ▶ NHF was non-inferior to BPAP for preventing reintubation: 13.8% (35/254) NHF group vs 17.6% (44/249) BPAP group reintubated.
- ▶ NHF was non-inferior to BPAP for preventing post-extubation respiratory failure: 20.9% (53/254) NHF group vs 20.9% (52/249) BPAP group post-extubation respiratory failure.
- ▶ No patients in the NHF group suffered adverse effects requiring withdrawal of the therapy, compared to 42.9% of patients in the BPAP group.
- ▶ Median ICU length of stay was lower in the NHF group: 3 days (IQR, 1 vs 4) days (BPAP).

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**Summary**

Differentiated mechanisms	Physiological effects	Clinical outcomes
Respiratory support	Improves ventilation and gas exchange	Reduces escalation of care
Airway hydration	Reduces respiratory rate	Reduces mortality rate
Patient comfort	Reduces carbon dioxide	Improves patient comfort and compliance
Supplemental oxygen (when required)	Increases tidal volume	Improves symptomatic relief
	Increases end-expiratory lung volume	Reduces exacerbation days
	Improves mucus clearance	
	Improves oxygenation	

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### Neonatal respiratory care continuum

Resuscitation    Invasive ventilation    nCPAP    Nasal high flow    Oxygen therapy

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### Optimizing the pediatric respiratory care continuum

EVIDENCE SUGGESTS:

- Early use of Nasal High Flow (NHF) in pediatrics may reduce escalation and length of stay.
- NHF is not only effective, but also gentle and easy.
- It is best used early and in an integrated manner.

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### Evidence supporting early use

**PHYSIOLOGICAL OUTCOMES**

**NHF is associated with:**<sup>1,2,3</sup>

- Improved breathing pattern
- Rapid unloading of respiratory muscles
- Significant reduction in respiratory effort
- Rapid improvement in respiratory distress

1. Pharm et al. Pediatr 2014

**CLINICAL OUTCOMES**

**Evidence suggests early use may:**

- Reduce clinical deterioration<sup>4,5</sup> and escalation of therapy<sup>6,7</sup>
- Decrease intubation rates<sup>8,9</sup>
- Reduce PICU length of stay<sup>7</sup>
- Reduce PICU admissions/transfers<sup>1</sup>

1. Journal of Intensive Care Medicine 2012; 27: 100-104  
 2. Pediatrics 2014; 134: 100-104  
 3. Pediatrics 2014; 134: 100-104  
 4. Pediatrics 2014; 134: 100-104  
 5. Pediatrics 2014; 134: 100-104  
 6. Pediatrics 2014; 134: 100-104  
 7. Pediatrics 2014; 134: 100-104  
 8. Pediatrics 2014; 134: 100-104  
 9. Pediatrics 2014; 134: 100-104

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**Usage**

"How do I know if my patient is responding to NHF?"

"What flows should I use with pediatric patients?"

"What is the evidence for NHF in pediatric populations?"




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**How do I know if my patient is responding to NHF?**

Literature suggests therapy outcome may be predicted within 60 minutes, using clinical indicators:

WITHIN 60 MINUTES:	LIKELY INDICATORS FOR:	
	SUCCESS	CAUTION
Respiratory rate	Improvement <sup>1,2</sup>	No improvement <sup>1,2</sup>
Heart rate	Improvement <sup>1,2</sup>	No improvement <sup>1,2</sup>
Work of breathing	Improvement <sup>1</sup>	Currently no data <sup>1</sup>
Oxygen desaturation	Currently no data	No improvement <sup>1</sup>

1. Resuscitation (2015) 115, 1035-1046. doi:10.1016/j.resusc.2015.08.005  
2. Resuscitation (2015) 115, 1035-1046. doi:10.1016/j.resusc.2015.08.005

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**What flows should I use with pediatric patients?**

**Dose by weight?**

Physiological evidence suggests that flows equal to or above 2 L/kg/min is associated with<sup>1,2</sup>

- Clinically relevant pharyngeal pressure
- Improved breathing pattern
- Rapid unloading of respiratory muscles
- Reduced work of breathing

It may be useful to think about jetting flow in terms of L/kg/min. This may help to standardize therapy across a broad population.



1. Resuscitation (2015) 115, 1035-1046. doi:10.1016/j.resusc.2015.08.005  
2. Resuscitation (2015) 115, 1035-1046. doi:10.1016/j.resusc.2015.08.005

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**What flows should I use with pediatric patients?**



1. Egan AT, Pediatric Cardiology. ABC of Pediatrics at a glance (Oxford: 2012).  
 2. Egan AT, Pediatric Cardiology. ABC of Pediatrics at a glance (Oxford: 2012).  
 3. Egan AT, Pediatric Cardiology. ABC of Pediatrics at a glance (Oxford: 2012).

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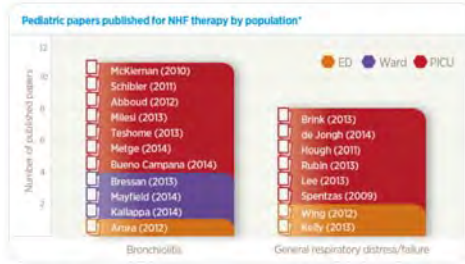
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**What is the evidence for NHF in pediatric populations?**



\*Includes randomized and observational clinical trials, guidelines, meta-analyses, observational studies, case reports, and guideline updates. Last updated: Aug 2014

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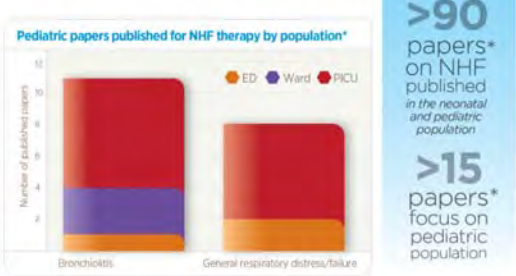
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**What is the evidence for NHF in pediatric populations?**



\*Includes randomized and observational clinical trials, guidelines, meta-analyses, observational studies, case reports, and guideline updates. Last updated: Aug 2014

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**BREAKING NEWS** Recent publication of PARIS II RCT

The much anticipated **Pediatric Acute Respiratory Intervention Study**, the largest NHF RCT to date, just published in New England Journal of Medicine (NEJM).

**Study Aim:** Investigate if the early use of NHF to treat bronchiolitis in less intensive setting could prevent the need for treatment escalation

**Study Details:** Pop: 1,472 infants younger than 12 months with bronchiolitis  
Setting: 17 ED's and Pediatric Floors across Australia & NZ  
Interventions: NHF (delivered 2L/kg/min) vs std. oxy (max 2L/min)  
Used: F&P Optiflow™ Junior 2 and F&P AIRVO™ 2 system

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**BREAKING NEWS** Recent publication of PARIS II RCT

**Study Results:** The early use of NHF was found to be effective strategy to reduce the level of care required in infants with bronchiolitis

12% of infants on NHF required escalation of care compared to 23% of infants on standard oxygen therapy (p<0.001)

There was no increased risk of adverse events reported

**Study Funding:** PARIS funded by the National Health and Medical Research Council and others

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**Adult respiratory care continuum**



Invasive Ventilation



Non Invasive Ventilation



Nasal High Flow

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### Usage



There are a number of possible approaches based on clinical research and the individual needs of the patient.

- "Is there a NHF protocol for AHRF patients?"
- "What flow rates and ranges are used?"
- "How much pressure is generated?"
- "When are the effects of Optiflow seen?"

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### Is there a NHF protocol for AHRF patients?

Ischaki et al. 2017  
*Ischaki Eur Respir Rev 2017*




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### Ischaki et al. 2017

*Ischaki Eur Respir Rev 2017*




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What flow rates and ranges are used?




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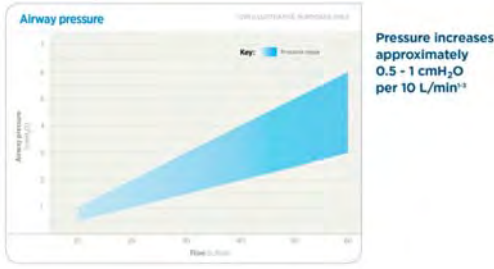
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How much pressure is generated?




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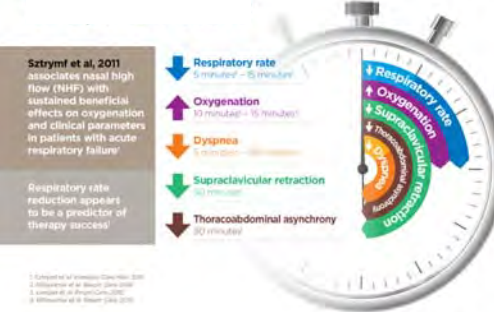
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When are the effects of NHF seen?




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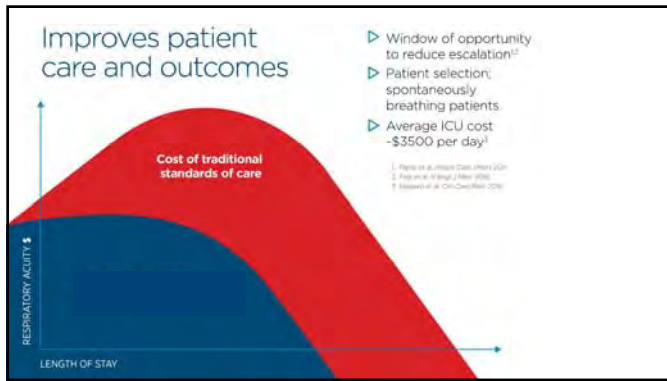
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**Outline**

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History & background

Mechanisms of action to physiological effects to clinical outcomes

Pediatric to Adult **BREAKING NEWS**

Implementation to usage

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**Learning Objectives**

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Attendees will be familiar with the application of Nasal High Flow in the pediatric and adult population and the literature supporting its use.

- Identify the four mechanisms of action for Nasal High Flow
- Understand the physiological effects of Nasal High Flow
- Describe the clinical outcomes of implementing Nasal High Flow

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Thank you from Fisher & Paykel Healthcare

Questions?



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