Noninvasive Ventilation and (/versus) High–flow Nasal Oxygen
when (not) to start, and when to stop?
Disclosures

• until January 2021 Xenios/Fresenius, Germany
• until January 2023 Hamilton Medical AG, Switzerland
• less experience with NIV than with HFNO
Limitations

• NIV and HFNO in patients in non–hypercapnic AHRF
• ‘beyond the guidelines’
Agenda

• changing landscapes?
• noninvasive ventilation
• high–flow oxygen
• pandemics
• conclusions
Agenda

• changing landscapes?
• noninvasive ventilation
• high–flow oxygen
• pandemics
• conclusions
# Increase in Use of Noninvasive Ventilation in Hypercapnic Patients

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of hospitals</th>
<th>Number of patients</th>
<th>Median age</th>
<th>Consolidation on radiograph</th>
<th>Median ( \text{initial PaCO}_2 )</th>
<th>Median Initial pH</th>
<th>NIV unsuccessful</th>
<th>IMV Died</th>
<th>Discharged from hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>All causes</td>
</tr>
<tr>
<td>2010</td>
<td>61</td>
<td>925</td>
<td>71</td>
<td>30%</td>
<td>10-2</td>
<td>7-30</td>
<td>27%</td>
<td>2.3%</td>
<td>29%</td>
</tr>
<tr>
<td>2011</td>
<td>122</td>
<td>2187</td>
<td>71</td>
<td>38%</td>
<td>10-1</td>
<td>7-26</td>
<td>33%</td>
<td>3.8%</td>
<td>30%</td>
</tr>
<tr>
<td>2012</td>
<td>130</td>
<td>2490</td>
<td>72</td>
<td>40%</td>
<td>10-2</td>
<td>7-25</td>
<td>31%</td>
<td>2.7%</td>
<td>31%</td>
</tr>
<tr>
<td>2013</td>
<td>148</td>
<td>2693</td>
<td>72</td>
<td>40%</td>
<td>10-2</td>
<td>7-24</td>
<td>33%</td>
<td>3.0%</td>
<td>34%</td>
</tr>
</tbody>
</table>

Table shows data for adult patients admitted to hospital with COPD exacerbation receiving NIV. NIV=non-invasive ventilation. \( \text{PaCO}_2 \)=arterial partial pressure of carbon dioxide. IMV=invasive mechanical ventilation. COPD=chronic obstructive pulmonary disease.

**Table:** British Thoracic Society national audits of NIV, 2010-13

Bourke *Lancet Resp Med* 2018; 6:935
Use of Noninvasive Ventilation in ARDS

Bellani *JAMA* 2016; 315:788
QUESTION In patients with non–hypercapnic acute hypoxemic respiratory failure (AHRF), what are the effects of treatment with high–flow nasal oxygen (HFNO), standard oxygen, or noninvasive ventilation on need for intubation?

CONCLUSION In patients with non–hypercapnic AHRF, treatment with HFNO, standard oxygen, or noninvasive ventilation did not result in different intubation rates; there was a significant difference in favor of HFNO in 90–day mortality.

POPULATION

98 Women 212 Men

patients with AHRF with PaO₂/FiO₂ < 300

mean age: 60 years

LOCATION

23 ICUs in the France

VENTILATION STRATEGIES

310 patients with non–hypercapnic AHRF

106 patients HFNO

110 patients NIV

94 patients standard O₂

(FRIMARY) OUTCOME

proportion of patients intubated at day 28 (primary); ICU and 90–day mortality

QUESTION Does a broadened Berlin definition of ARDS, in which ARDS can be diagnosed in patients who are not receiving ventilation, results in similar groups of patients receiving HFNO as in patients receiving ventilation?

CONCLUSION Using a broadened definition of ARDS may facilitate an earlier diagnosis of ARDS in patients receiving HFNO; however, ARDS patients receiving HFNO and ARDS patients receiving ventilation have distinct baseline characteristics and mortality rates.

POPULATION

344 Women 384 Men
COVID–19 patients with ARDS, including patients receiving HFNO (flow > 30 L/min)
Mean Age: 66 years

LOCATION

16 ICUs in The Netherlands

QUESTION What is the oxygen consumption with high-flow nasal oxygen (HFNO) vs with mechanical ventilation?

CONCLUSION Actual oxygen consumption, hourly oxygen consumption, and total oxygen consumption are substantially higher in patients that start with HFNO.

POPULATION

52 Women  194 Men

COVID–19 ARDS patients receiving oxygen support in the ICU

Mean Age: 64 years

LOCATION

2 ICUs in Europe

GROUPS

275 patients with ARDS according to new definition

147 patients HFNO

128 patients IMV

OUTCOMES

actual oxygen consumption (primary), hourly and total oxygen consumption, in the first 2 days

RESULTS

Noninvasive Ventilation vs Standard or High–flow Oxygen

- equipment
- interfaces
- PEEP
- cooperation
- failures
Intubation Rate with Noninvasive Ventilation vs Standard or High–flow Oxygen

Aswanetmanee *Scientific Reports* 2023; 13:8283
QUESTION What is the effect of noninvasive ventilation delivered by helmet vs usual respiratory support on the risk of mortality among adults with acute hypoxemic respiratory failure due to COVID-19?

CONCLUSION Helmet noninvasive ventilation did not significantly reduce 28-day mortality compared with usual respiratory support in patients with acute hypoxemic respiratory failure due to COVID-19; however, study interpretation is limited by imprecise effect estimate.

POPULATION
187 Men
133 Women
Adults with acute hypoxemic respiratory failure due to suspected or confirmed COVID-19
Median age: 58 years

LOCATIONS
8 ICUs in Saudi Arabia and Kuwait

INTERVENTION
322 Patients randomized
320 Patients analyzed
159 Helmet noninvasive ventilation
Oxygen delivered noninvasively via a helmet device
161 Usual respiratory support
Mask noninvasive ventilation, high-flow nasal oxygen, and standard oxygen

FINDINGS
Mortality rate at 28 days
Helmet noninvasive ventilation: 43 of 159 patients (27.0%)
Usual respiratory support: 42 of 161 patients (26.1%)
The between-group difference was not significant:
Risk difference, 1.0% (95% CI, −8.7% to 10.6%)
Relative risk, 1.04 (95% CI, 0.72 to 1.49); P = .85

Agenda

• changing landscapes?
• noninvasive ventilation
• high–flow oxygen
• pandemics
• conclusions
Use of NIV in ARDS

Limited information in the literature

Uncertain whether NIV should be used

Predictors of failure

• \( \text{PaO}_2/\text{FiO}_2 < 150 \text{ mm Hg} \)

Predictors of failure

• \( \text{PaO}_2/\text{FiO}_2 < 200 \text{ or } 150 \text{ mm Hg} \)

Predictors of failure

• \( \text{PaO}_2/\text{FiO}_2 < 150 \text{ mm Hg} \)

Predictors of failure

• High severity score (eg. Acute Physiology And Chronic Health Evaluation II or Sequential Organ Failure Assessment)

• Heart rate, acidosis, consciousness, oxygenation, respiratory rate score >5 after 1 h of NIV

Considerations

• Trial of high-flow nasal cannula for \( \text{PaO}_2/\text{FiO}_2 < 200 \text{ mm Hg} \)

• Avoid delaying intubation

Panel 2: Prognostic indices to be considered prior to initiation of acute non-invasive ventilation in acute hypercapnic respiratory failure

**Cause of acute hypercapnic respiratory failure**

• Favourable: chronic obstructive pulmonary disease, extra-pulmonary restriction, and cardiogenic pulmonary oedema

• Adverse: pulmonary fibrosis and isolated pneumonia

**Stable state**

• Poor performance status

• Unable to leave home unassisted

• Requires help washing and dressing

• High comorbidity burden

• Low body-mass index

**Severity of acute illness**

• Blood gas abnormalities

• Late development of acute hypercapnic respiratory failure after admission

• Coexistent metabolic acidemia or low base excess

• Severe acidemia (pH <7.25)

• Other organ failure or impairment

• Consolidation

• Observations including: respiratory rate >30, hypotension (particularly if unresponsive to fluid resuscitation), and low Glasgow Coma Scale (<11)

• Blood results including: eosinopenia (<50 cells per µL), raised urea, and hypoalbuminemia

• Inability to clear secretions

Indices listed are associated with worse outcome unless otherwise stated. No single index in isolation should preclude a trial of non-invasive ventilation.
Limited information in the literature

Text: Use of NIV in ARDS

Predictors of failure

- \( \text{PaO}_2/\text{FiO}_2 < 150 \text{ mm Hg} \)
Panel 2: Prognostic indices to be considered prior to initiation of acute non-invasive ventilation in acute hypercapnic respiratory failure

Cause of acute hypercapnic respiratory failure
- Favourable: chronic obstructive pulmonary disease, extra-pulmonary restriction, and cardiogenic pulmonary oedema
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Stable state
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- Unable to leave home unassisted
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Severity of acute illness
- Blood gas abnormalities
  - Late development of acute hypercapnic respiratory failure after admission
  - Coexistent metabolic acidemia or low base excess
  - Severe acidemia (pH < 7.25)
- Other organ failure or impairment
- Consolidation
- Observations including: respiratory rate > 30, hypotension (particularly if unresponsive to fluid resuscitation), and low Glasgow Coma Scale (< 11)
- Blood results including: eosinopenia (< 50 cells per μL), raised urea, and hypoalbuminaemia
- Inability to clear secretions

Indices listed are associated with worse outcome unless otherwise stated. No single index in isolation should preclude a trial of non-invasive ventilation.

Panel 4: Prognostic factors for successful non-invasive ventilation in acute hypoxaemic respiratory failure

Cause of acute hypoxaemic respiratory failure
- Favourable: cardiogenic pulmonary oedema, post-operative, and PaO₂/FiO₂ > 200 mm Hg
- Adverse: PaO₂/FiO₂ < 200 or 150 mm Hg

Predictors of failure
- PaO₂/FiO₂ < 150 mm Hg
- Tidal volume (exhaled) under non-invasive ventilation (NIV) ≥ 9·0 or 9·5 mL/kg
- High severity score (eg, Acute Physiology And Chronic Health Evaluation II or Sequential Organ Failure Assessment)
- Heart rate, acidoses, consciousness, oxygenation, respiratory rate score > 5 after 1 h of NIV

Considerations
- Trial of high-flow nasal cannula for PaO₂/FiO₂ < 200 mm Hg
- Avoid delaying intubation

Text: Use of NIV in ARDS

Limited information in the literature
- Uncertain whether NIV should be used

Predictors of failure
- PaO₂/FiO₂ < 150 mm Hg
**QUESTION** Is during NIV the categorization of ARDS severity based on the PaO$_2$/FiO$_2$ Berlin criteria is useful?

**CONCLUSION** NIV was used in 15% of patients with ARDS, irrespective of severity category; NIV seems to be associated with higher ICU mortality in patients with a PaO$_2$/FiO$_2$ lower than 150 mm Hg.

**POPULATION**

179 Women  257 Men

Patients with ARDS, managed with noninvasive ventilation on day 1 and 2

Mean Age: 65 years

**LOCATION**

459 ICUs in 50 countries

Key messages

- Guidelines for the use of non-invasive ventilation (NIV) in acute or chronic hypercapnic respiratory failure and acute hypoxaemic respiratory failure are evidence based and should be followed.
- The right patient
  - The cause of respiratory failure is important in determining the likelihood of a successful outcome with NIV.
  - NIV should not be used when it is very unlikely to succeed or when a purely palliative approach would be more appropriate—prediction tools should inform decision making.
- The right time
  - Physiological criteria should be used to determine the timing of NIV.
  - NIV should be discontinued in a timely manner if the patient is deteriorating on the basis of worsening pH and respiratory rate (for acute hypercapnic respiratory failure) or exhaled tidal volume >9.5 mL/kg and heart rate, acidosis, consciousness, oxygenation, respiratory rate score >5 after 1 h (for hypoxaemic respiratory failure).
- The right equipment
  - The correct interface should be used and should fit well.
  - Condition-specific settings should be used, and adjusted according to response.
- The right environment
  - The unit or ward should be properly staffed and resourced.
  - Staff should be NIV trained and competency assessed.
  - Training should be updated regularly.
- Ongoing audits and quality assurance should be done.
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98 Women  212 Men

patients with AHRF with PaO\textsubscript{2}/FiO\textsubscript{2} < 300

mean age: 60 years

LOCATION

23 ICUs in the France

VENTILATION STRATEGIES

310 patients with non–hypercapnic AHRF

106 patients HFNO

110 patients NIV

94 patients standard O\textsubscript{2}

FINDINGS

(PRIMARY) OUTCOME

proportion of patients intubated at day 28 (primary); ICU and 90–day mortality

Benefits and Risks of HFNO

• comfortable
• failures less well recognized
• oxygenation
• in case of hypoxic failure little reserves
• lower risk of P–SILI?
ROX index = \( \frac{\text{SpO}_2}{\text{FiO}_2} \) to RR

- predictors of HFNC failure
  - ROX < 2.85 at 2 hours
  - ROX < 3.47 at 6 hours
  - ROX < 3.85 at 12 hours

Roca *AJRCCM* 2019; 119:1368
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**QUESTION** Does a broadened Berlin definition of ARDS, in which ARDS can be diagnosed in patients who are not receiving ventilation, result in similar groups of patients receiving HFNO as in patients receiving ventilation?

**CONCLUSION** Using a broadened definition of ARDS may facilitate an earlier diagnosis of ARDS in patients receiving HFNO; however, ARDS patients receiving HFNO and ARDS patients receiving ventilation have distinct baseline characteristics and mortality rates.

**POPULATION**

- 344 Women
- 384 Men

COVID-19 patients with ARDS, including patients receiving HFNO (flow > 30 L/min)

Mean Age: 66 years

**LOCATION**

- 16 ICUs in The Netherlands

**GROUPS**

- 728 patients with ARDS according to new definition
- 229 patients receiving HFNO
- 499 patients receiving IMV

**OUTCOMES**

- ICU mortality (primary), hospital; 28 and 90–day mortality; need for ventilation within 7 days
- HFNO in patients

- 105 out of 229 (45.8%) HFNO patients needed IMV < 7 days

**OUTCOMES**

- HFNO
- Ventilation

**QUESTION** Does a broadened Berlin definition of ARDS, in which ARDS can be diagnosed in patients who are not receiving ventilation, results in similar groups of patients receiving HFNO as in patients receiving ventilation?

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- **Men**: 384

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Mean Age: 66 years

**LOCATION**

16 ICUs in The Netherlands

**GROUPS**

- **728 patients with ARDS according to new definition**
  - **229 patients** HFNO
  - **499 patients** IMV

**OUTCOMES**

- ICU mortality (primary), hospital; 28 and 90–day mortality; need for ventilation within 7 days

Oxygen Scarcity

• running out of oxygen = realistic scenario
QUESTION What is the oxygen consumption with high-flow nasal oxygen (HFNO) vs with mechanical ventilation?

CONCLUSION Actual oxygen consumption, hourly oxygen consumption, and total oxygen consumption are substantially higher in patients that start with HFNO.

POPULATION

52 Women 194 Men

COVID–19 patients with ARDS, including patients receiving HFNO

Mean Age: 64 years

LOCATION

2 ICUs in Europe

GROUPS

275 patients with ARDS according to new definition

147 patients HFNO

128 patients IMV

OUTCOMES

actual oxygen consumption (primary), hourly and total oxygen consumption, in the first 2 days

RESULTS
Oxygen Use with High–flow Oxygen

- 850 vs 176 L/hour, or 20,000 vs 4,200 L/day
  - 10,000 liquid oxygen tank ~ 400 HFNO days
  - pressure swing adsorption plant 1,000 l/min ~ 70 HFNO patients
- 50 L steel cylinder ~ 9 HFNO days
- oxygen generator ~ 1 HFNO patient

Oxygen Use with High–flow Oxygen

- oxygen–sparing strategies
  - automated oxygen titration
  - better bedside use of guidelines with strict cutoffs for SpO₂
- prone positioning
- noninvasively or invasive ventilation

**QUESTION** What is the efficacy of a closed–loop oxygen control in critically ill patients with moderate to severe acute hypoxemic respiratory failure (AHRF) treated with high flow nasal oxygen (HFNO).

**CONCLUSION** Closed–loop oxygen control improves oxygen administration in patients with moderate-to-severe AHRF treated with HFNO, increasing the percentage of time in the optimal oxygenation range and decreasing the workload of healthcare personnel.

**POPULATION**

45 patients under HFNO

patients with moderate to severe ARF, including patients with COVID-19

Median Age: 49 year

**LOCATION**

1 ICU in Spain

**INTERVENTION**

45 patients under HFNO

4 hours manual or automated FiO\(_2\) control

crossover

4 hours automated or manual FiO\(_2\) control

**RESULTS**

(PRIMARY) OUTCOME

percentage of time spent in the individualized optimal Sp\(_{O_2}\) ranges

Roca O. Closed–loop oxygen control improves oxygen therapy in acute hypoxemic respiratory failure patients under high flow nasal oxygen (HILOOP): a randomized cross-over study. [Crit Care 2022; 26:108; doi10.1186/s13054-022-03970-w]
QUESTION What is the effect of HFNO with closed–loop control of the fraction of inspired oxygen (FiO$_2$), compared to HFNO with manual titrations of the FiO$_2$, on time spent in predefined pulse oximetry (SpO$_2$) zones in pediatric critically ill patients?

CONCLUSION In this randomized crossover trial in pediatric critically ill patients under HFNO, the percentage of time spent within in optimal SpO$_2$ zones increased with the use of closed–loop FiO$_2$ control.

POPULATION

23 Pediatric Patients

Children with acute hypoxemic respiratory failure under HFNO

Median Age: 1 year

LOCATION

3 ICUs in Turkey

INTERVENTION

23 patients under HFNO for acute hypoxemia

Manual or automated FiO$_2$ control

crossover

automated or manual FiO$_2$ control

(PRIMARY) OUTCOME

FiO$_2$ settings and SpO$_2$ readings; alarms and manual adjustments

RESULTS

Percentage of time within SpO$_2$ zones:

- Optimal
- Suboptimally low
- Unacceptably low
- Suboptimally high
- Unacceptably high

Number of alarms and manual adjustments:

A: Number of alarms
B: Number of adjustments

QUESTION Does early application of prone positioning improve outcomes in patients with severe ARDS?

CONCLUSION In patients with severe ARDS, early application of prolonged prone-positioning sessions significantly decreased 28–day and 90–day mortality.

**POPULATION**

148 Women 318 Men

patients with moderate to severe ARDS

Mean Age: 59 years

**LOCATION**

26 ICUs in France and 1 ICU in Spain

**VENTILATION STRATEGIES**

466 patients with moderate to severe ARDS

237 patients early prone

299 patients supine

**FINDINGS**

(PRIMARY) OUTCOME

28–day and 90–day mortality

QUESTION Does awake prone positioning reduce the rate of treatment failure at 28 days, defined as either death or intubation, in patients with severe COVID–19 acute hypoxemic respiratory failure who require respiratory support with HFNO?

CONCLUSION Awake prone positioning of patients with hypoxemic respiratory failure due to COVID–19 reduces the incidence of treatment failure and the need for intubation without any signal of harm.

POPULATION

370 Women  750 Men

patients with hypoxemic ARF related to COVID–19

Median Age: 61 years

SOURCE

meta–trial including 5 RCTs worldwide

INTERVENTION

1121 patients with COVID–19 hypoxemic ARF

564 awake prone positioning

557 standard care

(PRIMARY) OUTCOME

treatment failure at 28 days, defined as either death or intubation

FINDINGS

Conclusions

• landscape is changing
• HFNO seems to outperform NIV in ARDS patients
• do not use NIV when $\text{PaO}_2/\text{FiO}_2 < 150$ mm Hg
• be aware of limitations of your oxygen resources when applying HFNO