XXX International Symposium of Mechanical Ventilation of Albert Einstein Hospital
Albert Einstein Hospital, São Paolo, Brazil
August 17, 2023; 14:50–15:10 am BRT

Noninvasive Ventilation and (/versus) High–flow Nasal Oxygen

when (not) to start, and when to stop?

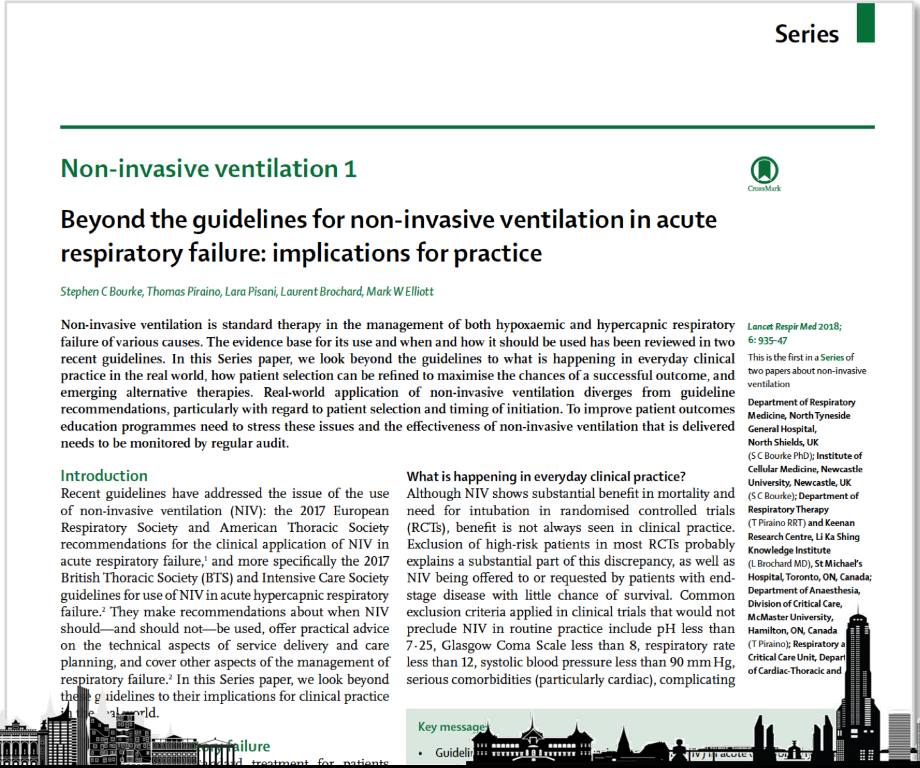
Disclosures

- 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’



Series

Non-invasive ventilation 1

Beyond the guidelines for non-invasive ventilation in acute respiratory failure: implications for practice

Stephen C Bourke, Thomas Piraino, Lara Pisani, Laurent Brochard, Mark W Elliott

Non-invasive ventilation is standard therapy in the management of both hypoxaemic and hypercapnic respiratory failure of various causes. The evidence base for its use and when and how it should be used has been reviewed in two recent guidelines. In this Series paper, we look beyond the guidelines to what is happening in everyday clinical practice in the real world, how patient selection can be refined to maximise the chances of a successful outcome, and emerging alternative therapies. Real-world application of non-invasive ventilation diverges from guideline recommendations, particularly with regard to patient selection and timing of initiation. To improve patient outcomes education programmes need to stress these issues and the effectiveness of non-invasive ventilation that is delivered needs to be monitored by regular audit.

Lancet Respir Med 2018; 6: 935–47

This is the first in a Series of two papers about non-invasive ventilation

Department of Respiratory Medicine, North Tyneside General Hospital, North Shields, UK (S C Bourke PhD); Institute of Cellular Medicine, Newcastle University, Newcastle, UK (S C Bourke); Department of Respiratory Therapy (T Piraino RRT) and Keenan Research Centre, Li Ka Shing Knowledge Institute (L Brochard MD), St Michael's Hospital, Toronto, ON, Canada; Department of Anaesthesia, Division of Critical Care, McMaster University, Hamilton, ON, Canada (T Piraino); Respiratory a… Critical Care Unit, Depart… of Cardiac-Thoracic and…

Introduction

Recent guidelines have addressed the issue of the use of non-invasive ventilation (NIV): the 2017 European Respiratory Society and American Thoracic Society recommendations for the clinical application of NIV in acute respiratory failure,[1] and more specifically the 2017 British Thoracic Society (BTS) and Intensive Care Society guidelines for use of NIV in acute hypercapnic respiratory failure.[2] They make recommendations about when NIV should—and should not—be used, offer practical advice on the technical aspects of service delivery and care planning, and cover other aspects of the management of respiratory failure.[2] In this Series paper, we look beyond the guidelines to their implications for clinical practice in the real world.

What is happening in everyday clinical practice?

Although NIV shows substantial benefit in mortality and need for intubation in randomised controlled trials (RCTs), benefit is not always seen in clinical practice. Exclusion of high-risk patients in most RCTs probably explains a substantial part of this discrepancy, as well as NIV being offered to or requested by patients with end-stage disease with little chance of survival. Common exclusion criteria applied in clinical trials that would not preclude NIV in routine practice include pH less than 7·25, Glasgow Coma Scale less than 8, respiratory rate less than 12, systolic blood pressure less than 90 mm Hg, serious comorbidities (particularly cardiac), complicating

Key messages

Bourke *Lancet Resp Med* 2018; **6**:935

Agenda

- changing landscapes?
- noninvasive ventilation
- high–flow oxygen
- pandemics
- conclusions

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Increase in Use of Noninvasive Ventilation in Hypercapnic Patients

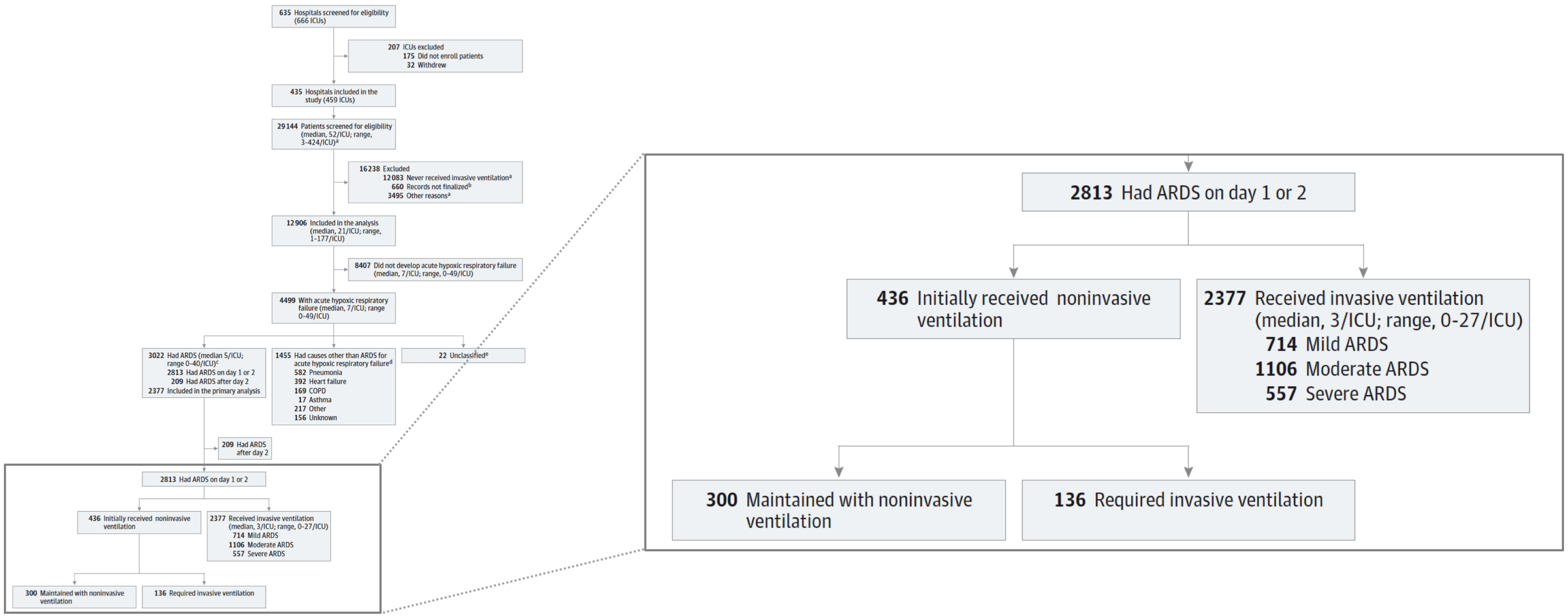
	Number of hospitals	Number of patients	Mean age	Consolidation on radiograph	Median initial $PaCO_2$	Median Initial pH	NIV unsuccessful	IMV	Died		Proportion discharged from hospital
									All causes	Respiratory	
2010	61	925	71	30%	10·2	7·30	27%	2·3%	29%	22%	67%
2011	122	2187	71	38%	10·1	7·26	33%	3·8%	30%	25%	66%
2012	130	2490	72	40%	10·2	7·25	31%	2·7%	31%	26%	65%
2013	148	2693	72	40%	10·2	7·24	33%	3·0%	34%	27%	66%

Table shows data for adult patients admitted to hospital with COPD exacerbation receiving NIV. NIV=non-invasive ventilation. $PaCO_2$=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

The NEW ENGLAND JOURNAL of MEDICINE

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 $PaO_2/FiO_2 < 300$

mean age: **60** years

LOCATION

23 ICUs in the France

VENTILATION STRATEGIES

310 patients with non–hypercapnic AHRF

106 patients **HFNO**

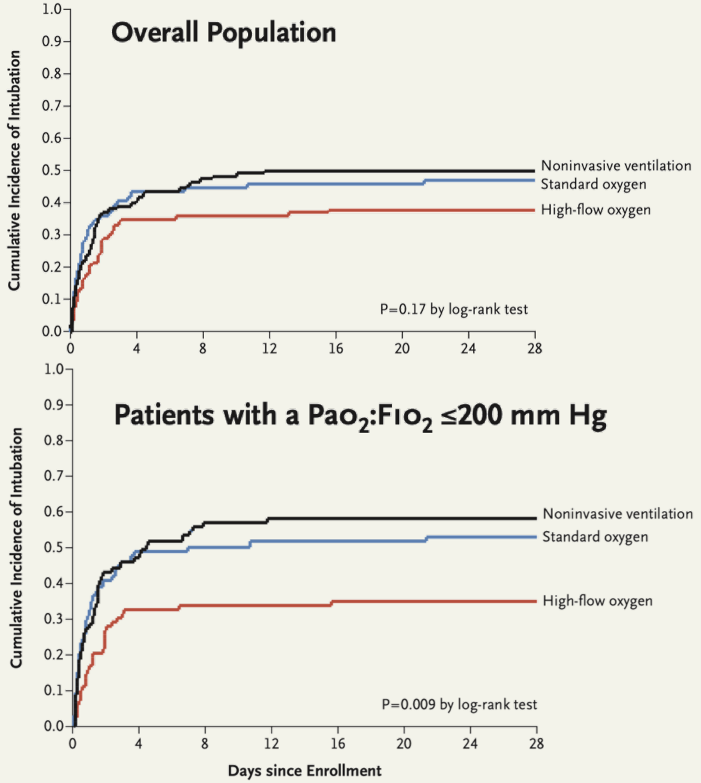
94 patients **standard O_2**

110 patients **NIV**

(PRIMARY) OUTCOME

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

FINDINGS



FLORALI–investigators. High–flow Oxygen through Nasal Cannula in Acute Hypoxemic Respiratory Failure. [*New Eng J Med* 2015; **372**:2185 doi: 10.1056/NEJMoa1503326]

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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

INICIDENCE OF HFNO

16 ICUs included

↓

976 patients assessed for eligibility

→ **227** patients excluded
- **137** not receiving HFNO or ventilatory support
- **3** HFNO airflow < 30 L/min
- **57** not having ARDS (PaO_2/FiO_2 ratio > 300 mmHg)
- **30** not having COVID–19

↓

749 patients with ARDS

→ **21** patients excluded because of incomplete data sets
- **21** lost to follow up before day 28

↓

728 patients with ARDS

↓

229 patients receiving HFNO | **499** patients receiving ventilation

PRoAcT–COVID study investigators. Broadening the Berlin definition of ARDS to patients receiving high-flow nasal oxygen: an observational study in patients with acute hypoxemic respiratory failure due to COVID–19. [*AoIC* 2023; **13**:64; doi:10.1186/s13613-023-01161-6]

ASTMH
AMERICAN SOCIETY OF TROPICAL MEDICINE & HYGIENE
THE AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE
official Journal of the American Society of Tropical Medicine and Hygiene

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

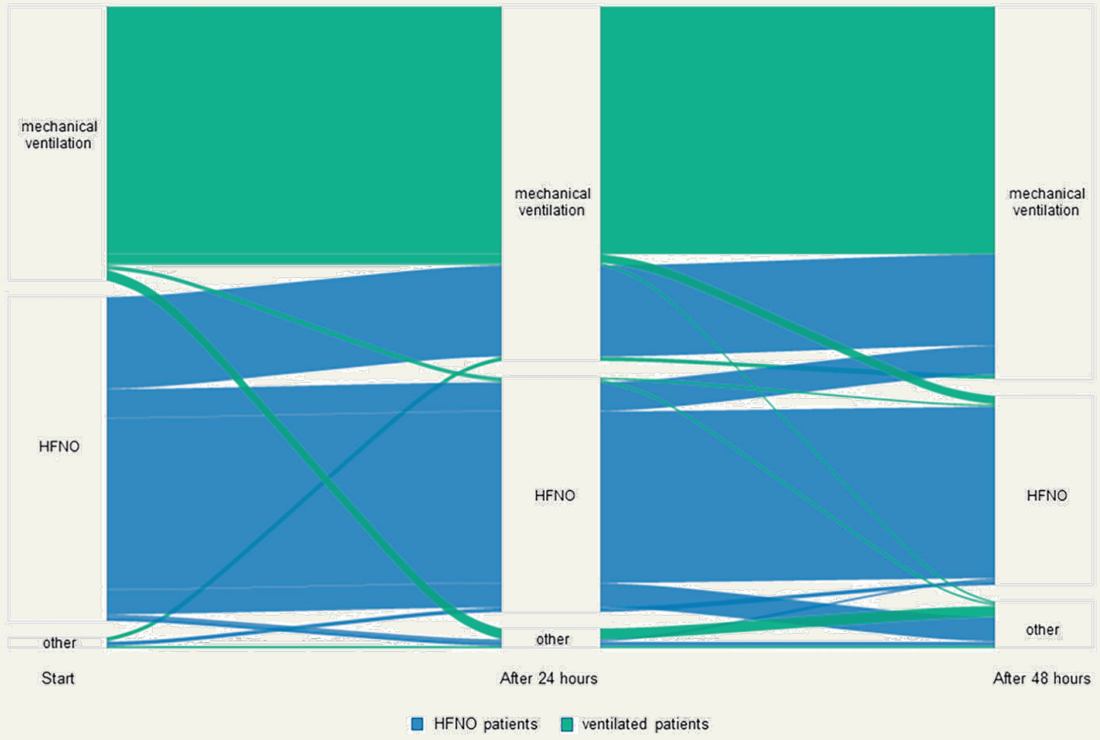
147 patients
HFNO

128 patients
IMV

OUTCOMES

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

RESULTS

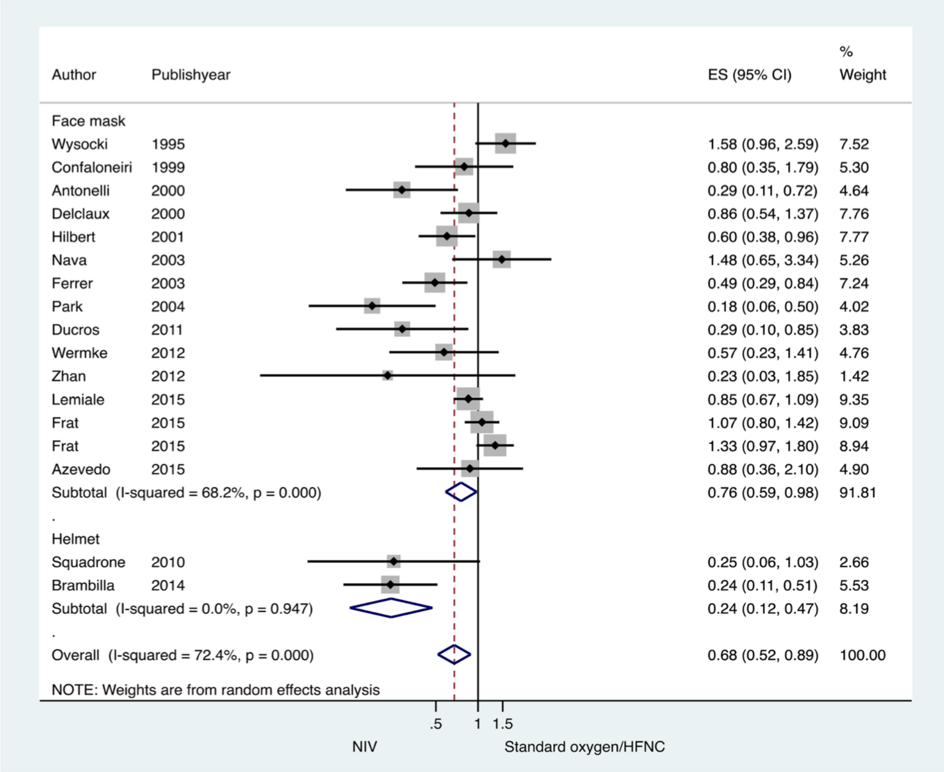


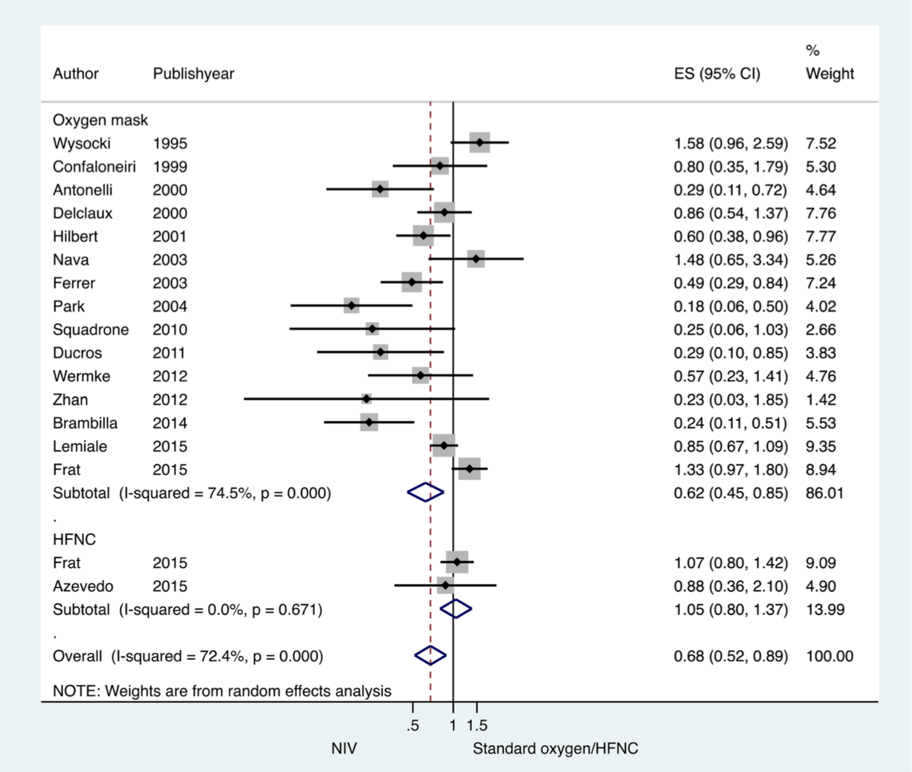
PROXY–COVID study investigators. Oxygen Consumption with High-Flow Nasal Oxygen versus Mechanical Ventilation—An International Multicenter Observational Study in COVID–19 Patients (PROXY–COVID). [*Am J Trop Med Hyg* 2023; **108**:1035; doi:10.4269/ajtmh.22-0793]

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

JAMA®

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

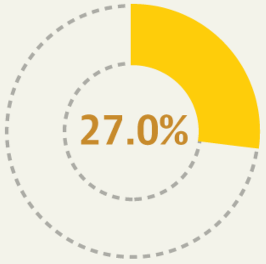
PRIMARY OUTCOMES

28-day all-cause mortality

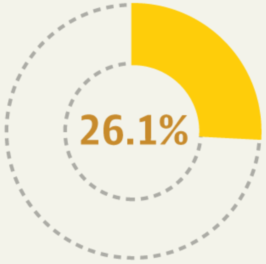
FINDINGS

Mortality rate at 28 days

Helmet noninvasive ventilation
43 of 159 patients



Usual respiratory support
42 of 161 patients



The between-group difference was not significant:

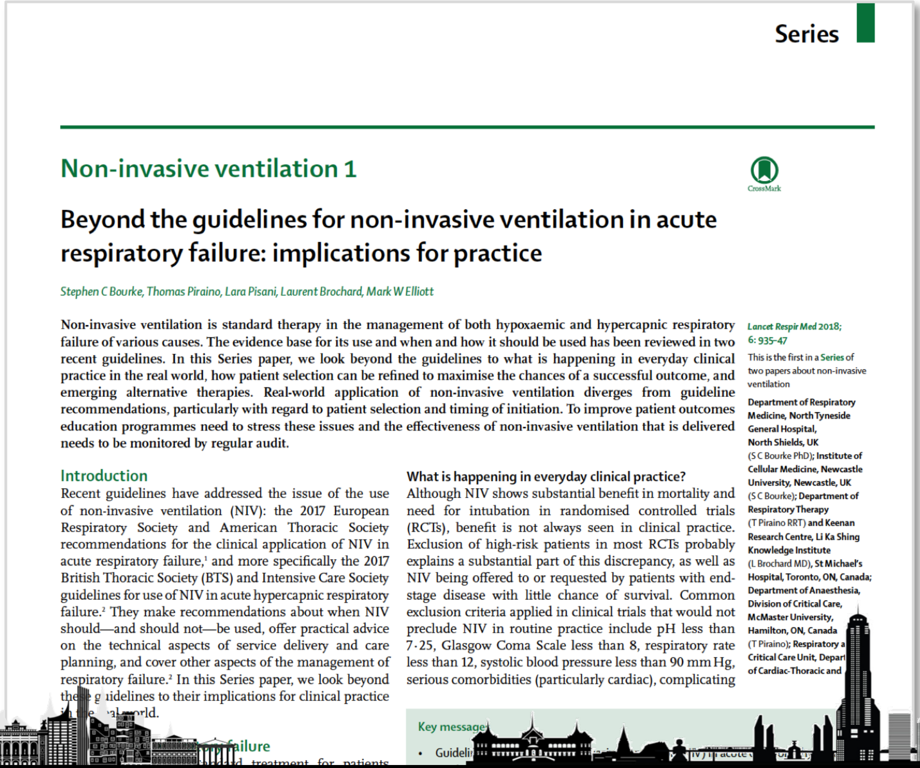
Risk difference, **1.0%** (95% CI, −8.7% to 10.6%)

Relative risk, **1.04** (95% CI, 0.72 to 1.49); *P* = .85

Arabi YM, Aldekhyl S, Al Qahtani S, et al; Saudi Critical Care Trials Group. Effect of helmet noninvasive ventilation vs usual respiratory support on mortality among patients with acute hypoxemic respiratory failure due to COVID-19. *JAMA*. Published September 20, 2022. doi:10.1001/jama.2022.15599

Agenda

- changing landscapes?
- noninvasive ventilation
- high–flow oxygen
- pandemics
- conclusions



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Key messages

Bourke *Lancet RM* 2018; **6**:935

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 acidaemia or low base excess
  - Severe acidaemia (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 PaO_2/FiO_2 >200 mm Hg
- Adverse: PaO_2/FiO_2 <200 or 150 mm Hg

Predictors of failure

- PaO_2/FiO_2 <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, acidosis, consciousness, oxygenation, respiratory rate score >5 after 1 h of NIV

Considerations

- Trial of high-flow nasal cannula for PaO_2/FiO_2 <200 mm Hg
- Avoid delaying intubation

Text: Use of NIV in ARDS

Limited information in the literature

- Uncertain whether NIV should be used

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ATS Journals

QUESTION Is during NIV the categorization of ARDS severity based on the PaO_2/FiO_2 Berlin criteria is useful?

CONCLUSION NIV was used in15%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

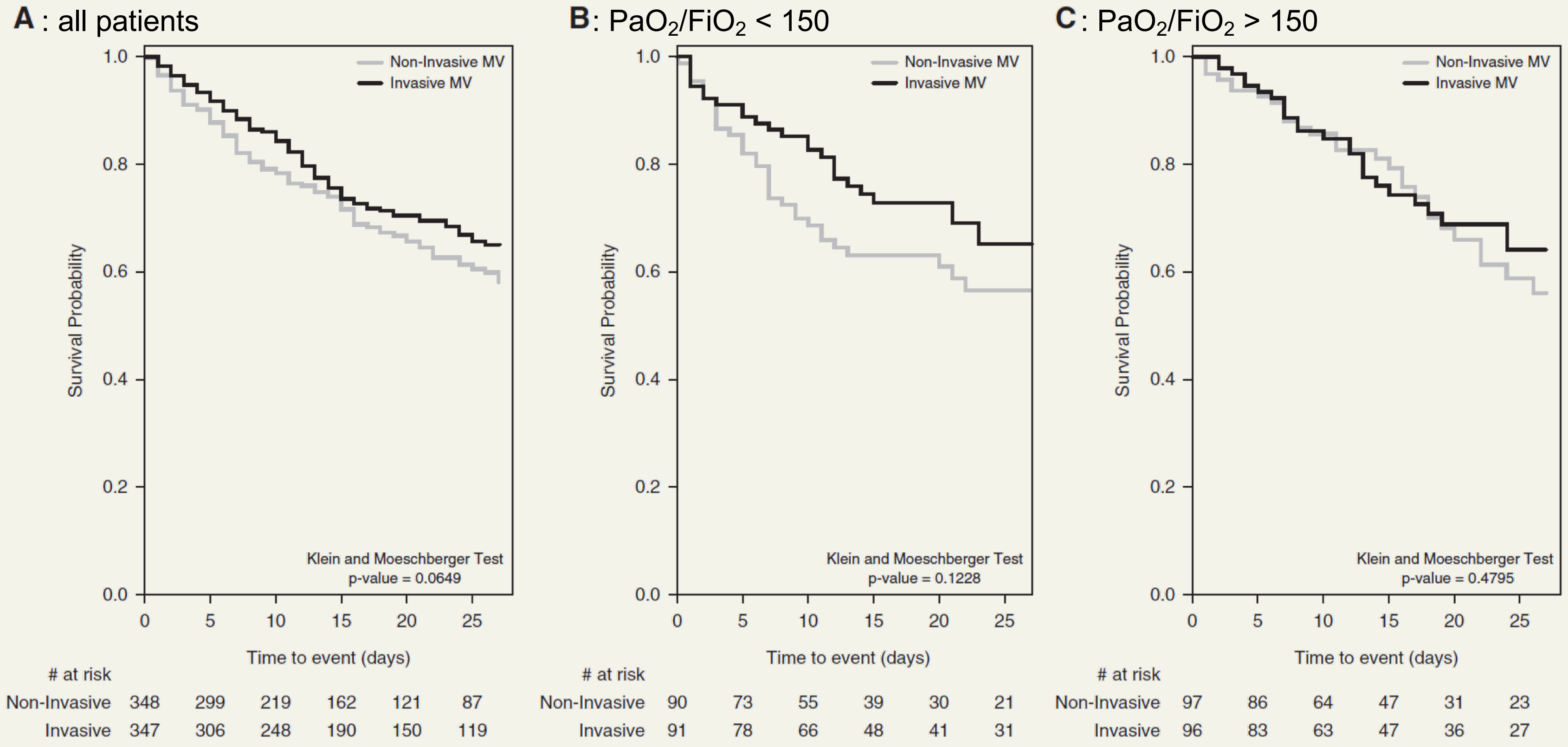
179 Women **257** Men

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

Mean Age: **65** years

LOCATION

459 ICUs
in **50** countries



LUNG SAFE investigators. Noninvasive Ventilation of Patients with Acute Respiratory Distress Syndrome - Insights from the LUNG SAFE Study. [*Am J Resp Crit Care Med* 2016; **175**:67; doi:10.1164/rccm.201606-1306OC]

Bourke *Lancet RM* 2018; **6**:935

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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- high–flow oxygen
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- conclusions

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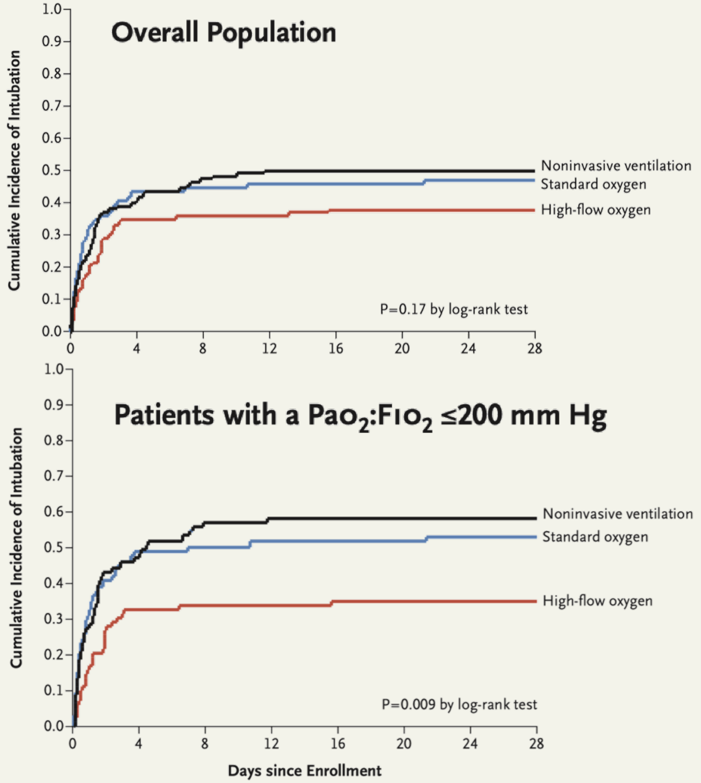

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Benefits and Risks of HFNO

- comfortable
- failures less well recognized
- oxygenation
- in case of hypoxic failure little reserves
- lower risk of P–SILI?

ROX index = SpO_2/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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POPULATION

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Mean Age: **66** years

LOCATION

16 ICUs in The Netherlands

GROUPS

728 patients with ARDS according to new definition

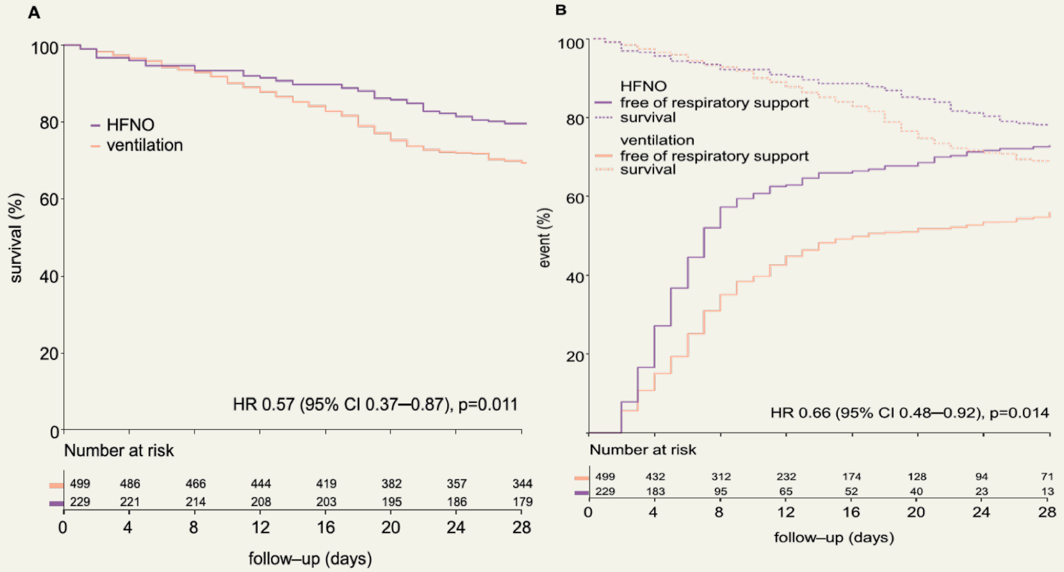
229 patients **HFNO**

499 patients **IMV**

OUTCOMES

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

OUTCOMES



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

PRoAcT–COVID study investigators. Broadening the Berlin definition of ARDS to patients receiving high-flow nasal oxygen: an observational study in patients with acute hypoxemic respiratory failure due to COVID–19. [*AoIC* 2023; **13**:64; doi:10.1186/s13613-023-01161-6]

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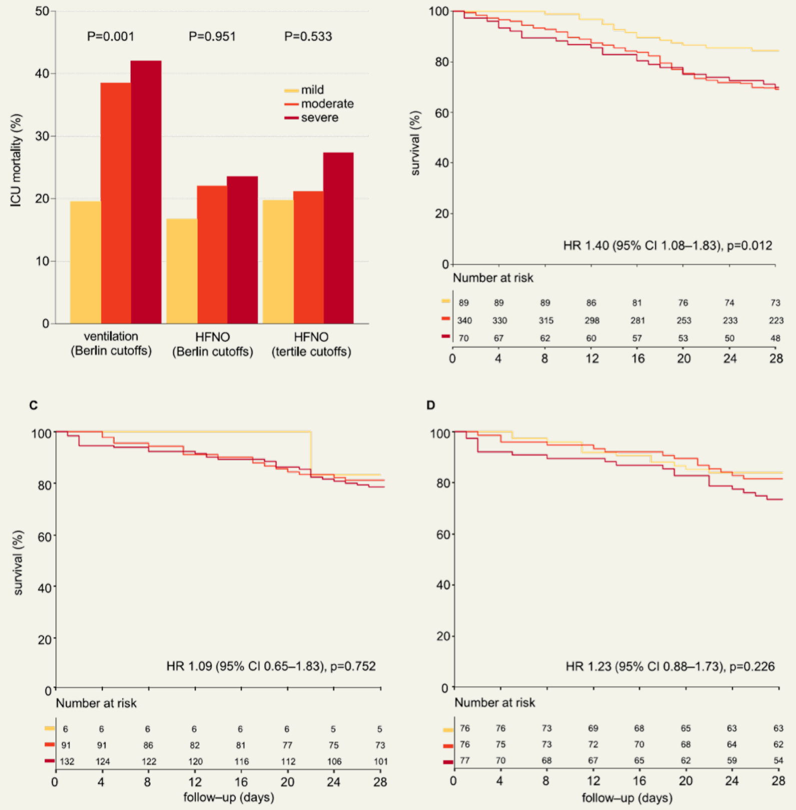


PRoAcT–COVID study investigators. Broadening the Berlin definition of ARDS to patients receiving high-flow nasal oxygen: an observational study in patients with acute hypoxemic respiratory failure due to COVID–19. [*AoIC* 2023; **13**:64; doi:10.1186/s13613-023-01161-6]

Oxygen Scarcity

- running out of oxygen = realistic scenario

ASTMH
AMERICAN SOCIETY OF TROPICAL MEDICINE & HYGIENE
ADVANCING GLOBAL HEALTH SINCE 1903
THE AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE
official Journal of the American Society of Tropical Medicine and Hygiene

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

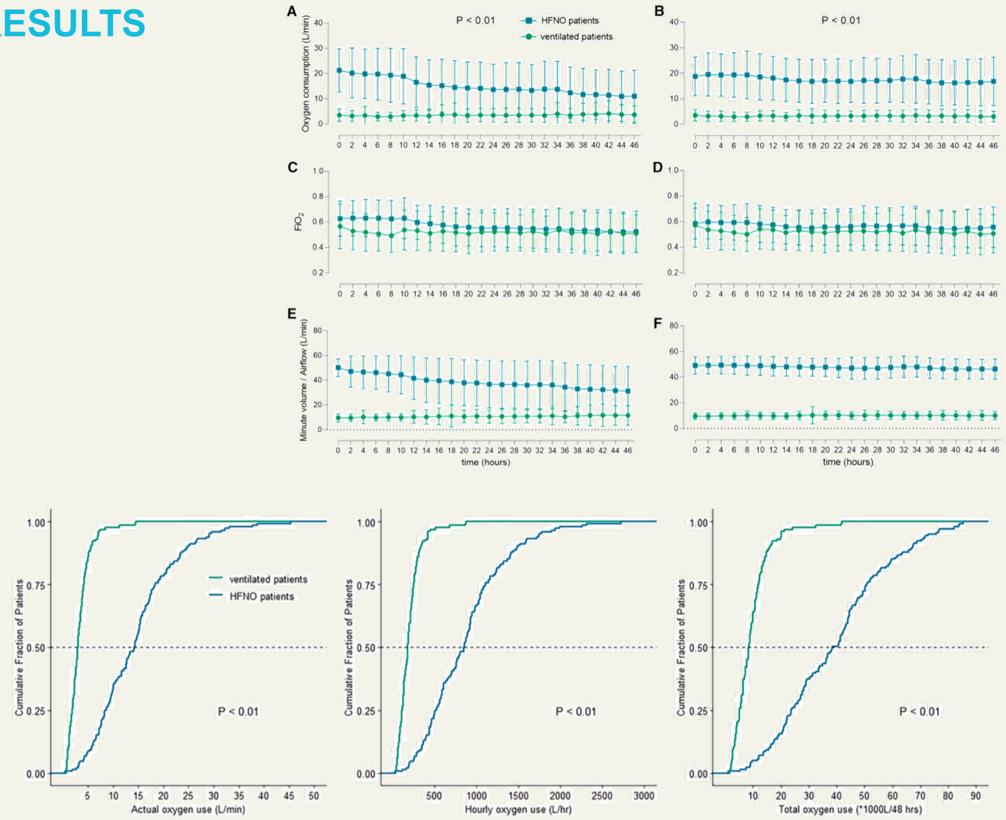
147 patients **HFNO**

128 patients **IMV**

OUTCOMES

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

RESULTS



PROXY–COVID study investigators. Oxygen Consumption with High-Flow Nasal Oxygen versus Mechanical Ventilation—An International Multicenter Observational Study in COVID–19 Patients (PROXY–COVID). [*Am J Trop Med Hyg* 2023; **108**:1035; doi:10.4269/ajtmh.22-0793]

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**

Botta *A J Trop Med Hyg* 2023; **108**:1035

Oxygen Use with High–flow Oxygen

- oxygen–sparing strategies
  - automated oxygen titration
  - better bedside use of guidelines with strict cutoffs for SpO_2
  - prone positioning
  - noninvasively or invasive ventilation

Botta *A J Trop Med Hyg* 2023; **108**:1035

CRITICAL CARE

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

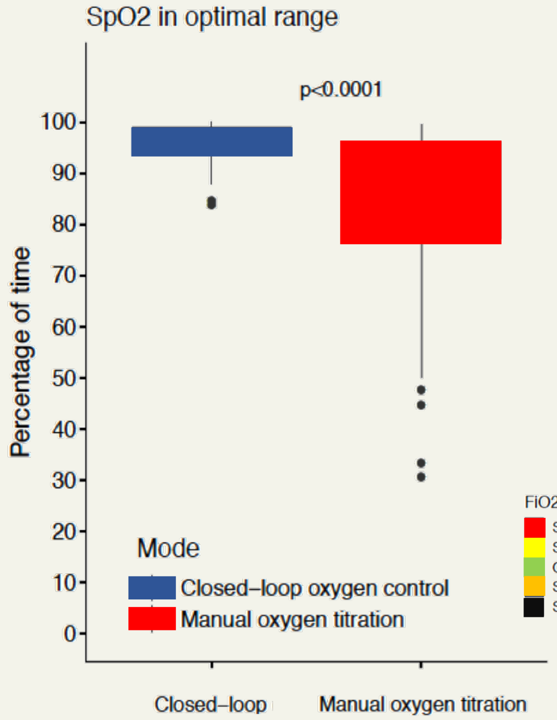
↓ *crossover*

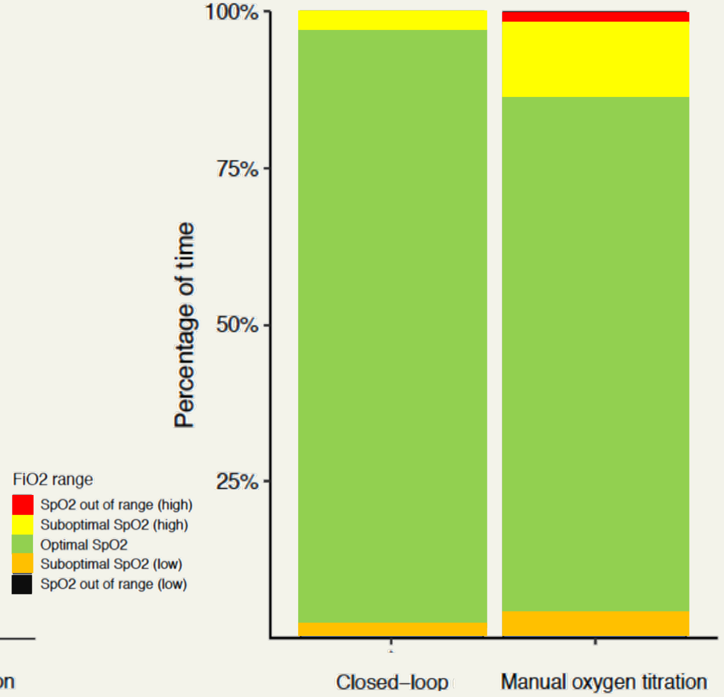
4 hours automated or manual FiO_2 control

(PRIMARY) OUTCOME

percentage of time spent in the individualized optimal SpO_2 ranges

RESULTS





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]

frontiers | Frontiers in Medicine

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

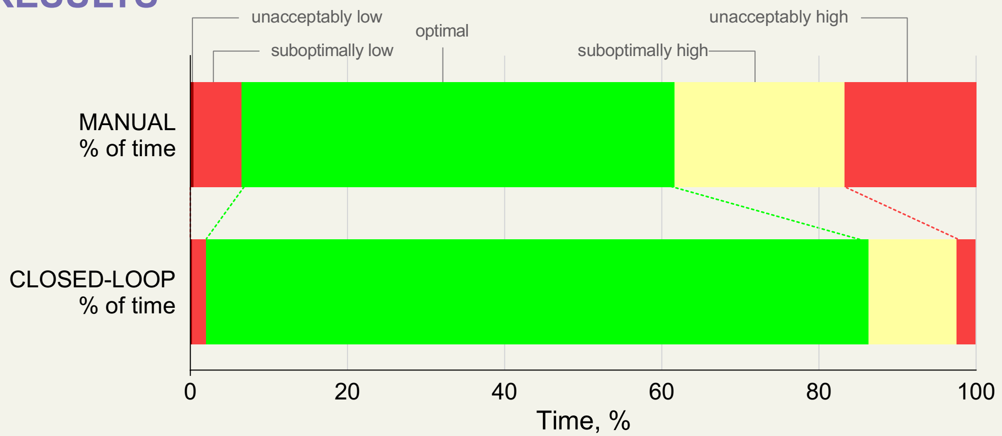
↓ *crossover*

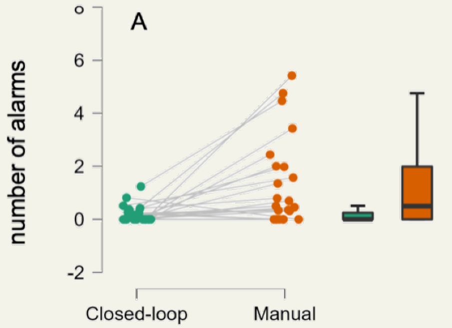
automated or manual FiO_2 control

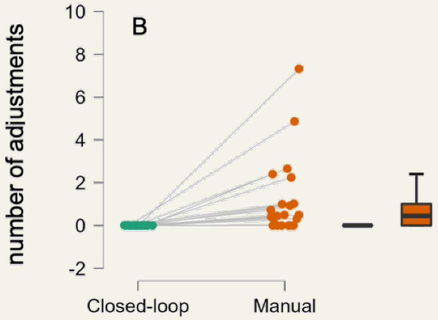
(PRIMARY) OUTCOME

FiO_2 settings and SpO_2 readings; alarms and manual adjustments

RESULTS







Sandal O. Closed–loop Oxygen Control Improves Oxygenation in Pediatric Patients Under High–flow Oxygen Therapy – a randomized crossover study. [Frontiers Med 2022; **9**:1046902; doi: 0.3389/fmed.2022.1046902]

The NEW ENGLAND JOURNAL of MEDICINE

QUESTION Does early application of prone positioning improves 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

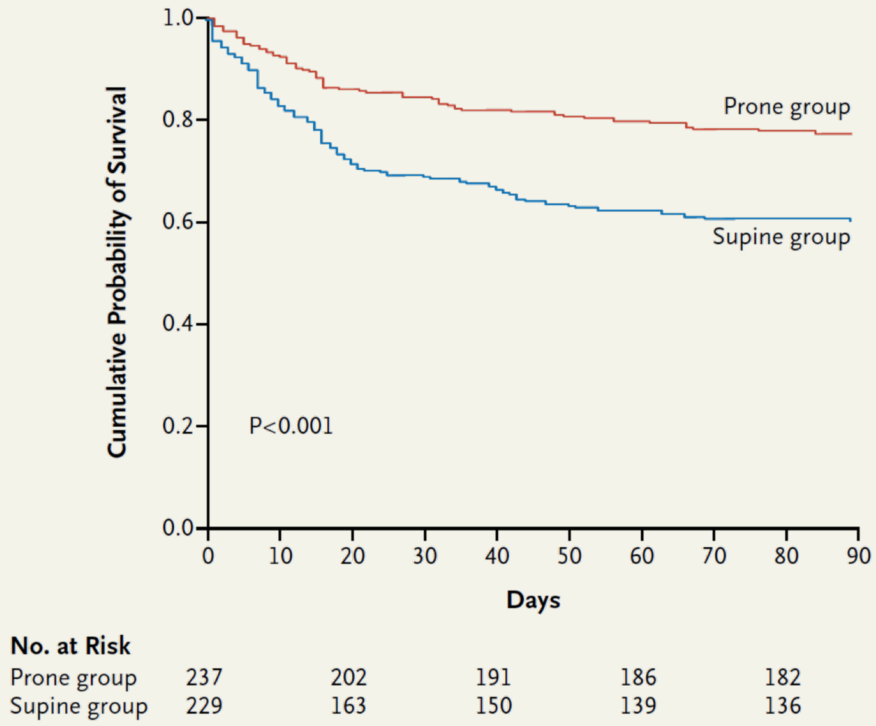
237 patients **early prone**

299 patients **supine**

(PRIMARY) OUTCOME

28–day and 90–day mortality

FINDINGS



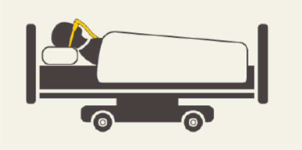
The PROSEVA study group. Prone Positioning in Severe Acute Respiratory Distress Syndrome. [*New Eng J Med* 2013; **368**:2159; doi:10.1056/NEJMoa1214103]

THE LANCET
Respiratory Medicine

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

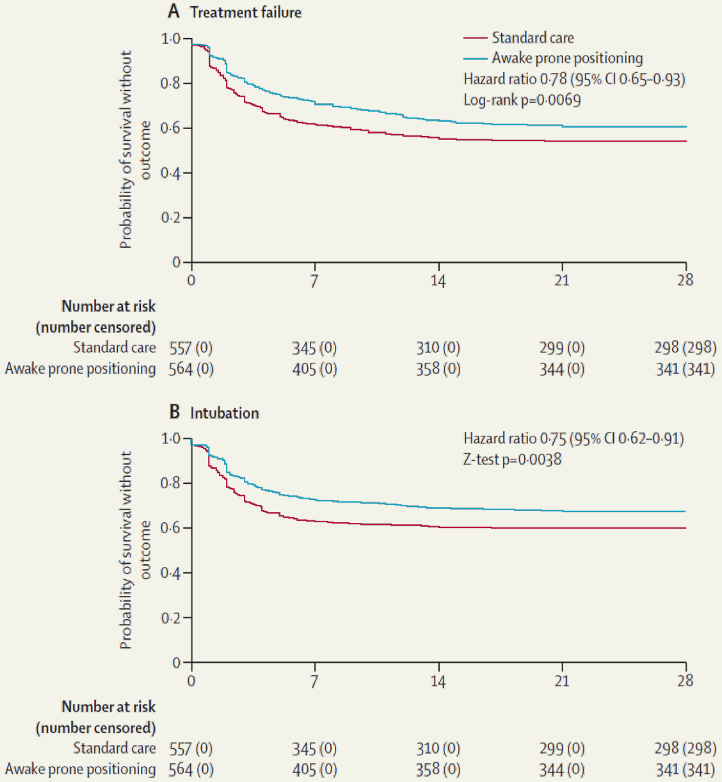
564 awake prone positioning

557 standard care

(PRIMARY) OUTCOME

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

FINDINGS



The Awake Prone Positioning Meta–Trial Group. Awake prone positioning for COVID-19 acute hypoxemic respiratory failure: a randomized, controlled, multinational, open-label meta–trial. [*Lancet Respir Med* 2021; **9**:1387; doi:10.1016/S2213-2600(21)00356-8]

Conclusions

- landscape is changing
- HFNO seems to outperform NIV in ARDS patients
- do not use NIV when PaO_2/FiO_2 < 150 mm Hg
- be aware of limitations of your oxygen resources when applying HFNO