# 급성 호흡부전 환자에서 산소치료

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# Contents

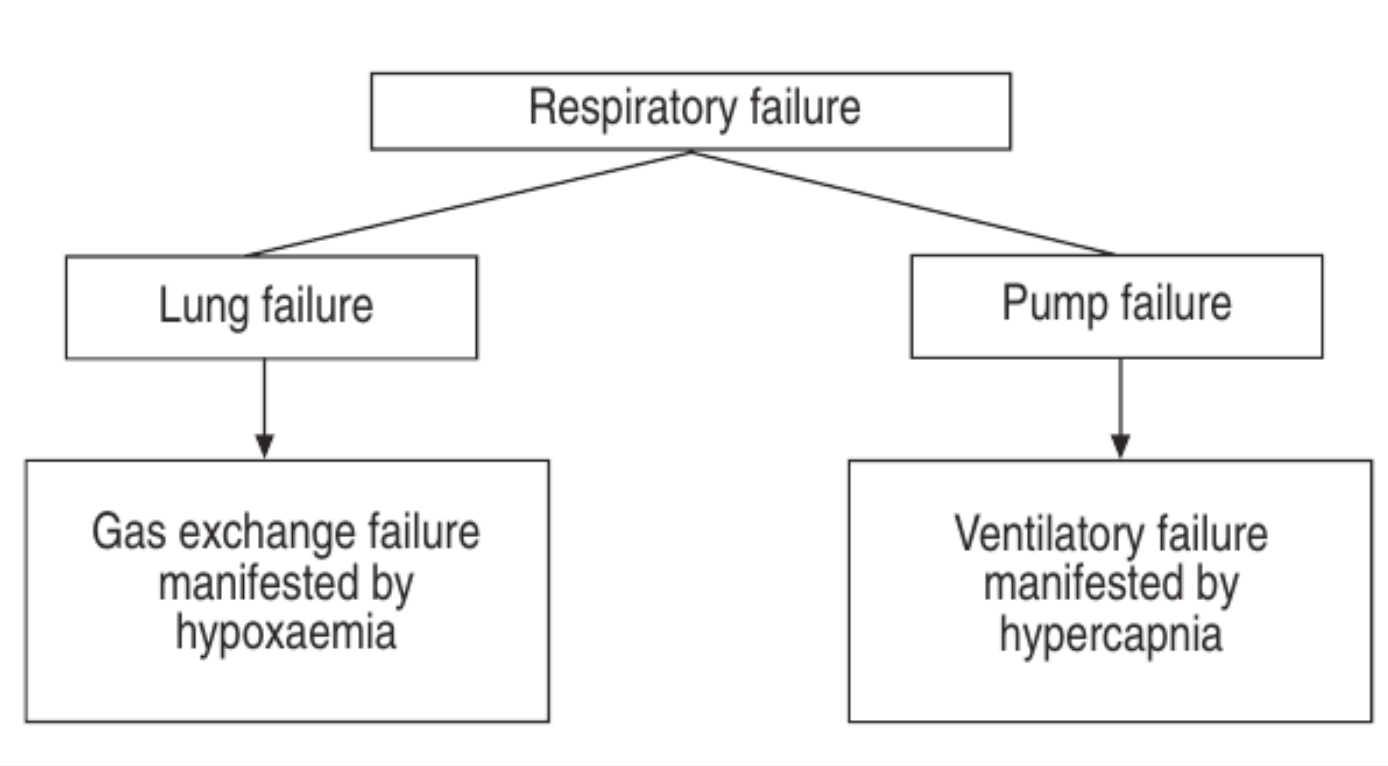
# Definition of Respiratory Failure

- Respiratory system fails in one of both of gas exchange functions
  - ✓ Oxygenation
  - ✓ Elimination of carbon dioxide

- Arterial oxygen tension ($PaO_2$) < 60mmHg
- Arterial carbon dioxide tension ($PaCO_2$) > 45mmHg

*C. Roussos et al. ERJ 2003; 22: Suppl. 47, 3s-14s*

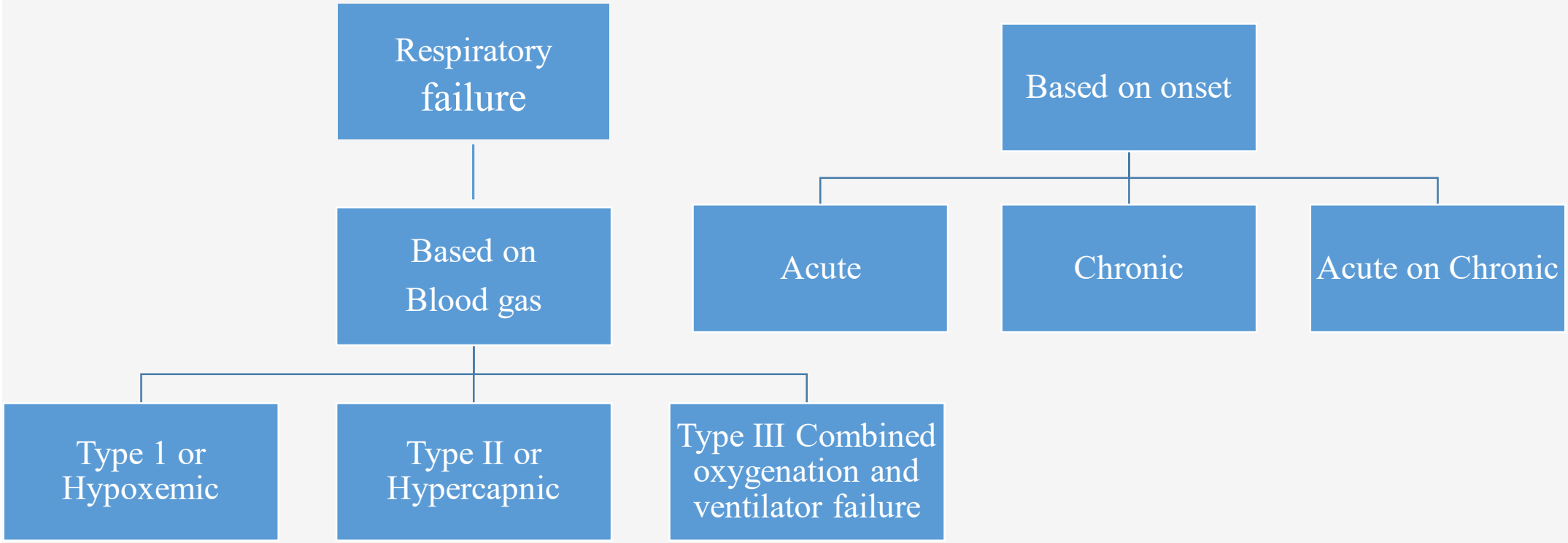
# Types of Respiratory Failure




- Gas exchanging organ
  - Lung
  - Pulmonary vessels
- Ventilation organ
  - Chest wall
    - Respiratory muscle
    - Chest cage
  - CNS
  - Spinal, Peripheral nerve

*C. Roussos et al. ERJ 2003; 22: Suppl. 47, 3s-14s*

# Classification of Respiratory Failure

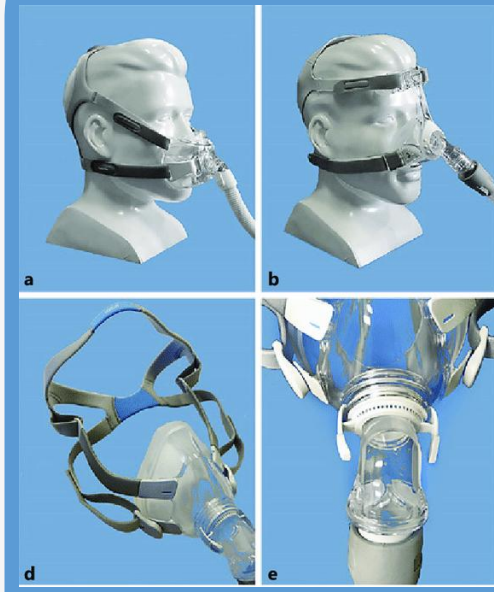



*TS Lamba et al. Crit Care Nurs Q Vol. 39, No. 2, pp. 85–93*

# Methods of $O_2$ supply

## Oxygen Supply

## Ventilator



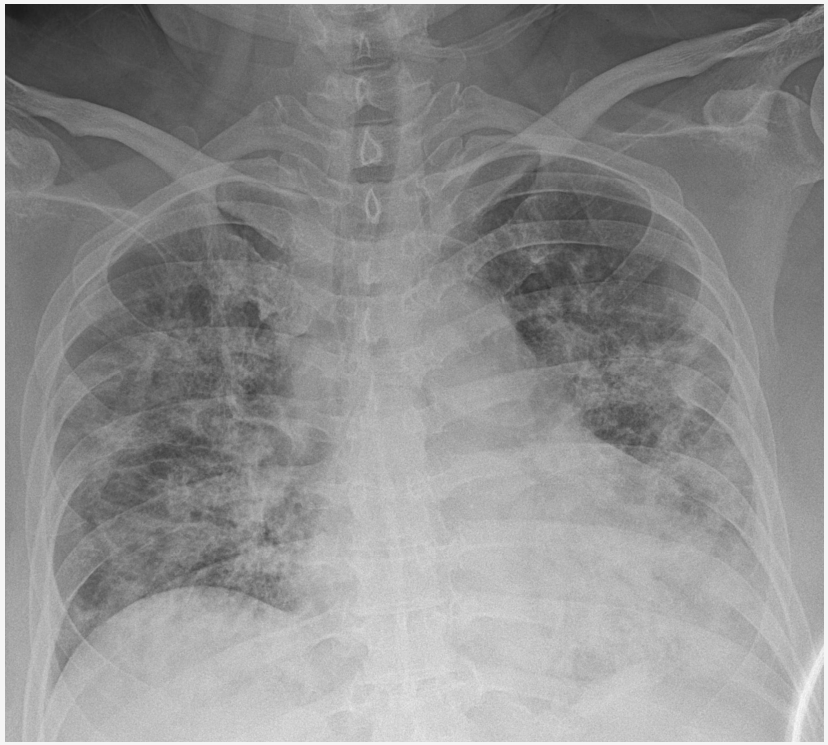

# CASE 1

- 55세 여자 환자가 3일전부터 발생한 기침, 가래를 동반한 호흡곤란 증상으로 응급실로 내원함.

- Vital sign
  - BP: 100/50mmHg, HR:120/min, RR:34/min, BT:38.2℃, SaO2 78%

- ABGA
  - RA : pH 7.39, $pCO_2$ 26mmHg, $PaO_2$ 46mmHg, SaO2 81%

# CASE 1



- No history of chronic pulmonary, cardiac disease
- Supply O2 via mask 10L/min
- Vital sign after O2 supply
  - ✓ BP: 100/50 mmHg, HR: 120/min, RR: 29/min
  - ✓ ABGA pH 7.45, pCO2 25mmHg, $PaO_2$ 70 mmHg, $SaO_2$ 92%

# Goals of Oxygen Therapy

- The ability to supply the patient with the oxygen they need
- Comfort
- Avoid endotracheal intubation
- Improve mortality
- Prevention of adverse effect

# Comparing HFNC and Conventional oxygen therapy

- 17 Patients with ARF requiring > 9L/min
- Face mask (9L/min – 15L/min)
- HFNC setting : $FiO_2$ 60%, initial Flow 40L/min

Table. Changes in Dyspnea and Respiratory Parameters Comparing Conventional Oxygen Therapy to High Flow Nasal Cannula

| | H0 | H + 15 min | H + 30 min | H + 60 min |
|---|---|---|---|---|
| Borg scale ($n$ = 9) | 6 (5–7) | 4 (3–4)* | 4 (2–4)† | 3 (2–4)† |
| Visual analog scale ($n$ = 9) | 7 (5–8) | 5 (2–6)* | 4 (2–6)† | 3 (1–5)‡ |
| Respiratory rate, breaths/min ($n$ = 17) | 28 (25–32) | 25 (23–30)* | 25 (21–30)‡ | 25 (21–28)† |
| $S_{pO_2}$, % ($n$ = 17) | 90 (88.5–94) | 96 (90–99)‡ | 95 (90–100)† | 97 (92.5–100)† |

Values are median (1QR).
* $P < .05$.
† $P < .001$.
‡ $P < .01$.
H0 = time just before switching from conventional oxygen therapy to high flow nasal cannula;

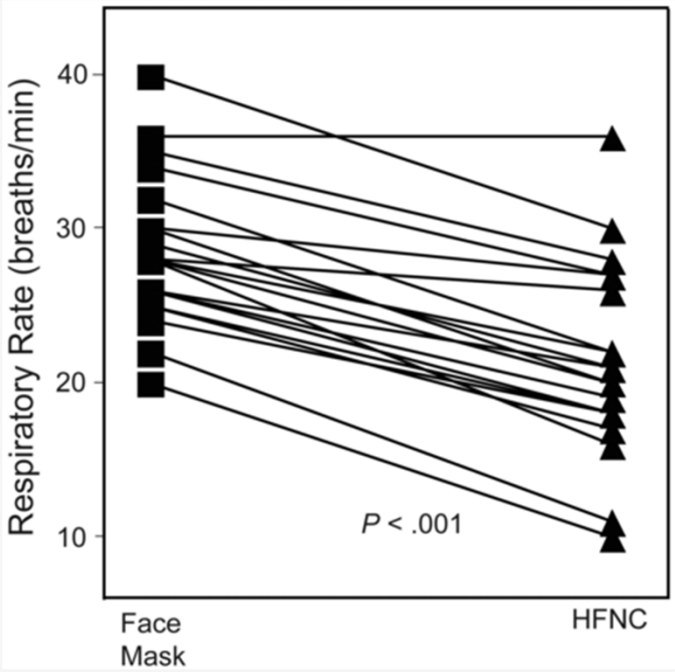
*Crit Care. 2009;13(6):R209*

# Comparing HFNC and Conventional oxygen therapy

- $SaO_2 < 96\%$ while receiving $FiO_2 \geq 0.5$ via face mask
- Comparing face mask(15L/min) and HFNC 30L/min

| | Face Mask | HFNC | *P* |
|---|---|---|---|
| Subjective Evaluation | | | |
| Dyspnea | 6.8 (4.1–7.9) | 3.8 (1.3–5.8) | .001 |
| Mouth dryness | 9.5 (8.0–10.0) | 5 (2.3–7.0) | < .001 |
| Overall comfort | 5.0 (2.3–6.8) | 9.0 (8.0–10.0) | < .001 |
| Respiratory and Gas-Exchange Variables | | | |
| Total oxygen flow (L/min) | 15.0 (12.0–20.0) | 30.0 (21.3–38.7) | < .001 |
| Fraction of delivered oxygen | 1.0 (0.8–1.0) | 1.0 (0.8–1.0) | .32 |
| Respiratory rate (breaths/min) | 28 (25–32) | 21 (18–27) | < .001 |
| pH† | 7.42 ± 7.38–7.47 | 7.44 (7.38–7.50) | .06 |
| $P_{aO_2}$ (mm Hg)† | 77 (64–88) | 127 (83–191) | .002 |
| $P_{aCO_2}$ (mm Hg)† | 37 (33–45) | 37 (32–43) | .51 |
| $HCO_3^-$ (mmol/L)† | 25.0 (22.1–28.5) | 24.5 (22.2–29.1) | .09 |
| Base excess (mmol/L)† | 1.0 (−2.3–4.8) | −1.0 (−2.3 to 5.3) | .055 |
| $S_{pO_2}$ (%) | 95 (91–97) | 98 (96–99) | .002 |
| Hemodynamic Variables | | | |
| Mean arterial pressure (mm Hg) | 87 (76–94) | 86 (71–93) | .36 |
| Heart rate (beats/min) | 94 (77–112) | 85 (73–108) | > .99 |

* All values are median and interquartile range.
† Only in patients with an arterial catheter.
HFNC = high-flow nasal cannula
$S_{pO_2}$ = blood oxygen saturation measured via pulse oximetry




*Roca O et al. Respir Care. 2010 Apr;55(4):408-13.*

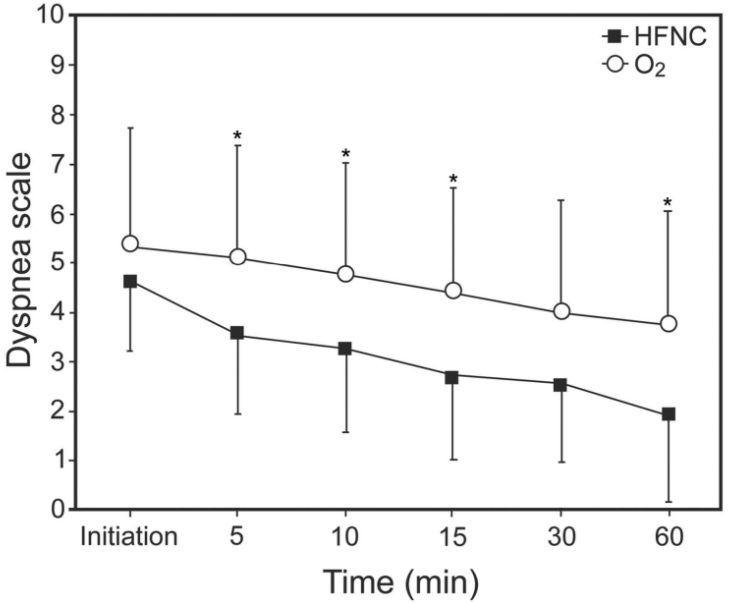
# Comparing HFNC and Conventional Oxygen Therapy

- 40 Patients with ARF (RR > 24/min and $SpO_2 < 94\%$ on RA)
- HFNC (Flow 35 L/min, $FiO_2$ adjusted to $SpO_2 \geq 94\%$) vs. COT for 60 min
- CHF, Asthma attack, COPD c AE, Pneumonia
- Mean $SpO_2$ 86-88%

Table 2. Comparing Clinical and Physiologic Parameters for the HFNC and COT Groups at the End of the Study

| Parameter | HFNC | COT |
|---|---|---|
| Dyspnea scale score, mean ± SD | 2.0 ± 1.8 | 3.8 ± 2.3 |
| Breathing frequency, mean ± SD breaths/min | 26.0 ± 6.2 | 27.5 ± 4.9 |
| Mean arterial pressure, mean ± SD mm Hg | 88.7 ± 10.9 | 101.0 ± 24.8 |
| Heart rate, mean ± SD beats/min | 91.7 ± 19.3 | 101.6 ± 24.2 |
| $S_{pO_2}$, mean ± SD % | 96.8 ± 2.5 | 97.6 ± 2.0 |
| Comfort scale score, mean ± SD | 1.6 ± 1.7 | 3.7 ± 2.4 |

HFNC = high-flow nasal oxygen cannula
COT = conventional oxygen therapy




*Respir Care 2015;60(10):1377–1382.*

# Comparing HFNC and Conventional Oxygen Therapy

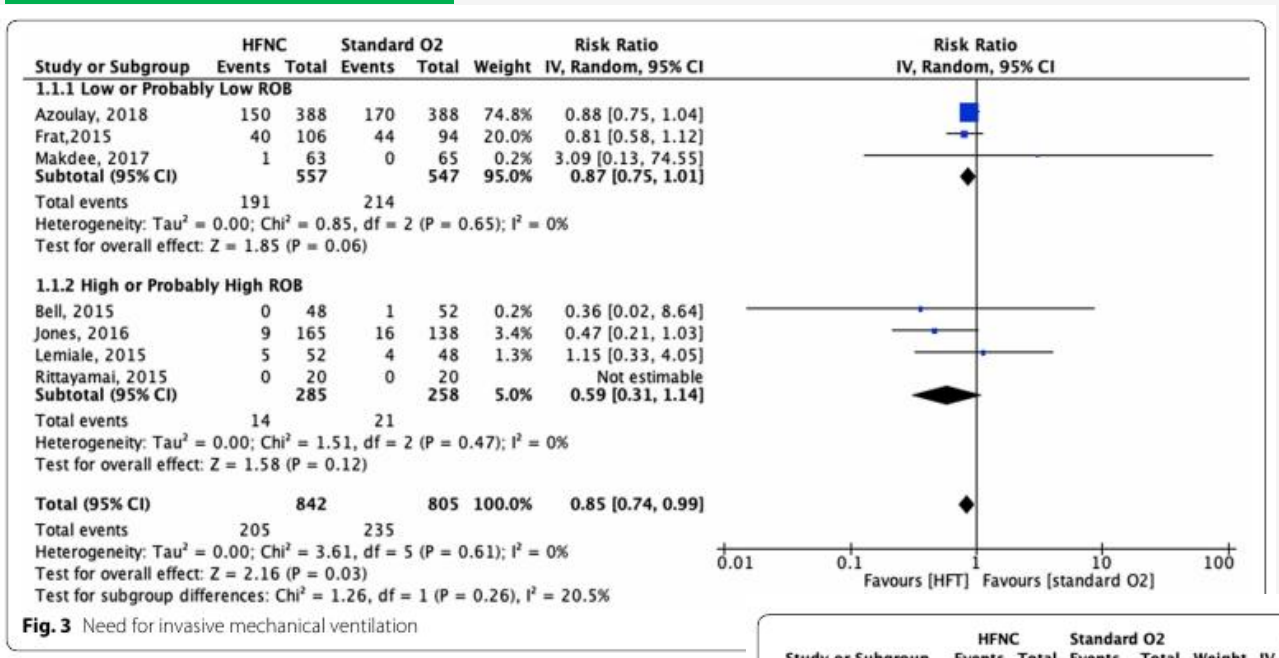
- 303 Patients with ARF (RR ≥ 22/min and $SpO_2$ < 92% on RA)
- HFNC (Flow 40 L/min, $FiO_2$ adjusted to $SpO_2$ ≥ 94%) vs. COT
- Outcomes : conversion to NIV or IMV, Hospital LOS, 90-day mortality
- Cause of hypoxia : COPD, Pneumonia, CHF, Asthma

| Outcome | HFNC ($n$ = 165) | Standard $O_2$ ($n$ = 138) | $P$ |
|---|---|---|---|
| Conversion to mechanical ventilation in emergency department, *n*, % (95% CI) | 6, 3.6 (1.5–7.9) | 10, 7.2 (3.8–13) | .16 |
| 90-d mortality, *n*, % (95% CI) | 35, 21.2 (15.6–28.1) | 24, 17.4 (11.9–24.6) | .40 |
| Pneumothorax, *n*, % (95% CI) | 0, 0 (0–3) | 0, 0 (0–3) | |
| Subcutaneous emphysema, *n*, % (95% CI) | 0, 0 (0–3) | 0, 0 (0–3) | |
| Pressure sore, *n*, % (95% CI) | 0, 0 (0–3) | 0, 0 (0–3) | |
| Apnea, *n*, % (95% CI) | 0, 0 (0–3) | 1, 0.7 (0–4) | .45 |
| Fall in GCS ≥2 points, *n*, % (95% CI) | 1, 0.6 (0–3.7) | 6, 4.3 (1.8–9.4) | .050 |
| Fall in GCS due to $CO_2$ retention,* *n*, % (95% CI) | 0, 0 (0–3) | 3, 2.2 (0.4–6) | .09 |
| Intubated,* *n*, % (95% CI) | 1, 0.6 (0–4) | 3, 2.2 (0.5–6) | .33 |
| Admitted to ICU,* *n*, % (95% CI) | 8, 4.8 (2.3–9.4) | 5, 3.6 (1.3–8.4) | .60 |
| Mechanical ventilation within 24 h,* *n*, % (95% CI) | 9, 5.5 (2.8–10.2) | 16, 11.6 (7.2–18.1) | .053 |
| In-hospital mortality,* *n*, % (95% CI) | 15, 9.1 (5.5–14.6) | 11, 8.0 (4.4–13.8) | .73 |
| Emergency department LOS, median (IQR) h | 4.5 (3.6–5.8) | 4.9 (3.6–5.9) | .32 |
| Hospital LOS, median (IQR) d | 5.0 (2.8–8.3) | 5.6 (2.8–9.3) | .43 |
| Time to mechanical ventilation in emergency department,* median (IQR) min | 6, 139.5 (70–214.5) | 10, 126 (19.75–197.75) | .43 |
| Time to mechanical ventilation in ward,* median (IQR) min | 3, 1,040 (755.5–1,222.5) | 6, 857 (395–1,116) | .71 |

*Respir Care 2016;61(3):291–299.*

# Comparing HFNC and Conventional oxygen therapy

## Intubation rate

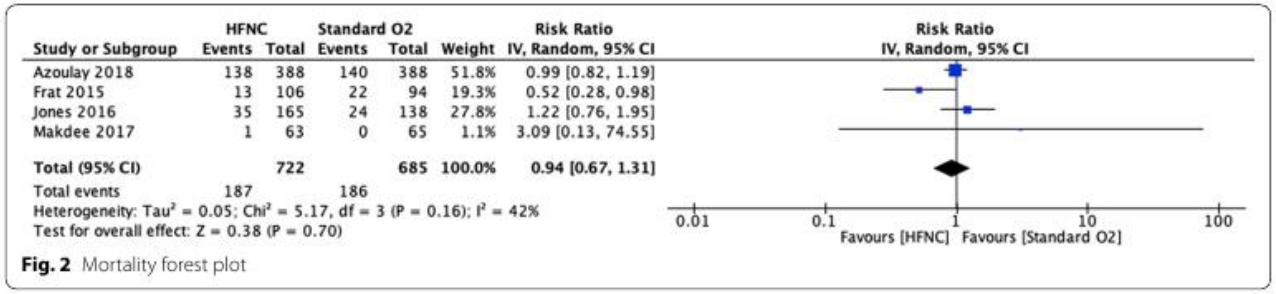


| Study or Subgroup | HFNC Events | HFNC Total | Standard O2 Events | Standard O2 Total | Weight | Risk Ratio IV, Random, 95% CI |
|---|---|---|---|---|---|---|
| **1.1.1 Low or Probably Low ROB** | | | | | | |
| Azoulay, 2018 | 150 | 388 | 170 | 388 | 74.8% | 0.88 [0.75, 1.04] |
| Frat,2015 | 40 | 106 | 44 | 94 | 20.0% | 0.81 [0.58, 1.12] |
| Makdee, 2017 | 1 | 63 | 0 | 65 | 0.2% | 3.09 [0.13, 74.55] |
| **Subtotal (95% CI)** | | **557** | | **547** | **95.0%** | **0.87 [0.75, 1.01]** |
| Total events | 191 | | 214 | | | |
| Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.85$, df = 2 (P = 0.65); $I^2 = 0\%$ | | | | | | |
| Test for overall effect: Z = 1.85 (P = 0.06) | | | | | | |
| **1.1.2 High or Probably High ROB** | | | | | | |
| Bell, 2015 | 0 | 48 | 1 | 52 | 0.2% | 0.36 [0.02, 8.64] |
| Jones, 2016 | 9 | 165 | 16 | 138 | 3.4% | 0.47 [0.21, 1.03] |
| Lemiale, 2015 | 5 | 52 | 4 | 48 | 1.3% | 1.15 [0.33, 4.05] |
| Rittayamai, 2015 | 0 | 20 | 0 | 20 | | Not estimable |
| **Subtotal (95% CI)** | | **285** | | **258** | **5.0%** | **0.59 [0.31, 1.14]** |
| Total events | 14 | | 21 | | | |
| Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.51$, df = 2 (P = 0.47); $I^2 = 0\%$ | | | | | | |
| Test for overall effect: Z = 1.58 (P = 0.12) | | | | | | |
| **Total (95% CI)** | | **842** | | **805** | **100.0%** | **0.85 [0.74, 0.99]** |
| Total events | 205 | | 235 | | | |
| Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 3.61$, df = 5 (P = 0.61); $I^2 = 0\%$ | | | | | | |
| Test for overall effect: Z = 2.16 (P = 0.03) | | | | | | |
| Test for subgroup differences: $Chi^2 = 1.26$, df = 1 (P = 0.26), $I^2 = 20.5\%$ | | | | | | |



**Fig. 3** Need for invasive mechanical ventilation

## Mortality



| Study or Subgroup | HFNC Events | HFNC Total | Standard O2 Events | Standard O2 Total | Weight | Risk Ratio IV, Random, 95% CI |
|---|---|---|---|---|---|---|
| Azoulay 2018 | 138 | 388 | 140 | 388 | 51.8% | 0.99 [0.82, 1.19] |
| Frat 2015 | 13 | 106 | 22 | 94 | 19.3% | 0.52 [0.28, 0.98] |
| Jones 2016 | 35 | 165 | 24 | 138 | 27.8% | 1.22 [0.76, 1.95] |
| Makdee 2017 | 1 | 63 | 0 | 65 | 1.1% | 3.09 [0.13, 74.55] |
| **Total (95% CI)** | | **722** | | **685** | **100.0%** | **0.94 [0.67, 1.31]** |
| Total events | 187 | | 186 | | | |
| Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 5.17$, df = 3 (P = 0.16); $I^2 = 42\%$ | | | | | | |
| Test for overall effect: Z = 0.38 (P = 0.70) | | | | | | |



**Fig. 2** Mortality forest plot

*Rochwerg B et al. Intensive Care Med. 2019 May;45(5):563-572.*

# ERS clinical practice guidelines: HFNC in acute respiratory failure

***HFNC for hypoxaemic acute respiratory failure***

*PICO question 1: Should HFNC or COT be used in patients with acute hypoxaemic respiratory failure?*

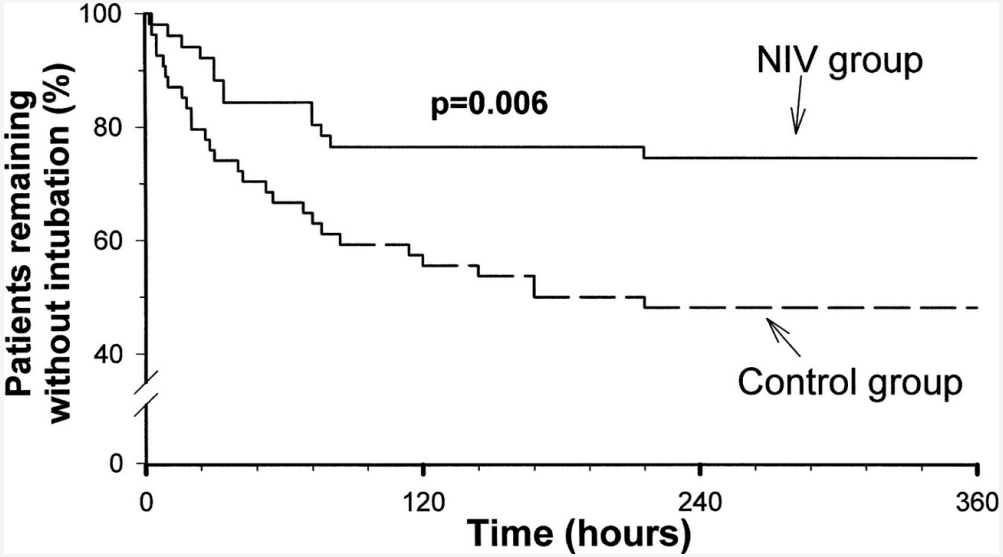
Recommendation 1

*We suggest the use of HFNC over COT in adults with acute hypoxaemic respiratory failure (conditional recommendation, moderate certainty of evidence).*

*Eur Respir J 2022; 59: 2101574*

# Comparing NIV and Conventional oxygen therapy

- 105 Patients with ARF (P/F ratio ≤ 120 )
- Venturi mask (54) vs. NIV (51)




Exclusion Criteria

(1) hypercapnia (PaCO2 of more than 45 mm Hg) on admission

(2) need for emergency intubation

(3) recent esophageal, facial, or cranial trauma or surgery

(4) severely decreased consciousness (a Glasgow coma score ≤ 11)

(5) severe hemodynamic instability despite fluid repletion and use of vasoactive agents

(6) a lack of cooperation

(7) tracheotomy or other upper airway disorders

(8) severe ventricular arrhythmia or myocardial ischemia

(9) active upper gastrointestinal bleeding

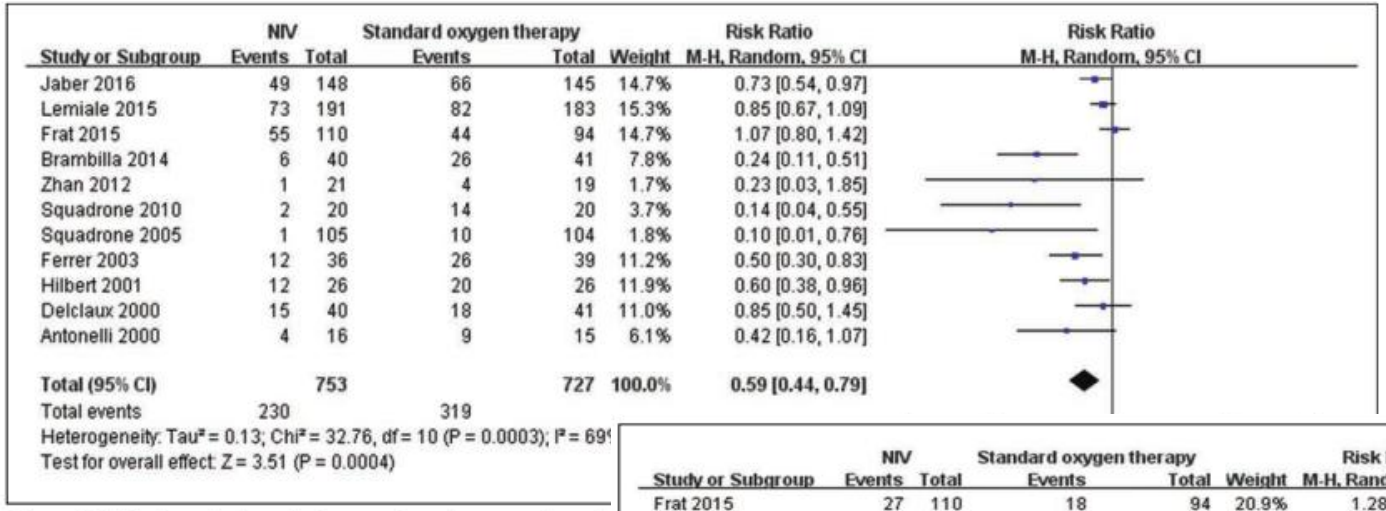
(10) an inability to clear respiratory secretions

(11) ≥1 severe organ dysfunction in addition to respiratory failure.

*Am J Respir Crit Care Med 2003; 168 (12) 1438-1444*

# Comparing NIV and Conventional oxygen therapy

## Intubation rate



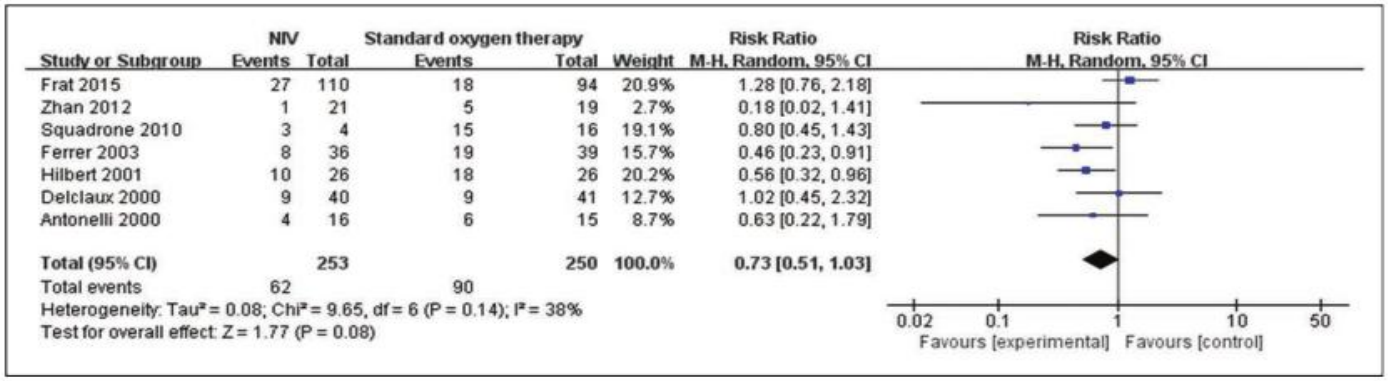
| Study or Subgroup | NIV Events | NIV Total | Standard oxygen therapy Events | Standard oxygen therapy Total | Weight | Risk Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Jaber 2016 | 49 | 148 | 66 | 145 | 14.7% | 0.73 [0.54, 0.97] |
| Lemiale 2015 | 73 | 191 | 82 | 183 | 15.3% | 0.85 [0.67, 1.09] |
| Frat 2015 | 55 | 110 | 44 | 94 | 14.7% | 1.07 [0.80, 1.42] |
| Brambilla 2014 | 6 | 40 | 26 | 41 | 7.8% | 0.24 [0.11, 0.51] |
| Zhan 2012 | 1 | 21 | 4 | 19 | 1.7% | 0.23 [0.03, 1.85] |
| Squadrone 2010 | 2 | 20 | 14 | 20 | 3.7% | 0.14 [0.04, 0.55] |
| Squadrone 2005 | 1 | 105 | 10 | 104 | 1.8% | 0.10 [0.01, 0.76] |
| Ferrer 2003 | 12 | 36 | 26 | 39 | 11.2% | 0.50 [0.30, 0.83] |
| Hilbert 2001 | 12 | 26 | 20 | 26 | 11.9% | 0.60 [0.38, 0.96] |
| Delclaux 2000 | 15 | 40 | 18 | 41 | 11.0% | 0.85 [0.50, 1.45] |
| Antonelli 2000 | 4 | 16 | 9 | 15 | 6.1% | 0.42 [0.16, 1.07] |
| **Total (95% CI)** | | **753** | | **727** | **100.0%** | **0.59 [0.44, 0.79]** |
| Total events | 230 | | 319 | | | |

Heterogeneity: Tau² = 0.13; Chi² = 32.76, df = 10 (P = 0.0003); I² = 69
Test for overall effect: Z = 3.51 (P = 0.0004)

Risk Ratio M-H, Random, 95% CI

**Figure 3.** Intubation rate in acute hypoxemic nonhypercapnic respir
gen therapy. M-H = Mantel-Haenszel.

## Mortality



| Study or Subgroup | NIV Events | NIV Total | Standard oxygen therapy Events | Standard oxygen therapy Total | Weight | Risk Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Frat 2015 | 27 | 110 | 18 | 94 | 20.9% | 1.28 [0.76, 2.18] |
| Zhan 2012 | 1 | 21 | 5 | 19 | 2.7% | 0.18 [0.02, 1.41] |
| Squadrone 2010 | 3 | 4 | 15 | 16 | 19.1% | 0.80 [0.45, 1.43] |
| Ferrer 2003 | 8 | 36 | 19 | 39 | 15.7% | 0.46 [0.23, 0.91] |
| Hilbert 2001 | 10 | 26 | 18 | 26 | 20.2% | 0.56 [0.32, 0.96] |
| Delclaux 2000 | 9 | 40 | 9 | 41 | 12.7% | 1.02 [0.45, 2.32] |
| Antonelli 2000 | 4 | 16 | 6 | 15 | 8.7% | 0.63 [0.22, 1.79] |
| **Total (95% CI)** | | **253** | | **250** | **100.0%** | **0.73 [0.51, 1.03]** |
| Total events | 62 | | 90 | | | |

Heterogeneity: Tau² = 0.08; Chi² = 9.65, df = 6 (P = 0.14); I² = 38%
Test for overall effect: Z = 1.77 (P = 0.08)

Risk Ratio M-H, Random, 95% CI

0.02 0.1 1 10 50
Favours [experimental] Favours [control]

**Figure 4.** ICU mortality in acute hypoxemic nonhypercapnic respiratory failure patients randomized to noninvasive ventilation (NIV) versus standard oxygen therapy. M-H = Mantel-Haenszel.

*XP Xu et al. Critical Care Medicine: July 2017 - Volume 45 - Issue 7 - p e727-e733.*

## Benefit of NIV in acute hypoxemic respiratory failure

- Patients likely to benefit
  - ✓ Acute cardiogenic pulmonary edema

- Patients likely to benefit
  - ✓ Hypoxemic nonhypercapnic respiratory failure not due to ACPE
    (Inability to cooperate, protect airway, or clear secretions)
  - ✓ Acute respiratory failure due to asthma exacerbation
  - ✓ Post-operative or chest trauma induced acute respiratory failure

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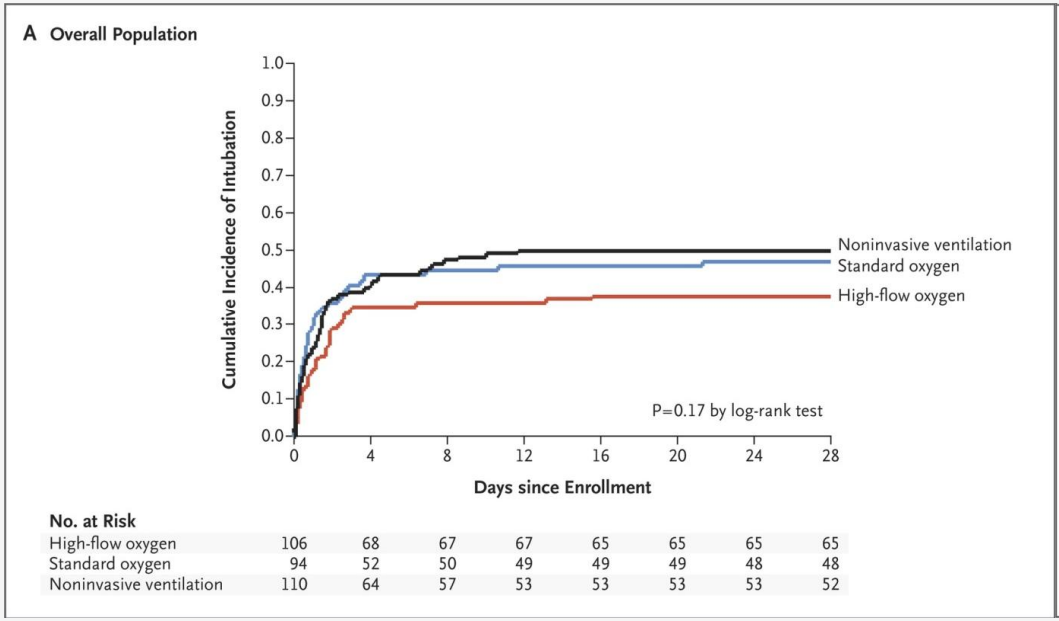
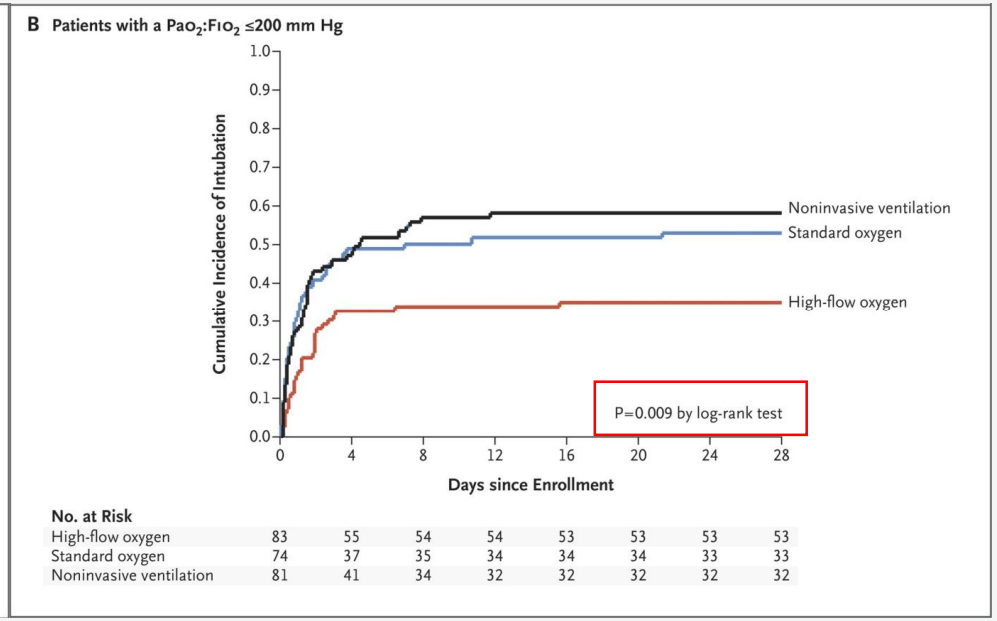
# High-Flow Oxygen through Nasal Cannula in Acute Hypoxemic Respiratory Failure

- Multi-center Randomized controlled trial, 23 ICUs in France and Belgium
- 310 patients with acute hypoxemic respiratory failure, HFNC(106) vs. SOT(94) vs. NIV(110)
- Acute hypoxemic respiratory failure : P/F ratio < 300
- Outcome
  - ✓ Primary outcome : Intubation rate at day 28
  - ✓ 2ndary outcome : All cause mortality in ICU and at 90 days

*JP Frat et. al. N Engl J Med 2015; 372:2185-2196*

# Intubation rate



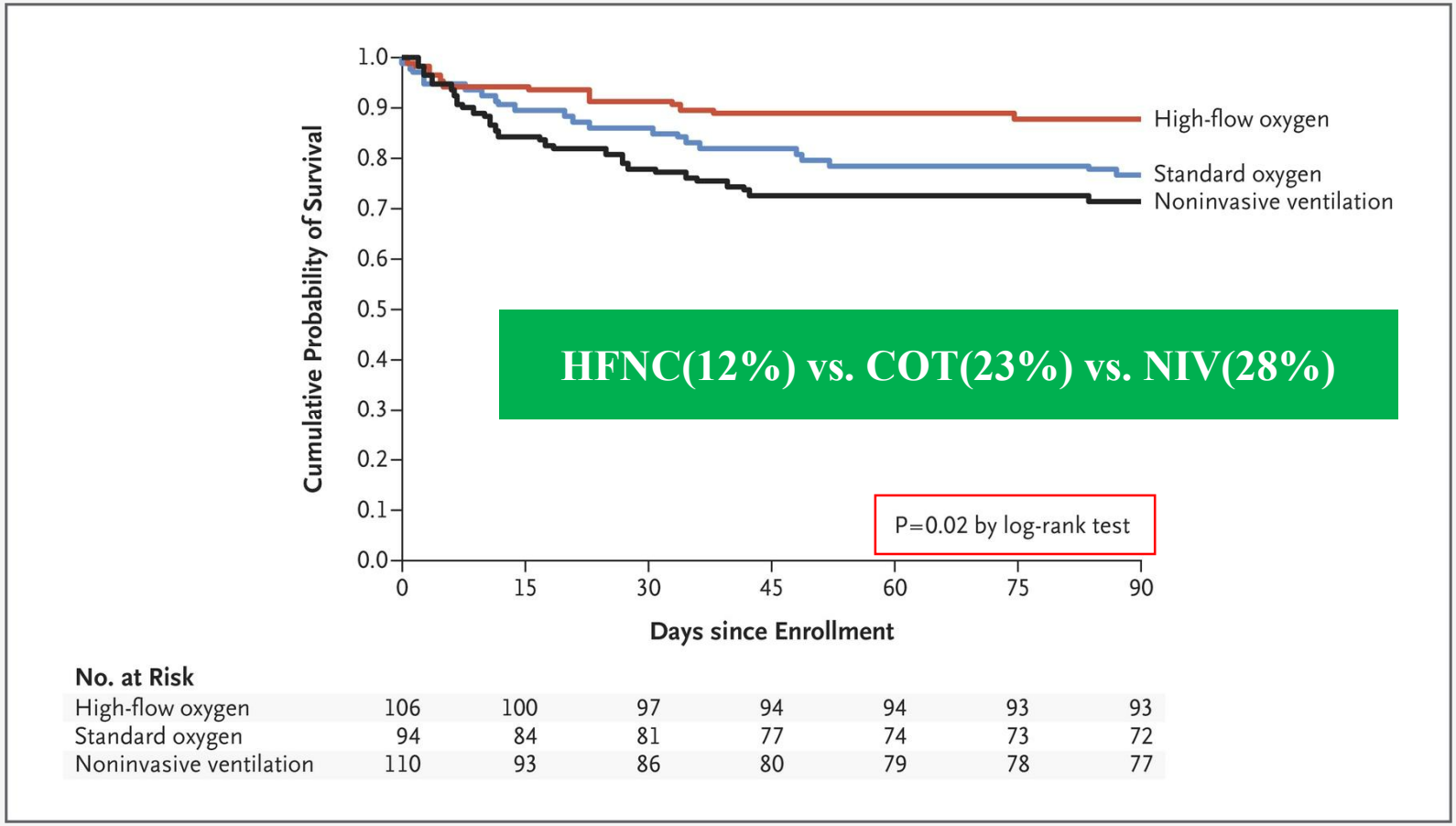




HFNC(38%) vs. COT(47%) vs. NIV(50%)

HFNC(35%) vs. COT(53%) vs. NIV(58%)

JP Frat et. al. N Engl J Med 2015; 372:2185-2196

# All cause mortality




| No. at Risk | | | | | | | |
|---|---|---|---|---|---|---|---|
| High-flow oxygen | 106 | 100 | 97 | 94 | 94 | 93 | 93 |
| Standard oxygen | 94 | 84 | 81 | 77 | 74 | 73 | 72 |
| Noninvasive ventilation | 110 | 93 | 86 | 80 | 79 | 78 | 77 |

*JP Frat et. al. N Engl J Med 2015; 372:2185-2196*

**Table 1. Characteristics of the Patients at Baseline, According to Study Group.***

| Characteristic | High-Flow Oxygen (N=106) | Standard Oxygen (N=94) | Noninvasive Ventilation (N=110) |
|---|---|---|---|
| Age — yr | 61±16 | 59±17 | 61±17 |
| Male sex — no. (%) | 75 (71) | 63 (67) | 74 (67) |
| Body-mass index† | 25±5 | 26±5 | 26±6 |
| SAPS II‡ | 25±9 | 24±9 | 27±9 |
| Current or past smoking — no. (%) | 34 (32) | 36 (38) | 40 (36) |
| Reason for acute respiratory failure — no. (%) | | | |
| Community-acquired pneumonia | 71 (67) | 57 (61) | 69 (63) |
| Hospital-acquired pneumonia | 12 (11) | 13 (14) | 12 (11) |
| Extrapulmonary sepsis | 4 (4) | 5 (5) | 7 (6) |
| Aspiration or drowning | 3 (3) | 1 (1) | 2 (2) |
| Pneumonia related to immunosuppression | 6 (6) | 4 (4) | 10 (9) |
| Other | 10 (9) | 14 (15) | 10 (9) |
| Bilateral pulmonary infiltrates — no. (%) | 79 (75) | 80 (85) | 85 (77) |
| Respiratory rate — breaths/min | 33±6 | 32±6 | 33±7 |

*JP Frat et. al. N Engl J Med 2015; 372:2185-2196*

# Adverse effect of NIV

| Incidence of side effects | Any grade | Grade 3-4 |
|---|---|---|
| Eye redness | 76 (17%) | 17 (4%) |
| Rhinorrhea | 137 (31%) | 28 (6%) |
| Mouth dryness | 329 (75%) | 116 (27%) |
| Hourseness | 74 (27%) | 11 (3%) |
| Bloating | 89 (20%) | 21 (3%) |
| Interface related pain | 377 (86%) | 19 (4%) |
| Pressure sore | 209 (48%) | 4 (1%) |
| Noticeable leaks | 267 (61%) | 65 (15%) |
| Deventilation dyspnoea | 83 (19%) | 21 (5%) |
| Perceived patient ventilator-asynchrony | 75 (17%) | 23 (5%) |

European Respiratory Journal 2018 52: PA2378

# NIV Interfaces

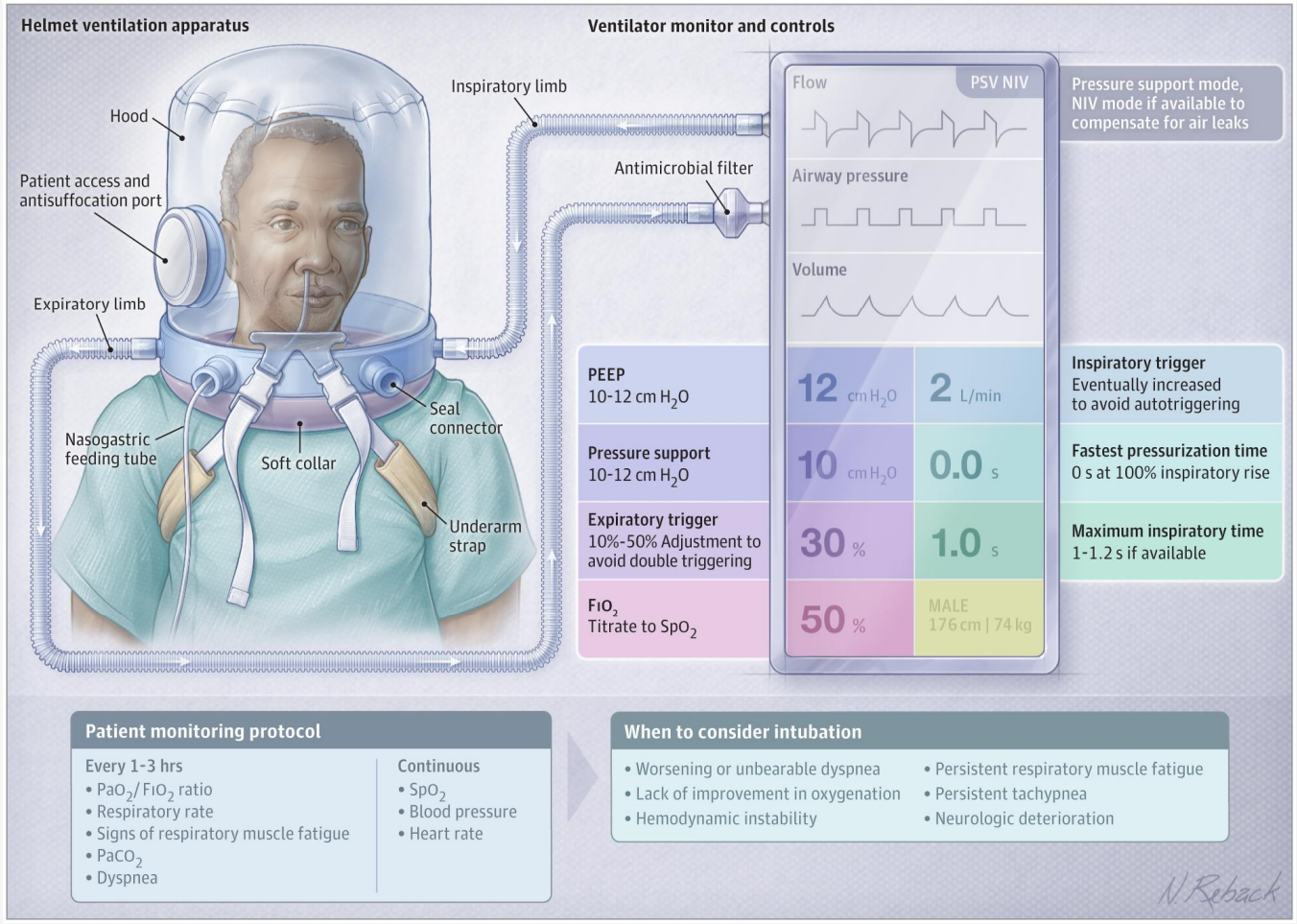
Full face mask

face mask

Nasal mask

Helmet mask

# Helmet NIV



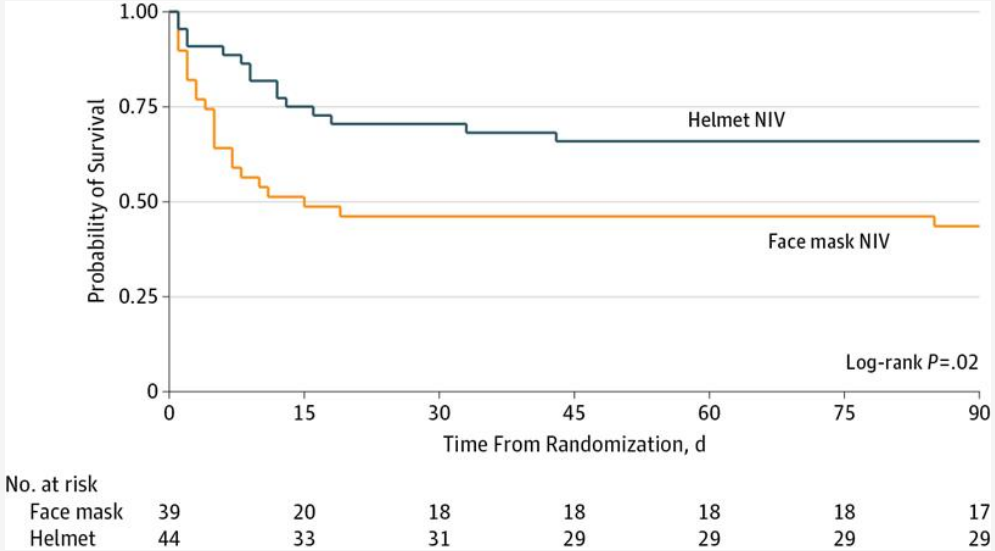

*JAMA*. 2021;325(17):1731-1743.

# Comparing between NIV interfaces

- 83 Patients with ARDS, P/F ratio 90-220, Shock (25%)
- Helmet device (44) vs. Face mask device (39)

Table 2. Primary and Secondary Outcomes and Adverse Events

| | Face Mask (n = 39) | Helmet (n = 44) | Absolute Difference (95% CI) | *P* Value |
|---|---|---|---|---|
| Primary outcome, No. (%) | | | | |
| Endotracheal intubation | 24 (61.5) | 8 (18.2) | −43.3 (−62.4 to −24.3) | <.001 |
| Reason for intubation | | | | |
| Respiratory failure | 20 (83.3) | 3 (37.5) | −45.3 (−82.5 to −9.1) | .01 |
| Circulatory failure | 3 (12.5) | 0 (0) | −12.5 (−25.7 to 0.7) | .55 |
| Neurologic failure | 1 (4.2) | 5 (62.5) | 58.3 (24.8 to 92.8) | .001 |
| Secondary outcomes, median (IQR), d | | | | |
| Ventilator-free days | 12.5 (0.49-28) | 28 (13.7-28) | 8.4 (13.4 to 3.4) | <.001 |
| ICU length of stay | 7.8 (3.9-13.8) | 4.7 (2.5-8.7) | −2.76 (−6.07 to 0.54) | .04 |
| Hospital length of stay | 15.2 (7.8-19.7) | 10.1 (6.5-15.9) | −2.92 (−8.47 to 2.63) | .16 |
| Mortality, No. (%) | | | | |
| Hospital | 19 (48.7) | 12 (27.3) | −21.4 (−41.9 to −1.0) | .04 |
| 90 d[a] | 22 (56.4) | 15 (34.1) | −22.3 (−43.3 to −1.4) | .02 |
| Adverse events | | | | |
| Mask deflation | 0 (0) | 2 (4.5) | | |
| Skin ulceration | 3 (7.6) | 3 (6.8) | | |




*BK Patel et al. JAMA. 2016;315(22):2435-2441.*

# Comparing between NIV interfaces

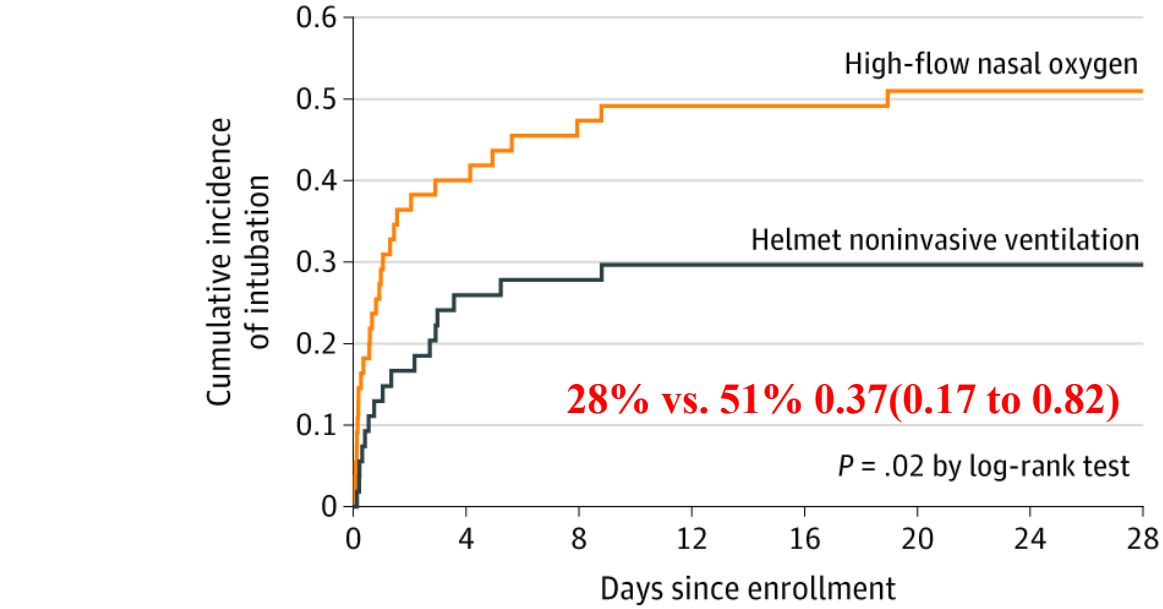
**Table 3. Level of Respiratory Support and Physiologic Parameters During Noninvasive Ventilation**

| | Noninvasive Ventilation, Median (IQR) | | |
|---|---|---|---|
| | Face Mask (n = 39) | Helmet (n = 44) | *P* Value |
| Respiratory support with NIV[a] | | | |
| Duration of NIV, h | 26.4 (7.0-60.0) | 19.8 (8.4-45.6) | .68 |
| PEEP, cm $H_2O$ | 5.1 (5.0-8.0) | 8 (5.0-10.0) | .006 |
| Pressure support, cm $H_2O$ | 11.2 (10.0-14.5) | 8 (5.6-10.0) | <.001 |
| $FIO_2$, % | 60 (50.0-68.6) | 50 (40.0-60.0) | .02 |
| $SpO_2$, % | 95.3 (92.3-96.7) | 96.2 (94.8-98.4) | .13 |
| Respiratory rate, breaths/min | | | |
| Baseline | 28.3 (22.1-34.4)[b] | 27.7 (21.5-34.6)[b] | |
| After randomization | 29.1 (22.1-37.6) | 24.5 (20.4-30.5) | |

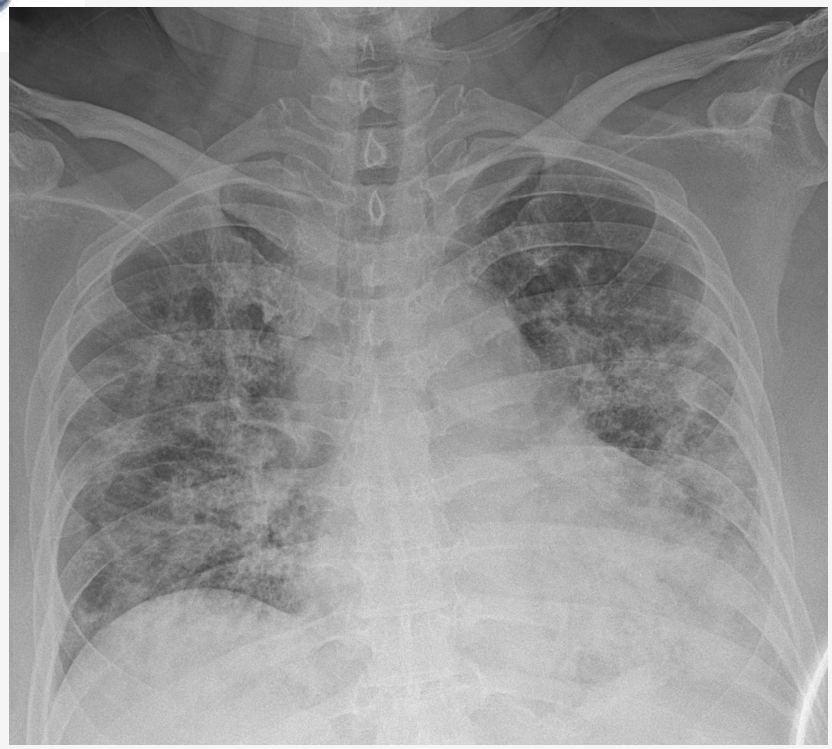
BK Patel et al. JAMA. 2016;315(22):2435-2441.

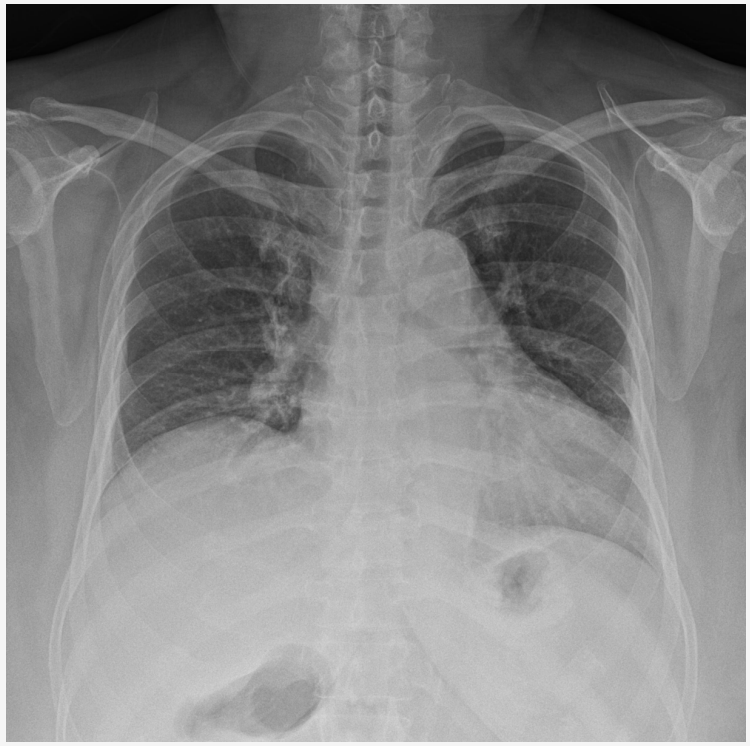
# Helmet NIV vs. HFNC in COVID-19

- 109 Patients with ARF ($PaO_2/FiO_2 \leq 200$), HFNC vs. Helmet NIV
- Outcomes : respiratory support free days, intubation rate, mortality



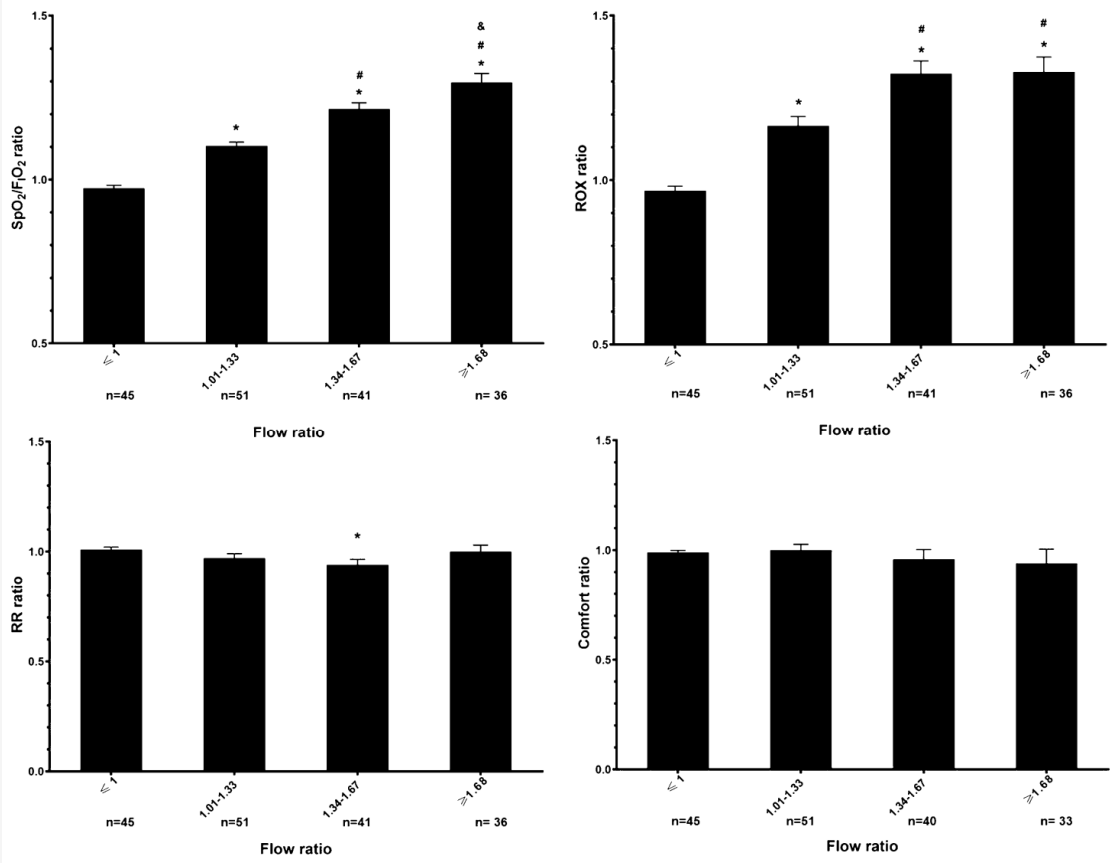

*JAMA*. 2021;325(17):1731-1743.





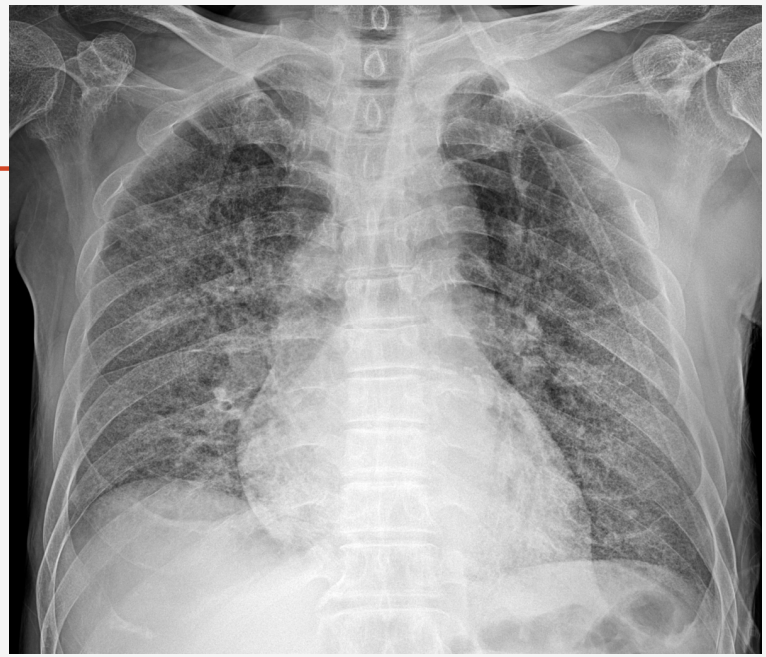
# Response to different flow ratios.

- HFNC and required a minimum $FiO_2$ of 0.4 to maintain pulse oximetry ($SpO_2$) of 90–97%
- Peak tidal inspiratory flow
  - ✓ Mean : 34 ± 9
  - ✓ Median : 31 [27-42]




*Li et al. Annals of Intensive Care (2021) 11:164*

# CASE 2



- 60/M
- C/C dyspnea (onset : 3 days ago)
- fever, chill, cough, sputum after greenhouse work

- Vital sign
  - BP: 100/60mmHg, HR:79/min, RR:24/min, BT:38.1℃

- ABGA via Mask 8L/min
  - RA : pH 7.44, $pCO_2$ 33mmHg, $PaO_2$ 65mmHg, SaO2 93%

| | Flow (L/min) | FiO2 | SaO2 | RR |
|---|---|---|---|---|
| Day 1 | 60 | 0.7 | 94% | 24 |
| Day 2 | 60 | 0.5 | 96% | 20 |
| Day 3 | 60 | 0.8 | 95% | 24 |
| Day 4 | 60 | 0.8 | 93% | 28 |
| Day 5 | 60 | 0.9 | 91% | 34 |

# Is HFNC safe to all patients?

- Restrospective, HFNC failure
- 175 patients, Timing of intubation before 48hr(early) and after 48hr(late)

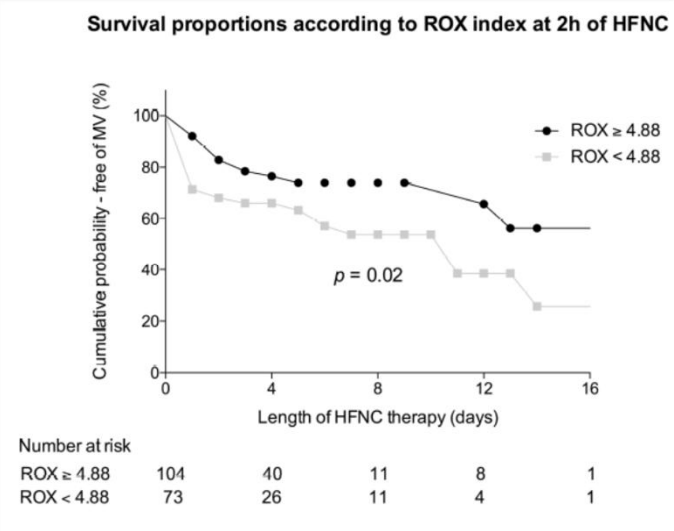
| Variables | Crude | | Propensity-adjusted[a] | | Propensity-matched[b] | |
|---|---|---|---|---|---|---|
| | Odds ratio (95 % CI) | *P* value[c] | Odds ratio (95 % CI) | *P* value[c] | Odds ratio (95 % CI) | *P* value[c] |
| Primary outcome | | | | | | |
| Overall ICU mortality | 0.323 (0.158–0.658) | 0.002 | 0.317 (0.143–0.700) | 0.005 | 0.369 (0.139–0.984) | 0.046 |
| Secondary outcomes | | | | | | |
| Extubation success | 3.284 (1.361–7.923) | 0.008 | 3.091 (1.193–8.013) | 0.020 | 2.057 (0.746–5.672) | 0.163 |
| Ventilator-weaning | 3.056 (1.470–6.351) | 0.003 | 3.380 (1.492–7.656) | 0.004 | 2.495 (1.039–5.991) | 0.041 |
| Ventilator-free days to day 28 | 0.542 (0.383–0.768)[d] | 0.001[e] | 0.516 (0.349–0.763)[d] | 0.001[e] | 0.639 (0.431–0.946)[d] | 0.026[e] |
| 14-Day mortality from HFNC application | 0.949 (0.455–1.977) | 0.888 | 0.712 (0.312–1.622) | 0.418 | 0.608 (0.231–1.606) | 0.316 |
| 14-Day mortality from intubation | 0.653 (0.325–1.311) | 0.231 | 0.482 (0.218–1.067) | 0.072 | 0.447 (0.168–1.184) | 0.105 |
| 28-Day mortality from HFNC application | 0.820 (0.416–1.616) | 0.566 | 0.680 (0.318–1.457) | 0.322 | 0.896 (0.440–1.824) | 0.763 |
| 28-Day mortality from intubation | 0.571 (0.287–1.138) | 0.111 | 0.557 (0.258–1.198) | 0.134 | 0.802 (0.380–1.692) | 0.563 |
| Length of ICU stay | 0.827 (0.586–1.169)[f] | 0.282[g] | 0.830 (0.552–0.800)[f] | 0.372[g] | 1.329 (0.598–2.952)[f] | 0.485[g] |

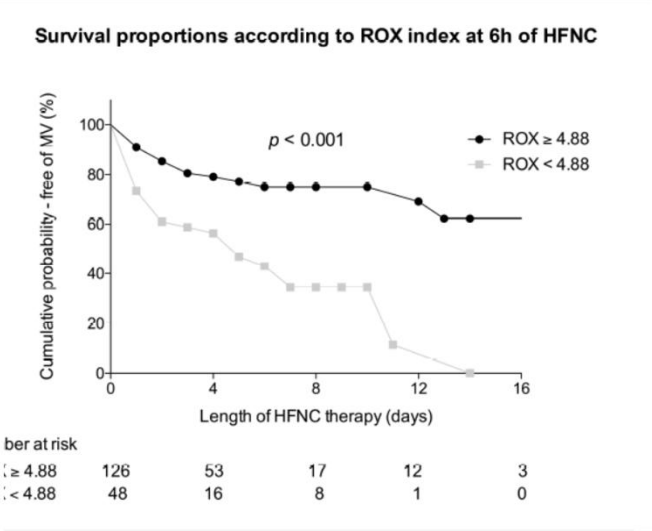
- The early intubated patients had better overall ICU mortality

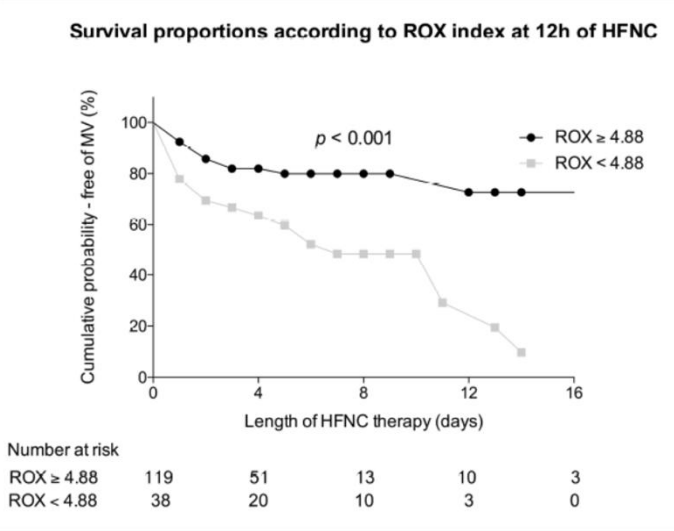
*BJ Kang et al. Intensive Care Med (2015) 41:623-632.*

# ROX index – Predict outcome of HFNC

- Acute respiratory failure d/t Pneumonia., 191 patients
- ROX index $\dfrac{SaO_2 / FiO_2}{\text{Respiratory rate}}$



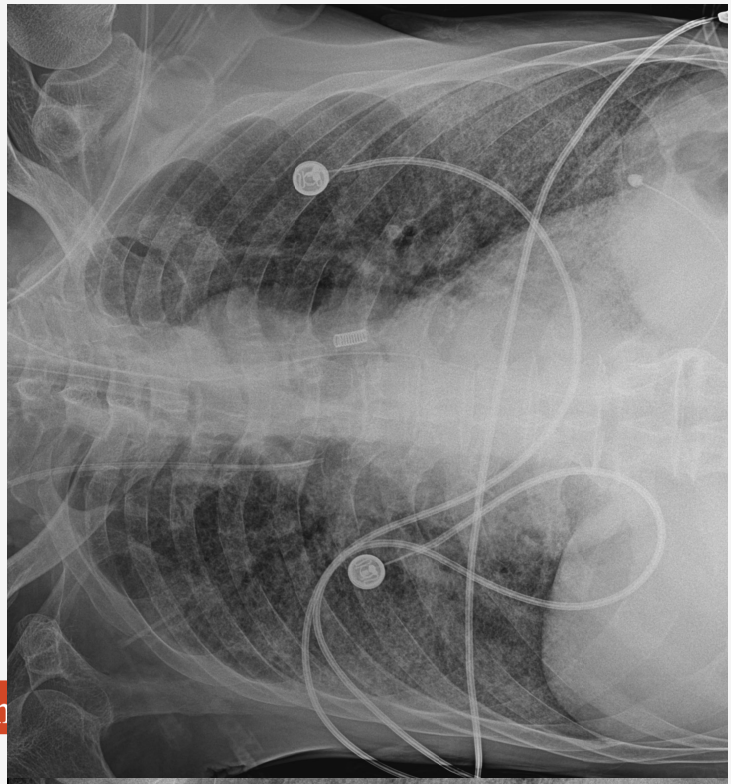



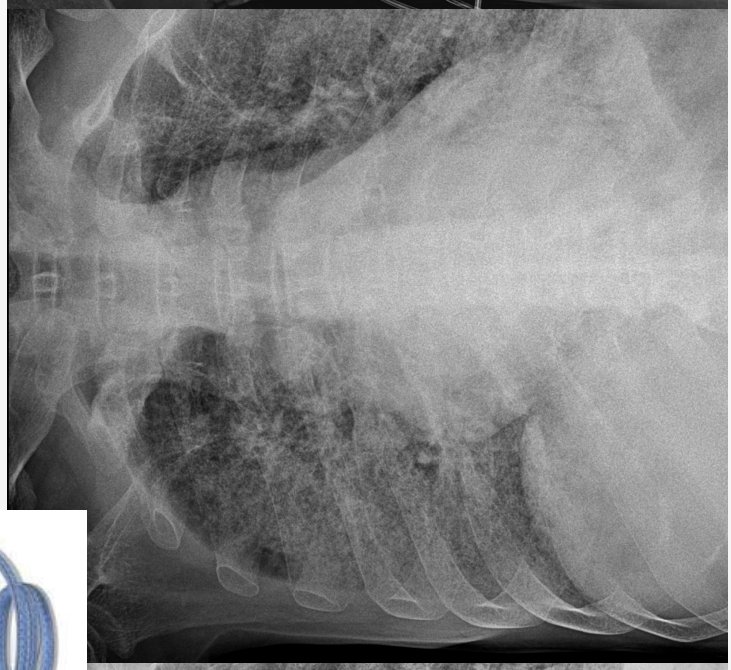



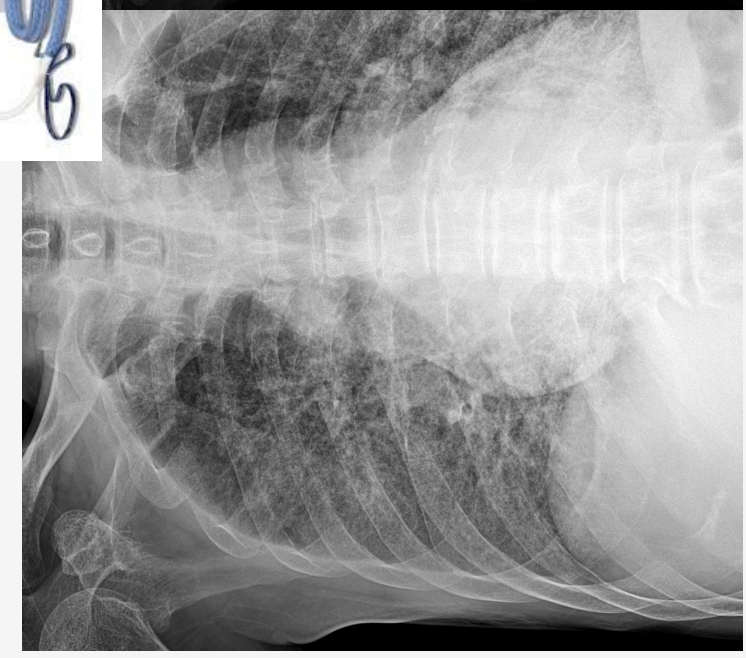

*Roca O et al. Am J Respir Crit Care Med. 2018 Dec 21. doi: 10.1164/rccm.201803-0589OC*

| | Flow (L/min) | FiO2 | SaO2 | RR | ROX index |
|---|---|---|---|---|---|
| Day 1 | 60 | 0.7 | 94% | 24 | 2.74 |
| Day 2 | 60 | 0.5 | 96% | 20 | 9.60 |
| Day 3 | 60 | 0.8 | 95% | 24 | 3.16 |
| Day 4 | 60 | 0.8 | 93% | 28 | 2.65 |
| Day 5 | 60 | 0.9 | 91% | 34 | 2.40 |

Intubation







# Risk factor of HFNC failure

- 180 patients, HFNC (n=87)
- First line Treatment of ARDS (n=45)

| | All Subjects With ARDS ($N = 45$) | HFNC Success ($n = 27$) | HFNC Failure ($n = 18$) | $P$ |
|---|---|---|---|---|
| Age, median (IQR), y | 57.9 (38.7–74.2) | 46.1 (39–75.2) | 62.8 (37.1–72.6) | .89 |
| Males, *n* (%) | 22 (49) | 13 (48) | 9 (50) | .86 |
| At least one comorbid condition, *n* (%) | 27 (60) | 14 (52) | 14 (78) | .08 |
| Chronic heart failure | 5 (11) | 2 (7) | 3 (17) | .33 |
| COPD | 5 (11) | 3 (11) | 2 (11) | > .99 |
| Neurodegenerative disease | 4 (9) | 3 (11) | 1 (6) | .52 |
| Reason for HFNC oxygen therapy, *n* (%) | | | | |
| Pneumonia | 36 (80) | 23 (85) | 13 (72) | .44 |
| ALI of extra-pulmonary origin | 4 (9) | 2 (7) | 2 (11) | .67 |
| Toxic ARDS | 5 (11) | 2 (7) | 3 (17) | .33 |
| At least one associated organ failure, *n* (%) | 20 (44) | 7 (26) | 13 (76) | .002 |
| Hemodynamic | 11 (24) | 2 (7) | 9 (50) | .001 |
| Kidney | 12 (27) | 6 (22) | 6 (33) | .59 |
| Neurological | 4 (9) | 0 | 4 (22) | .01 |
| SAPS II score, median (IQR) | 36 (24–44) | 29 (22–37) | 46 (29–61.5) | .001 |
| Highest breathing frequency, median (IQR), breaths/min | 34 (30–40) | 33 (30–40) | 37 (29–40) | .57 |
| Initial $P_{aO_2}/F_{IO_2}$, median (IQR) | 137 (88.5–208.5) | 145.3 (97.5–223.5) | 115.3 (84–177.1) | .26 |
| Lowest $P_{aO_2}/F_{IO_2}$, median (IQR) | 108.6 (73–137.1) | 124 (93–217) | 91.5 (64–129.5) | .02 |
| HFNC oxygen therapy duration of < 24 h, *n* (%) | 22 (49) | 10 (37) | 12 (67) | .05 |
| Duration of therapy, median (IQR), h | 24 (12.5–50) | 32 (16–53) | 20 (12–31) | .16 |
| ICU stay, median (IQR), d | 4 (3–12.5) | 3 (2–5) | 13.5 (5.5–19) | .001 |
| Alive at ICU discharge, *n* (%) | 35 (78) | 26 (96) | 9 (50) | .001 |
| Alive at day 28, *n* (%) | 33 (71) | 24* (89) | 9 (50) | .003 |

*J Messika et al. Respir Care 2015;60(2):162–169.*

# Delayed intubation was associated with higher mortality

- 449 patients with hypoxemia who were receiving NIV

**Table 5 Early versus late intubation in patients with a HACOR score of >5 at 1 h of noninvasive ventilation**

| NIV time points and hospital mortality | Intubation at ≤12 h (*N* = 88) | Intubation at >12 h (*N* = 175) | *p* |
|---|---|---|---|
| HACOR score at NIV initiation | 8.9 ± 3.9 | 7.7 ± 3.0 | <0.01 |
| HACOR score at 1 h of NIV | 11.4 ± 4.0 | 8.8 ± 3.1 | <0.01 |
| HACOR score before intubation | 12.2 ± 4.7 | 11.4 ± 5.0 | 0.22 |
| Time from NIV initiation to intubation (h) | 5 (2–10) | 53 (23–132) | <0.01 |
| Hospital mortality | 58 (66%) | 138 (79%) | 0.03 |

Values in table are presented as the mean ± SD, the median with the IQR in parenthesis, or as a number with the percentage in parenthesis, as appropriate

*HACOR* heart rate, acidosis, consciousness, oxygenation, and respiratory rate, *NIV* noninvasive ventilation

- **NIV failure rate : 58%**
- **Mortality of patients with NIV failure : 75%**
- **Hospital Mortality : Early intubation (66%) vs. Late intubation (79%) p=0.03**

*BJ Kang et al. Intensive Care Med (2015) 41:623-632.*

# Risk factor of NIV failure

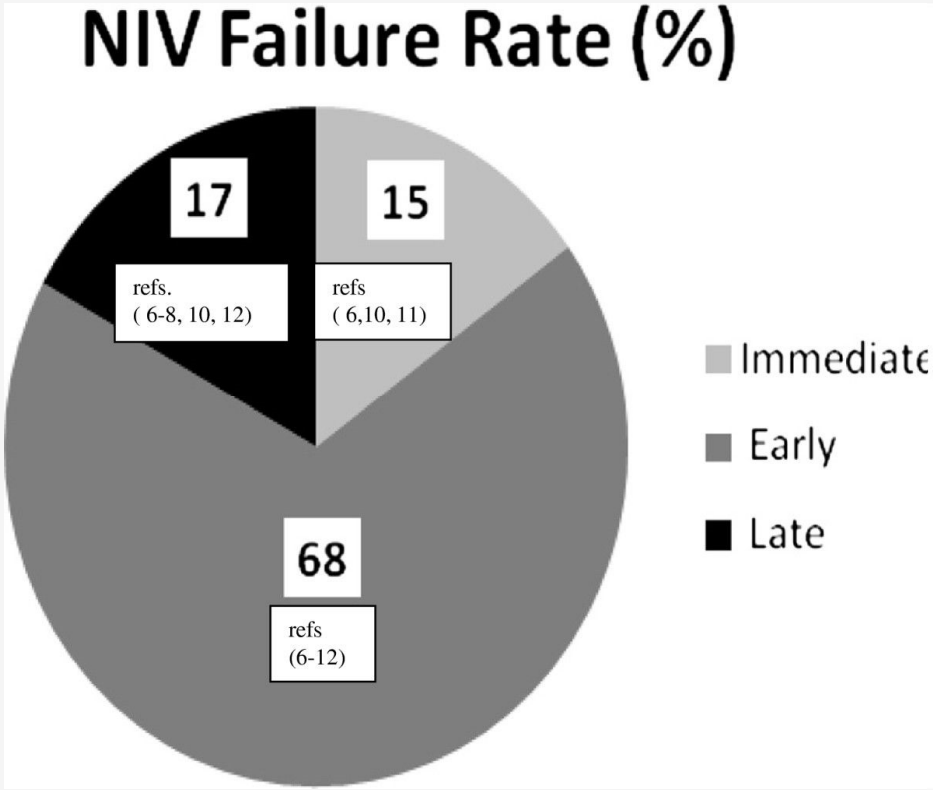



Table 3. Risk Factors for NIV Failure in Patients With Acute Hypoxemic Respiratory Failure

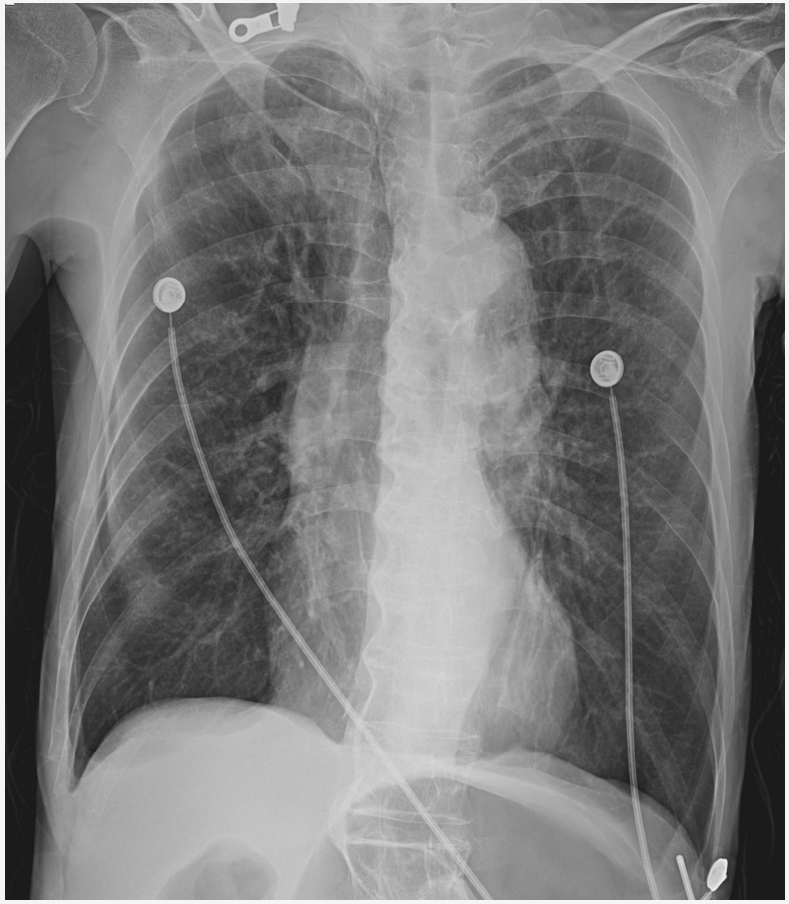
| |
|---|
| Diagnosis of ARDS or pneumonia |
| Age > 40 y |
| Hypotension (systolic blood pressure < 90 mm Hg) |
| Metabolic acidosis (pH < 7.25) |
| Low oxygenation index ($P_{aO_2}/F_{IO_2}$) |
| Simplified Acute Physiology Score II > 34 |
| Failure to improve oxygenation within first hour of NIV ($P_{aO_2}/F_{IO_2}$ > 175 mm Hg) |

ARDS = acute respiratory distress syndrome
$F_{IO_2}$ = fraction of inspired oxygen
(Based on data in References 23-25.)

*E Ozyilmaz et al. BMC Pulm Med. 2014; 14: 19.* *NS Hill et al. Respir Care. 2009 Jan;54(1):62-70.*

# CASE 3

- C/C dyspnea (O : 2 days ago)
- COPD로 외래 추적 중 – ICS/LABA
- URI history (+)
- Wheezing(+)
- Alert mental state

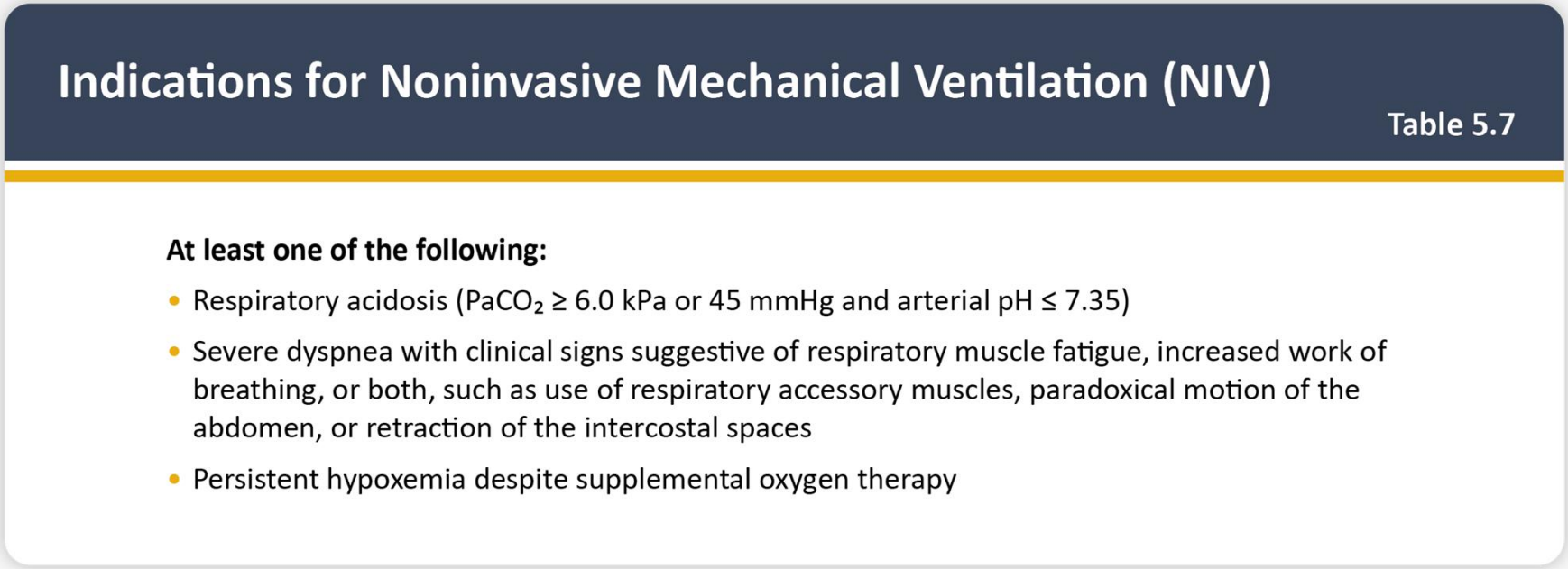


# CASE 3

| | |
|---|---|
| pH | 7.23 |
| PCO2 | 62 |
| PO2 | 55 |
| Hct | 55 |
| Na+ | 143 |
| K+ | 3.8 |
| Ca++ | 1.11 |
| Hgb | 17.1 |
| BE-ECF | -1.6 |
| BE-B | -3.2 |
| SBC | 21.9 |
| HCO3 | 26.0 |
| TCO2 | 27.9 |
| O2 SAT | 82 |
| O2 CT | . |
| nCa++ | . |
| An. gap | . |
| 유산 | 1.9 |
| 포도당(blo | 109 |

- Diagnosis
  - Acute exacerbation of COPD
  - Acute hypercapnic respiratory failure

# Indications for NIV in AECOPD




- ABGA
  - ✓ **pH 7.23, $pCO_2$ 62mmHg**, $PO_2$ 55mmHg, SaO2 82%

GOLD 2023

# Comparing NIV and Convention oxygen Therapy

- Prospective multicenter RCT, 14 UK hospitals
- 236 patients, COPD c AE, pH 7.25-35, $PaCO_2$ > 45 mmHg
- NIV vs. COT (Target $SaO_2$ 85-90%)

| | Standard treatment (n=118) | NIV (n=118) |
|---|---|---|
| Mean age (SD) | 69 (8) | 69 (7) |
| Sex (M/F) | 63/55 | 54/64 |
| Respiratory rate per min (range) | 28 (24–40) | 28 (24–36) |
| pH (range) | 7·31 (7·26–7·35) | 7·32 (7·25–7·3 |
| $PaCO_2$ kPa (SD) | 8·65 (1·70) | 8·82 (1·51) |
| $PaO_2$ kPa (range) | 7·00 (4·71–12·31) | 6·88 (4·50–13·8 |

Ranges in parentheses are median data with 5th and 95th centiles.

| | Standard | NIV | p |
|---|---|---|---|
| **Intention-to-treat** | | | |
| Failed | 32/118 (27%) | 18/118 (15%) | 0·02 |
| Died | 24/118 (20%) | 12/118 (10%) | 0·05 |
| **Subgroup analysis** | | | |
| pH<7·30 | | | |
| Failed | 16/38 (42%) | 13/36 (36%) | 0·64 |
| Died | 13/38 (34%) | 8/36 (22%) | 0·31 |
| pH>=7·30 | | | |
| Failed | 16/80 (20%) | 5/82 (6%) | 0·01 |
| Died | 11/80 (14%) | 4/82 (5%) | 0·06 |

Table 2: **Primary outcome and in-hospital mortality**

*PK Plant et al. Lancet 2000; 355: 1931–35*

Cochrane Library

Cochrane Database of Systematic Reviews

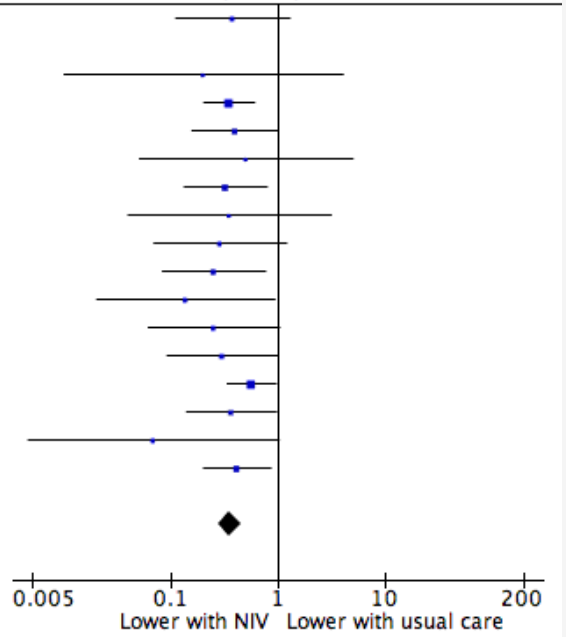
# Non-invasive ventilation for the management of acute hypercapnic respiratory failure due to exacerbation of chronic obstructive pulmonary disease (Review)

Osadnik CR, Tee VS, Carson-Chahhoud KV, Picot J, Wedzicha JA, Smith BJ

| Study or Subgroup | NIV Events | NIV Total | Usual care Events | Usual care Total | Weight | Risk Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Avdeev 1998 | 3 | 29 | 8 | 29 | 4.2% | 0.38 [0.11, 1.27] |
| Barbe 1996 | 0 | 14 | 0 | 10 | | Not estimable |
| Bott 1993 | 0 | 30 | 2 | 30 | 1.3% | 0.20 [0.01, 4.00] |
| Brochard 1995 | 11 | 43 | 31 | 42 | 16.7% | 0.35 [0.20, 0.60] |
| Carrera 2009 | 5 | 37 | 13 | 38 | 6.8% | 0.40 [0.16, 1.00] |
| Celikel 1998 | 1 | 15 | 2 | 15 | 1.1% | 0.50 [0.05, 4.94] |
| Collaborative 2005 | 6 | 100 | 17 | 91 | 9.5% | 0.32 [0.13, 0.78] |
| del Castillo 2003 | 1 | 20 | 3 | 21 | 1.6% | 0.35 [0.04, 3.09] |
| Dikensoy 2002 | 2 | 17 | 7 | 17 | 3.7% | 0.29 [0.07, 1.18] |
| Khilnani 2010 | 3 | 20 | 12 | 20 | 6.4% | 0.25 [0.08, 0.75] |
| Kramer 1995 | 1 | 11 | 8 | 12 | 4.1% | 0.14 [0.02, 0.92] |
| Liu 2005 | 2 | 18 | 8 | 18 | 4.2% | 0.25 [0.06, 1.02] |
| Matuska 2006 | 3 | 30 | 10 | 30 | 5.3% | 0.30 [0.09, 0.98] |
| Plant 2001 | 18 | 118 | 32 | 118 | 17.0% | 0.56 [0.34, 0.94] |
| Samaria 2009 | 4 | 20 | 11 | 20 | 5.8% | 0.36 [0.14, 0.95] |
| Thys 2002 | 0 | 7 | 5 | 5 | 3.3% | 0.07 [0.00, 1.01] |
| Zhou 2001 | 7 | 30 | 17 | 30 | 9.0% | 0.41 [0.20, 0.85] |
| **Total (95% CI)** | | **559** | | **546** | **100.0%** | **0.36 [0.28, 0.46]** |
| Total events | 67 | | 186 | | | |

Heterogeneity: Chi² = 6.68, df = 15 (P = 0.97); I² = 0%

Test for overall effect: Z = 8.22 (P < 0.00001)




Intubation rate

*Osadnik CR et al. Cochrane Database of Systematic Reviews2017, Issue 7. Art. No.: CD004104.*

Cochrane Library

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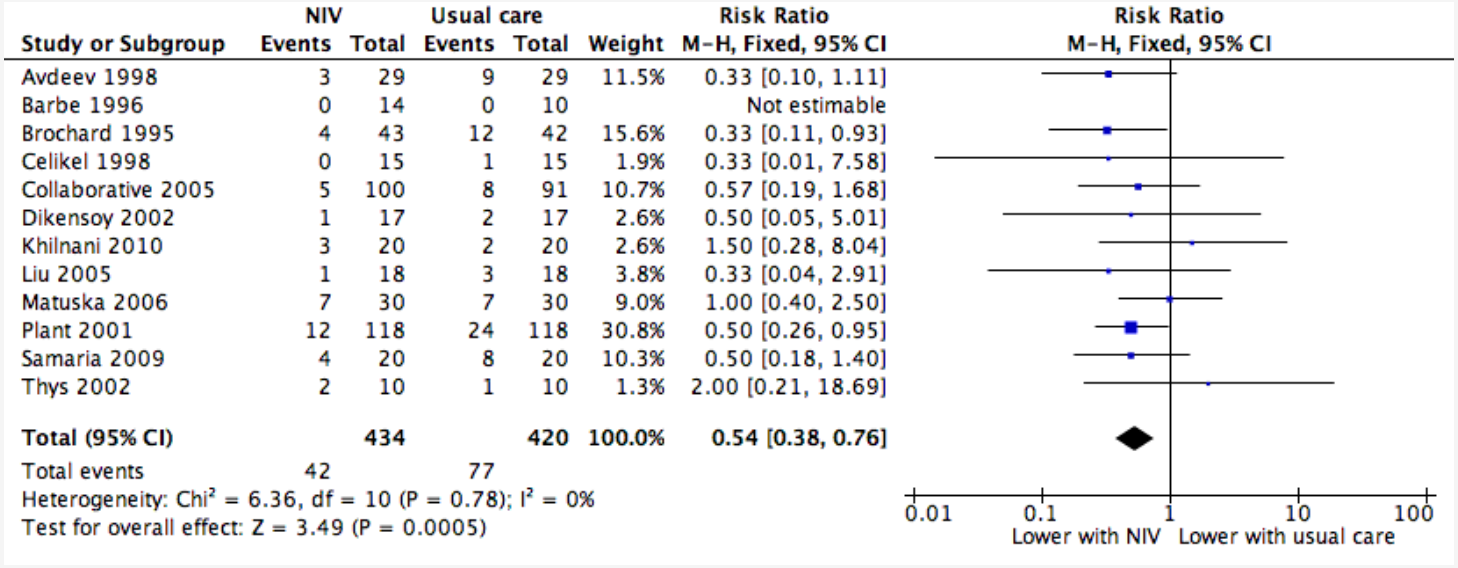
# Non-invasive ventilation for the management of acute hypercapnic respiratory failure due to exacerbation of chronic obstructive pulmonary disease (Review)

Osadnik CR, Tee VS, Carson-Chahhoud KV, Picot J, Wedzicha JA, Smith BJ



| Study or Subgroup | NIV Events | NIV Total | Usual care Events | Usual care Total | Weight | Risk Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Avdeev 1998 | 3 | 29 | 9 | 29 | 11.5% | 0.33 [0.10, 1.11] |
| Barbe 1996 | 0 | 14 | 0 | 10 | | Not estimable |
| Brochard 1995 | 4 | 43 | 12 | 42 | 15.6% | 0.33 [0.11, 0.93] |
| Celikel 1998 | 0 | 15 | 1 | 15 | 1.9% | 0.33 [0.01, 7.58] |
| Collaborative 2005 | 5 | 100 | 8 | 91 | 10.7% | 0.57 [0.19, 1.68] |
| Dikensoy 2002 | 1 | 17 | 2 | 17 | 2.6% | 0.50 [0.05, 5.01] |
| Khilnani 2010 | 3 | 20 | 2 | 20 | 2.6% | 1.50 [0.28, 8.04] |
| Liu 2005 | 1 | 18 | 3 | 18 | 3.8% | 0.33 [0.04, 2.91] |
| Matuska 2006 | 7 | 30 | 7 | 30 | 9.0% | 1.00 [0.40, 2.50] |
| Plant 2001 | 12 | 118 | 24 | 118 | 30.8% | 0.50 [0.26, 0.95] |
| Samaria 2009 | 4 | 20 | 8 | 20 | 10.3% | 0.50 [0.18, 1.40] |
| Thys 2002 | 2 | 10 | 1 | 10 | 1.3% | 2.00 [0.21, 18.69] |
| **Total (95% CI)** | | **434** | | **420** | **100.0%** | **0.54 [0.38, 0.76]** |
| Total events | 42 | | 77 | | | |

Heterogeneity: $Chi^2 = 6.36$, df = 10 (P = 0.78); $I^2 = 0\%$

Test for overall effect: Z = 3.49 (P = 0.0005)



Mortality

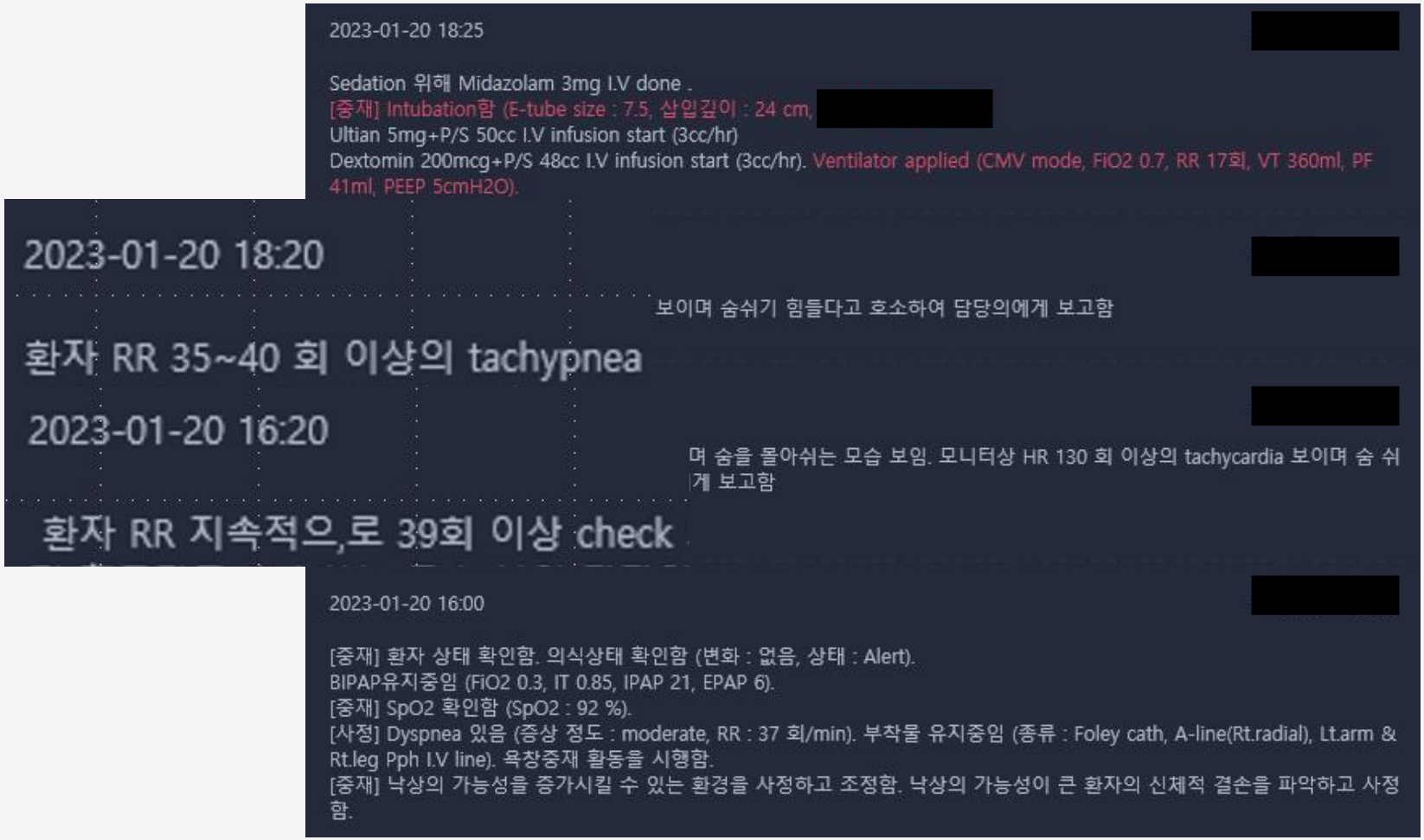
*Osadnik CR et al. Cochrane Database of Systematic Reviews2017, Issue 7. Art. No.: CD004104.*

# CASE 2

| | |
|---|---|
| pH | 7.23 |
| PCO2 | 62 |
| PO2 | 55 |
| Hct | 55 |
| Na+ | 143 |
| K+ | 3.8 |
| Ca++ | 1.11 |
| Hgb | 17.1 |
| BE-ECF | -1.6 |
| BE-B | -3.2 |
| SBC | 21.9 |
| HCO3 | 26.0 |
| TCO2 | 27.9 |
| O2 SAT | 82 |
| O2 CT | . |
| nCa++ | . |
| An. gap | . |
| 유산 | 1.9 |
| 포도당(blo | 109 |

| | |
|---|---|
| pH | 7.32 |
| PCO2 | 43 |
| PO2 | 74 |
| Hct | 48 |
| Na+ | 147 |
| K+ | 2.9 |
| Ca++ | 1.02 |
| Hgb | 14.9 |
| BE-ECF | -3.9 |
| BE-B | -3.9 |
| SBC | 21.7 |
| HCO3 | 22.2 |
| TCO2 | 23.5 |
| O2 SAT | 93 |
| O2 CT | . |
| nCa++ | . |
| An. gap | . |
| 유산 | 1.4 |
| 포도당(blo | 193 |

# CASE 2


2023-01-20 18:25
Sedation 위해 Midazolam 3mg I.V done .
[중재] Intubation함 (E-tube size : 7.5, 삽입깊이 : 24 cm,
Ultian 5mg+P/S 50cc I.V infusion start (3cc/hr)
Dextomin 200mcg+P/S 48cc I.V infusion start (3cc/hr). Ventilator applied (CMV mode, FiO2 0.7, RR 17회, VT 360ml, PF 41ml, PEEP 5cmH2O).
2023-01-20 18:20
보이며 숨쉬기 힘들다고 호소하여 담당의에게 보고함
환자 RR 35~40 회 이상의 tachypnea
2023-01-20 16:20
며 숨을 몰아쉬는 모습 보임. 모니터상 HR 130 회 이상의 tachycardia 보이며 숨 쉬
게 보고함
환자 RR 지속적으,로 39회 이상 check
2023-01-20 16:00
[중재] 환자 상태 확인함. 의식상태 확인함 (변화 : 없음, 상태 : Alert).
BIPAP유지중임 (FiO2 0.3, IT 0.85, IPAP 21, EPAP 6).
[중재] SpO2 확인함 (SpO2 : 92 %).
[사정] Dyspnea 있음 (증상 정도 : moderate, RR : 37 회/min). 부착물 유지중임 (종류 : Foley cath, A-line(Rt.radial), Lt.arm & Rt.leg Pph I.V line). 욕창중재 활동을 시행함.
[중재] 낙상의 가능성을 증가시킬 수 있는 환경을 사정하고 조정함. 낙상의 가능성이 큰 환자의 신체적 결손을 파악하고 사정함.

# Monitoring of NIV failure

Table 4. Monitoring Capabilities Recommended for NIV in Acute Respiratory Failure

| |
|---|
| Continuous observation from central monitoring area |
| Frequent checks of: |
| Comfort |
| Tolerance |
| Mask fit |
| Air leak |
| Patient-ventilator synchrony |
| Vital signs, especially respiratory rate |
| Accessory muscle use |
| Ventilator tidal volume (aim for 6–7 mL/kg) |
| Continuous telemetry |
| Electrocardiogram trace |
| Oximetry |
| Blood gas values at baseline, after 1–2 h, and as indicated |

NIV = noninvasive ventilation

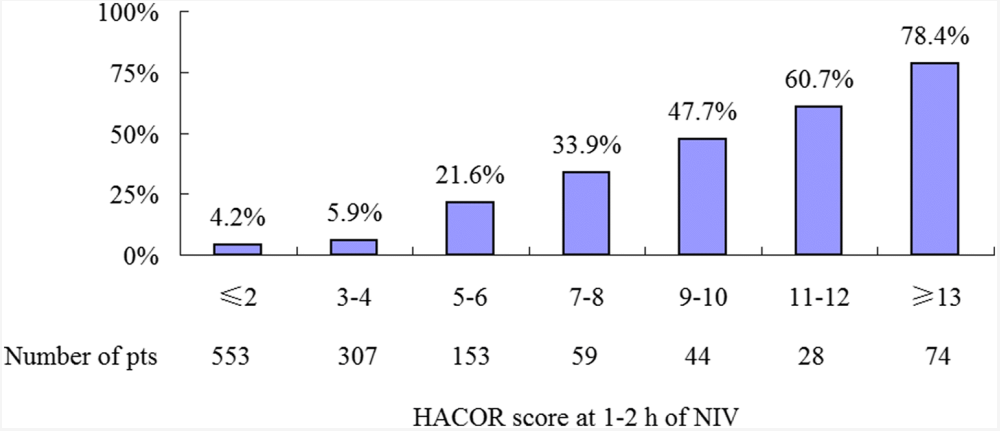
*NS Hill et al. Respir Care. 2009 Jan;54(1):62-70.*

# Signs of treatment failure of NIV

- Worsening or lack of improvement in gas exchange
- Signs of respiratory muscle fatigue
- Feeling of unbearable dyspnea
- Development of respiratory acidosis
- Presence of unmanageable tracheal secretions
- Hemodynamic instability

# Prediction of NIV failure

| Variable | Value | Score |
|---|---|---|
| **HR** | ≤ 120 | 0 |
| | ≥ 121 | 1 |
| **pH** | ≥ 7.35 | 0 |
| | 7.30-7.34 | 2 |
| | 7.25-7.29 | 3 |
| | < 7.25 | 4 |
| **Glasgow** | 15 | 0 |
| | 13-14 | 2 |
| | 11-12 | 5 |
| | ≤ 10 | 10 |
| **$PaO_2/FiO_2$** | >201 | 0 |
| | 176-200 | 2 |
| | 151-175 | 3 |
| | 126-150 | 4 |
| | 101-125 | 5 |
| | ≤ 100 | 6 |
| **RR** | ≤ 30 | 0 |
| | 31-35 | 1 |
| | 36-40 | 2 |
| | 41-45 | 3 |
| | ≥ 46 | 4 |




*Duan et al. Ann. Intensive Care (2019) 9:108*

# Prediction of in-hospital mortality in AHRF requiring NIV

| NIVO score | Points |
|---|---|
| Chest radiograph consolidation | 1 |
| Glasgow Coma Scale ≤14 | 1 |
| Atrial fibrillation | 1 |
| pH <7.25 | 1 |
| Time to acidaemia >12 h | 2 |
| eMRCD 5a | 2 |
| eMRCD 5b | 3 |
| Total | 9 |

**TABLE 4** In-hospital and 90-day mortality by Noninvasive Ventilation Outcomes (NIVO) score increment and risk category

| | Patients n | In-hospital mortality | 90-day mortality |
|---|---|---|---|
| **NIVO score** | | | |
| 0 | 67 | 0 | 10.4 |
| 1 | 79 | 8.9 | 20.3 |
| 2 | 133 | 5.3 | 15.8 |
| 3 | 152 | 15.1 | 26.3 |
| 4 | 116 | 19.0 | 40.5 |
| 5 | 97 | 35.1 | 46.4 |
| 6 | 54 | 53.7 | 59.3 |
| 7 | 26 | 65.4 | 76.9 |
| 8 | 8 | 87.5 | 87.5 |
| 9 | 1 | 100 | 100 |
| **Total** | 733 | 20.1 | 32.2 |
| **Risk category** | | | |
| Low (0–2) | 279 | 5.0 | 15.8 |
| Medium (3–4) | 268 | 16.8 | 32.5 |
| High (5–6) | 151 | 41.2 | 50.1 |
| Very high (7–9) | 35 | 71.4 | 80.0 |

*European Respiratory Journal 2021 58: 2004042*

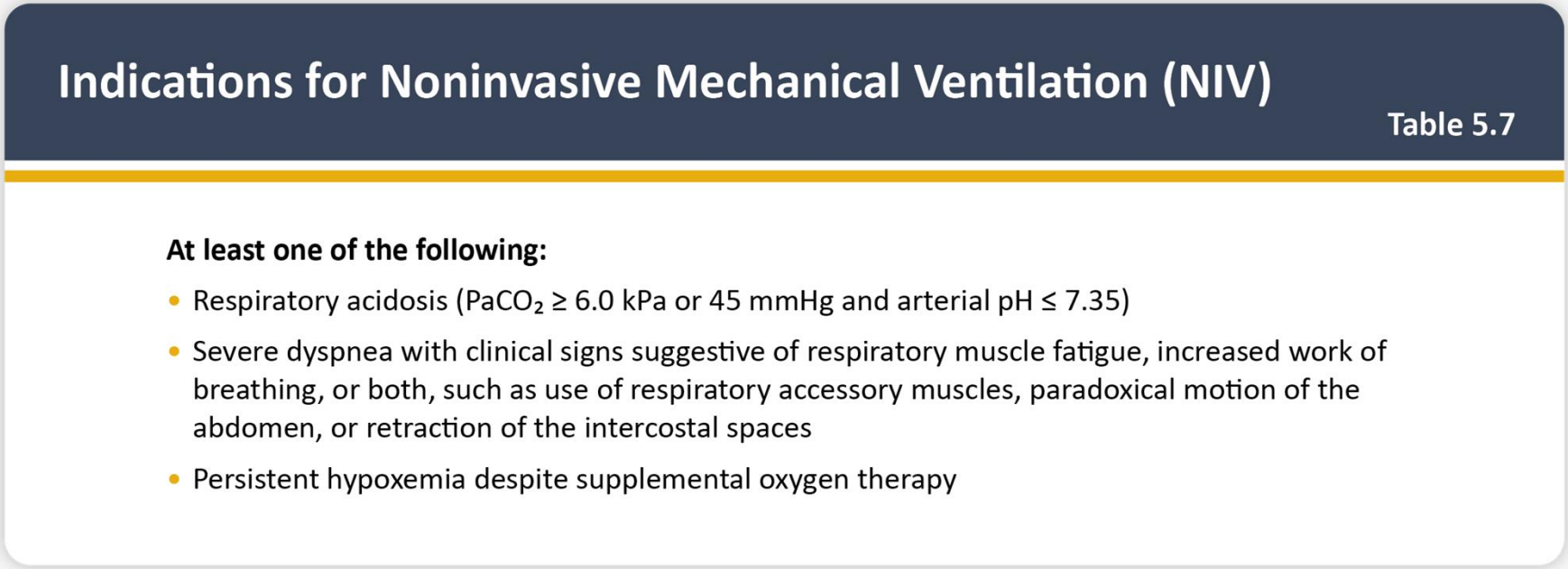
## CASE 4

- 기저로 COPD를 가지고 있는 80세 남자 환자가 호흡곤란을 주소로 내원하였다. 내원시 양폐로 천명음(wheezing)이 들렸다. 의식은 명료하였다.

- ABGA
  - RA state : pH 7.38 $pCO_2$ 72mmHg, $PO_2$ 43mmHg, SaO2 78%

- IV steroid 및 IV antibiotics 치료를 시작하였다.
- 다음으로 선택할 수 있는 Oxygen Therapy는?

# Indications for NIV in AECOPD

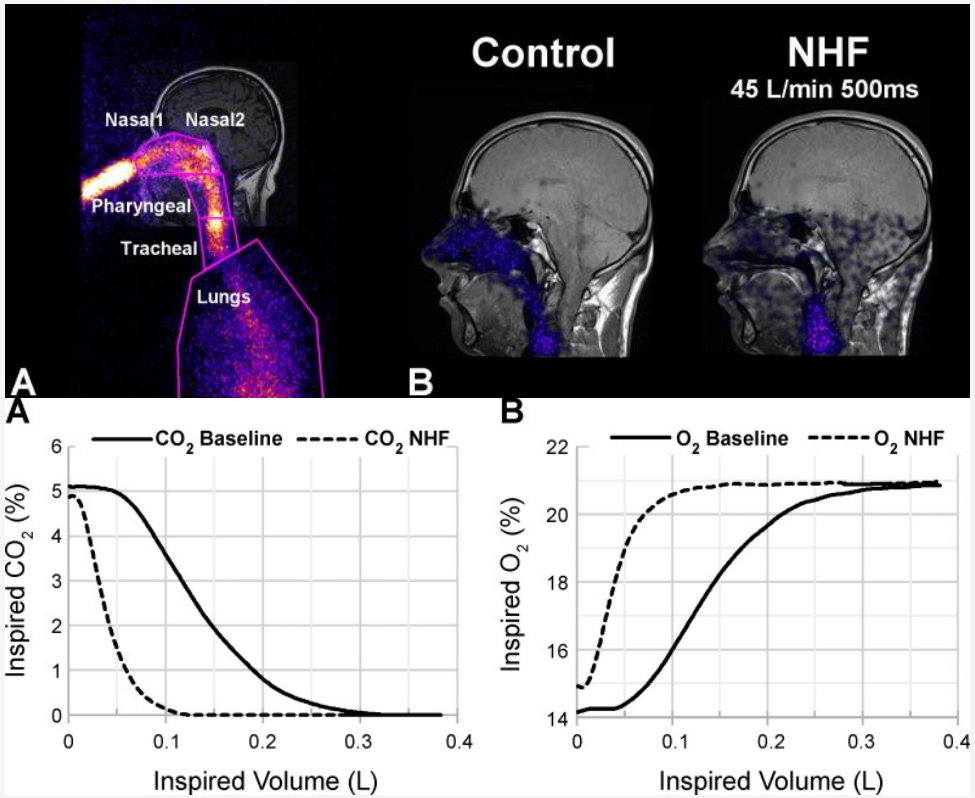



- ABGA
  - **pH 7.38 $pCO_2$ 72mmHg**, $PO_2$ 43mmHg, SaO2 78%

GOLD 2023

# Mechanism of HFNC in COPD patients

- Improve mucociliary clearance
- Reduce dead space
- Deliver low level of airway pressure
- Comfort



# HFNC may be useful in COPD

| | Total patients (n = 81) | Hypercapnia group (n = 46) | Nonhypercapnia group (n = 35) |
|---|---|---|---|
| Males, n (%) | 46 (56.8) | 18 (39.1) | 28 (80.0) |
| Age, y (±SD) | 69.5 (±14.7) | 69.7 (±13.6) | 69.2 (±16.3) |
| Diabetes mellitus, n (%) | 20 (24.7) | 10 (21.7) | 10 (28.6) |
| Hypertension, n (%) | 29 (35.8) | 17 (37.0) | 12 (34.3) |
| Chronic lung diseases, n (%) | 49 (60.5) | 35 (76.1) | 14 (40.0) |
| Chronic obstructive pulmonary disease | 42 (85.7) | 33 (94.3) | 9 (64.3) |
| Lung cancer | 3 (6.1) | 0 (0) | 3 (21.4) |
| Asthma | 2 (4.1) | 2 (5.7) | 0 (0) |
| Interstitial lung disease | 2 (4.1) | 0 (0) | 2 (14.3) |
| Causes of respiratory failure | | | |
| Acute exacerbation of chronic obstructive pulmonary disease | 38 (46.9) | 30 (65.2) | 8 (22.9) |

**Table 2**
Arterial blood gas analysis an

| | Hypercapnia group (n = 46) | | |
|---|---|---|---|
| | Before-HFNC ABG | After-HFNC ABG | *P* |
| $Paco_2$, mm Hg (±SD) | 73.2 (±20.0) | 67.2 (±23.4) | .02 |
| $Pao_2$, mm Hg (±SD) | 71.6 (±40.0) | 85.0 (±34.7) | .02 |
| pH (±SD) | 7.28 (±0.08) | 7.31 (±0.08) | <.01 |
| $HCO_3^-$, mmol/L (±SD) | 32.9 (±7.0) | 32.0 (±7.9) | .21 |
| $SpO_2$, % (±SD) | 82.5 (±17.2) | 91.9 (±7.4) | <.01 |
| Respiratory rate | 24.7 (±5.8) | 23.6 (±5.2) | .03 |

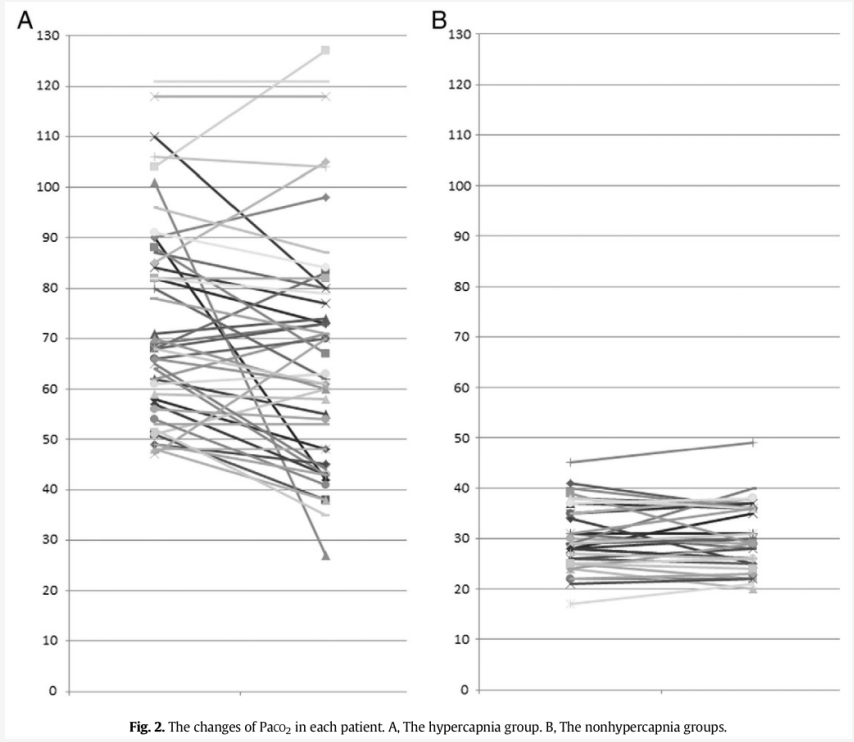


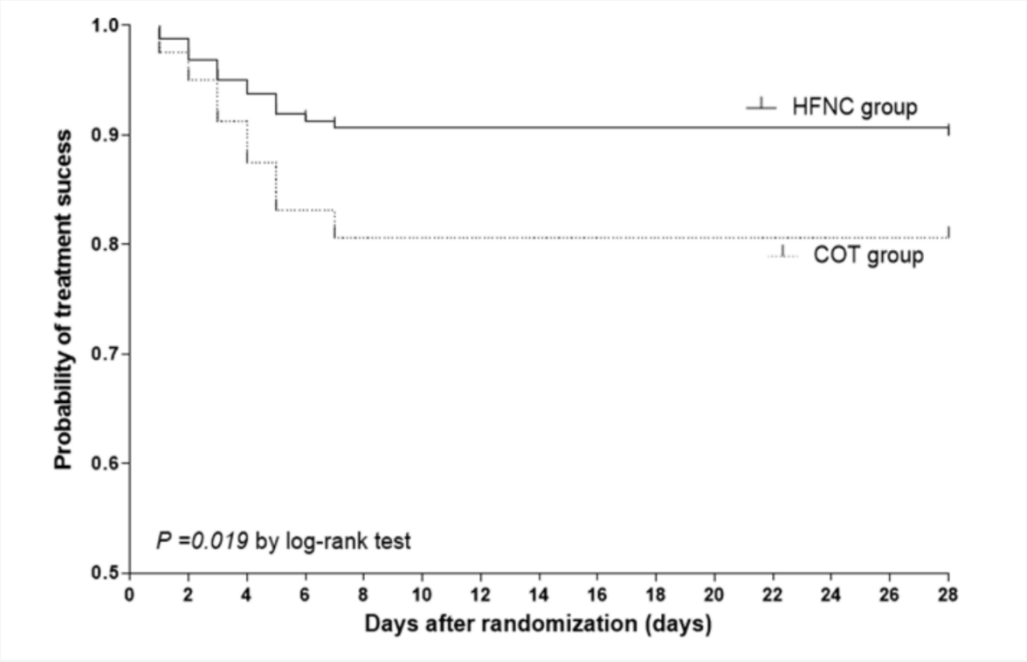

**Fig. 2.** The changes of $Paco_2$ in each patient. A, The hypercapnia group. B, The nonhypercapnia groups.

American Journal of Emergency Medicine 33 (2015) 1344–1349

# HFNC may reduce the need to intubation

- Prospective RCT, 320 patients, China
- Patients with AECOPD with pH ≥ 7.35, $PaO_2$ < 60 mmHg, and $PaCO_2$ > 45 mmHg

| Outcome | HFNC | COT | P |
|---|---|---|---|
| Treatment failure | 16 (10.0%) | 31 (19.4%) | 0.026 |
| Patients received NIV | 13 (8.1%) | 26 (16.3%) | 0.039 |
| CAT scores at discharge | 12.0 ± 7.6 | 17.0 ± 7.3 | 0.002 |
| Subjective discomfort score | 2.3 ± 1.1 | 3.9 ± 1.6 | <0.001 |
| Reason for NIV | | | |
| Respiratory acidosis | 12 (7.5) | 24 (15.0) | 0.050 |
| Obvious dyspnea | 4 (2.5) | 7(4.4) | |




Xu-Yan Li et al. Int J Chron Obstruct Pulmon Dis. 2020; 15: 3051–3061.

# HFNC may be useful in AECOPD

- Not tolerated NIV, COPD c AE, pH ≤ 7.38 and $PaCO_2$ > 45mmHg
- 38 patients, Initiation setting : Flow 50L/min

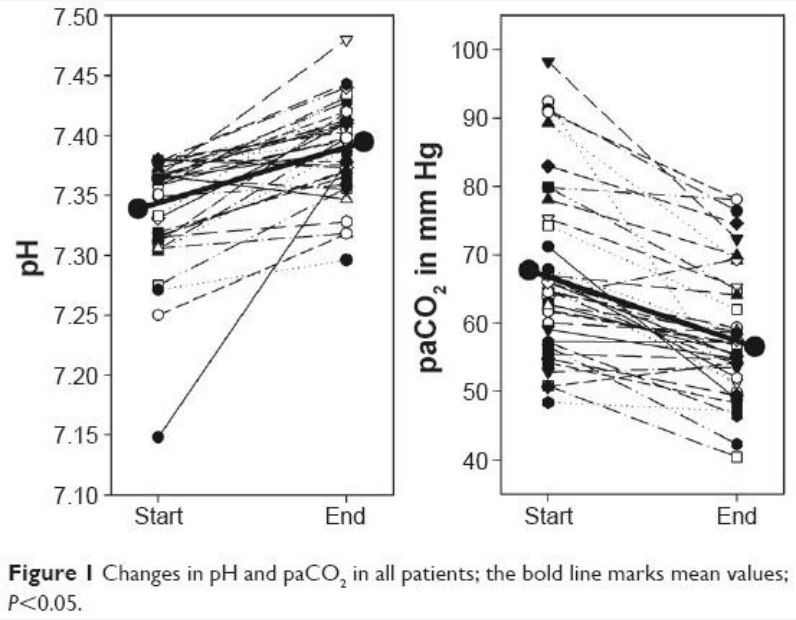


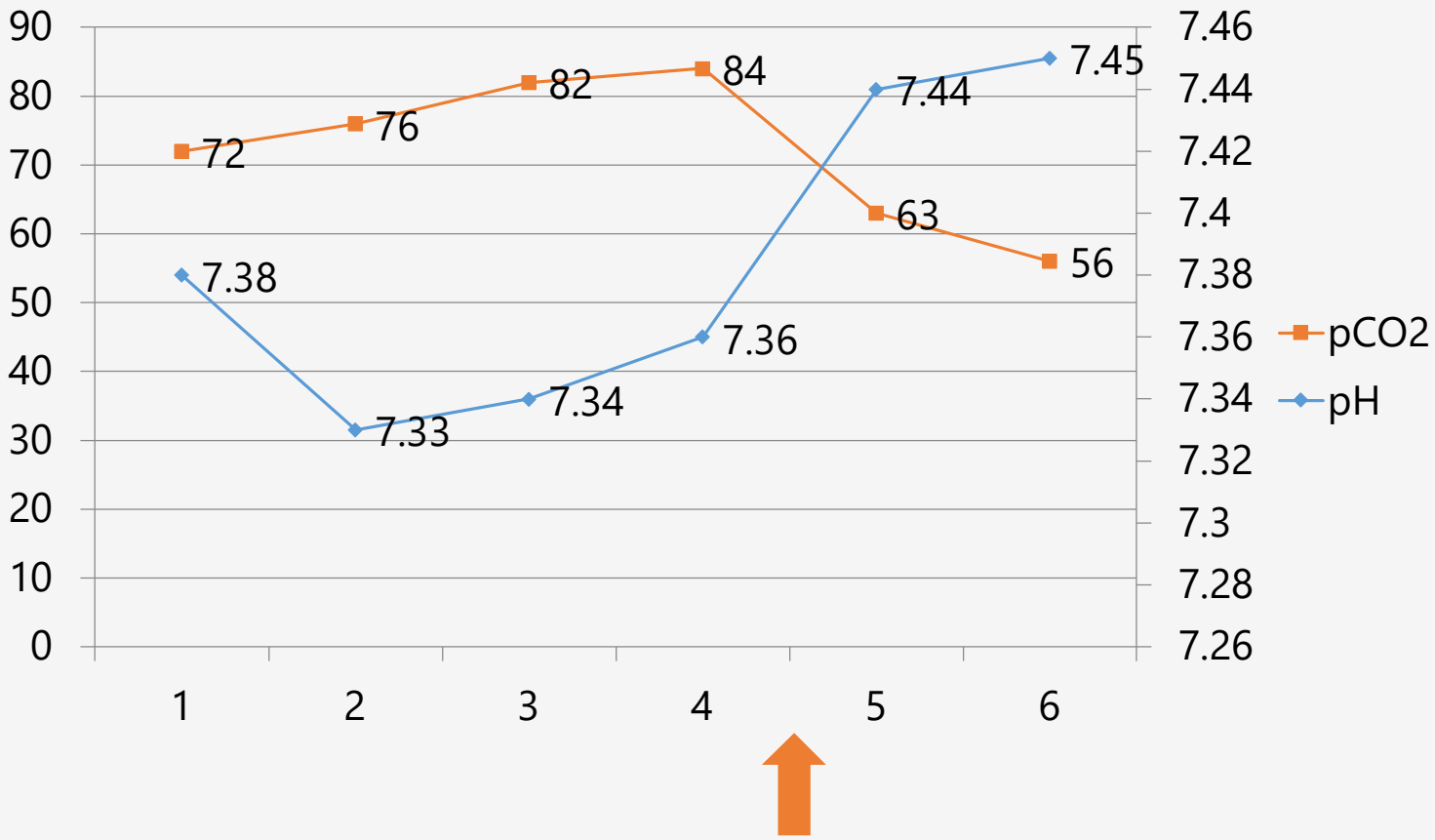

**Figure 1** Changes in pH and $paCO_2$ in all patients; the bold line marks mean values; $P<0.05$.

**Table 1** Parameters during NHF treatment

| Parameters | All patients (pH ≤7.38; n=38) | | | |
|---|---|---|---|---|
| | Baseline (mean±SD) | End (mean±SD) | Change (mean±SD) | *P*-value |
| pH | 7.339±0.041 | 7.392±0.048 | 0.052±0.048 | 0.000 |
| $pCO_2$ mmHg | 67.6±12.9 | 58.5±9.7 | −9.1±8.8 | 0.001 |
| $pO_2$ mmHg | 58.3±15.2 | 58.3±17.6 | – | 0.983 |
| $SO_2$ % | 85.3±9.5 | 86.2±11.3 | – | 0.798 |
| $HCO_3$ mmol/L | 30.8±5.1 | 31.6±5.3 | – | 0.636 |
| Base excess mmol/L | 6.9±4.9 | 7.7±5.4 | – | 0.633 |
| NHF flow L/min | – | 25.8±8.2 | – | – |
| Treatment time min | – | 195±231 | – | – |
| | Patients with pH <7.35 (n=17) | | | |
| pH | 7.298±0.046 | 7.379±0.051 | 0.082±0.060 | 0.000 |
| $pCO_2$ mmHg | 73.7±13.7 | 59.6±11.2 | −14.2±10.6 | 0.002 |
| $pO_2$ mmHg | 56.9±14.8 | 55.6±20.7 | – | 0.845 |
| $SO_2$ % | 84.8±10.1 | 84.3±11.9 | – | 0.904 |
| $HCO_3$ mmol/L | 31.6±5.5 | 32.5±5.6 | – | 0.661 |
| Base excess mmol/L | 7.4±5.3 | 8.5±5.7 | – | 0.591 |
| NHF flow L/min | – | 26.3±7.9 | – | – |
| Treatment time min | – | 252±251 | – | – |

**Notes:** Changes in blood gas analyses data, usage time and flow rates during NHF therapy in all patients and in the subgroup with pH <7.35. All data are organized as mean±SD. "–" indicates no significant differences to report.
**Abbreviation:** NHF, nasal high-flow.

Bräunlich J et al. IJCOPD. 2018 Nov 30;13:3895-3897.




**HFNC (Flow 60L/min, $FiO_2$ 60%)**

# Risk factor Failure of HFNC in COPD patients

**Table 4** Comparison of Physiological Parameters Between HFNC Success and Failure Groups

| Characteristic | HFNC Group | Baseline | 24 h | 48 h | 72 h | 120 h | $p^a$ |
|---|---|---|---|---|---|---|---|
| pH | Success | 7.38±0.05 | 7.40±0.04 | 7.40±0.04 | 7.41±0.04 | 7.41±0.04 | 0.253 |
| | Failure | 7.40±0.04 | 7.38±0.04 | 7.39±0.02 | 7.38±0.06 | 7.37±0.07 | 0.197 |
| | $p^c$ | 0.281 | 0.334 | 0.756 | 0.018 | 0.030 | 0.050[b] |
| $PaO_2$ (mmHg) | Success | 54.8±4.8 | 72.1±8.7 | 70.6±14.0 | 71.3±15.5 | 71.2±16.4 | 0.000 |
| | Failure | 54.9±5.0 | 71.2±11.7 | 68.1±10.3 | 68.9±15.2 | 78.2±25.1 | 0.487 |
| | $p^c$ | 0.518 | 0.786 | 0.649 | 0.629 | 0.384 | 0.878[b] |
| $PaCO_2$ (mmHg) | Success | 54.6±6.9 | 52.4±8.0 | 51.5±5.6 | 52.2±7.2 | 50.9±8.9 | 0.000 |
| | Failure | 58.0±8.9 | 59.0±11.8 | 55.8±5.6 | 63.8±11.0 | 68.7±13.2 | 0.144 |
| | $p^c$ | 0.086 | 0.006 | 0.012 | 0.006 | 0.000 | 0.000[b] |
| $SaO_2$ (%) | Success | 89.1±4.7 | 93.3±2.7 | 93.3±2.2 | 93.1±3.3 | 93.7±2.6 | 0.000 |
| | Failure | 90.5±4.8 | 92.9±1.9 | 92.3±2.5 | 92.2±4.1 | 95.4±4.2 | 0.160 |
| | $p^c$ | 0.295 | 0.592 | 0.237 | 0.460 | 0.179 | 0.628[b] |
| Respiratory rate (bpm) | Success | 20.1±1.5 | 21.3±2.3 | 22.4±5.9 | 21.8±2.8 | 21.4±2.4 | 0.013 |
| | Failure | 22.4±2.5 | 22.7±2.6 | 22.0±2.8 | 23.0±2.4 | 21.5±1.9 | 0.896 |
| | $p^c$ | 0.032 | 0.059 | 0.829 | 0.205 | 0.936 | 0.784[b] |

*Xu-Yan Li et al. Int J Chron Obstruct Pulmon Dis. 2020; 15: 3051–3061.*

# Risk factor of HFNC failure in AECOPD

**TABLE 2.**

**Changes in Respiratory Rate, $Paco_2$, and pH After 1 Hour of High-Velocity Nasal Insufflation According to the Result of the Therapy**

| | Success | | | Failure | | |
|---|---|---|---|---|---|---|
| Variable | Baseline | 1 hr HVNI | *p* | Baseline | 1 hr HVNI | *p* |
| Respiratory rate (breaths/min)[a] | 29 (28–31) | 22 (20–24) | < 0.001 | 30 (25–31) | 23 (22–29) | 0.379 |
| $Paco_2$ (mm Hg)[a] | 56 (51–67) → | 51 (44–59) | < 0.001 | 66 (56–77) → | 72 (68–78) | 0.392 |
| pH[a,b] | 7.32 (7.28–7.34) | 7.37 (7.34–7.40)[b] | 0.006 | 7.31 (7.29–7.32) | 7.31 (7.28–7.35)[b] | 0.56 |

HVNI = high-velocity nasal insufflation.[a]Values expressed as median (interquartile range).[b]$p = 0.022$ for pH at the time of HVNI therapy (Mann-Whitney *U* test).

Crit Care Explor. 2021 Feb; 3(2): e0337.

# HFNC vs. NIV in COPD Patients

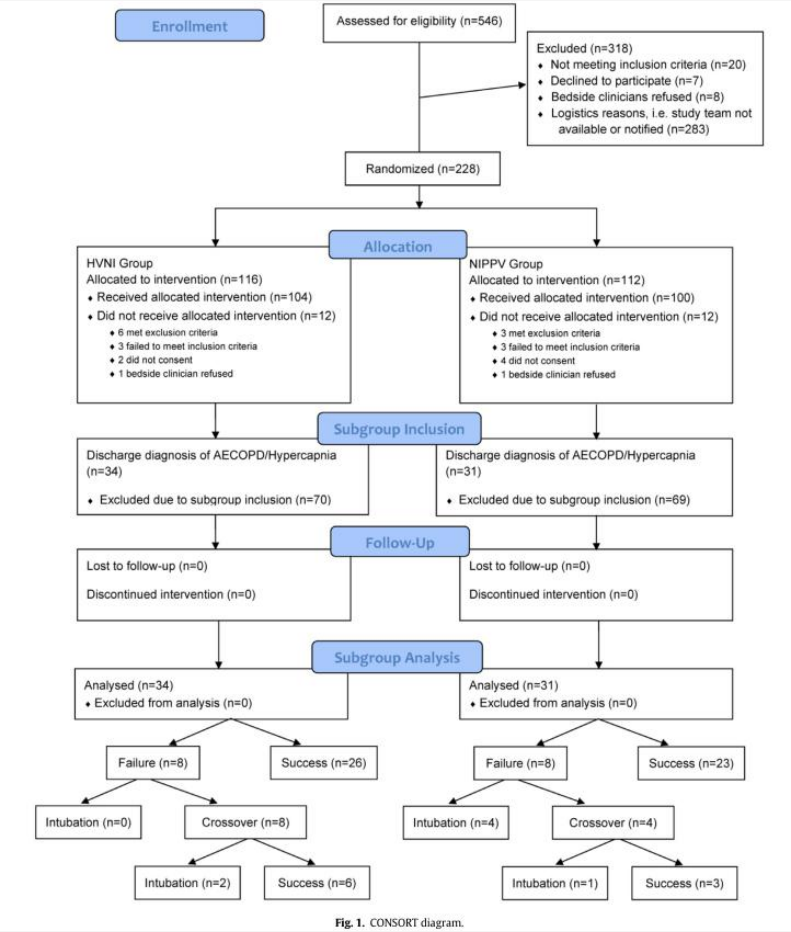



**Fig. 1.** CONSORT diagram.

- 65 patients
- NIV IPAP 10-20 $cmH_2O$ $FiO_2$ 1.0
- HFNC 35 L/min, $FiO_2$ 1.0

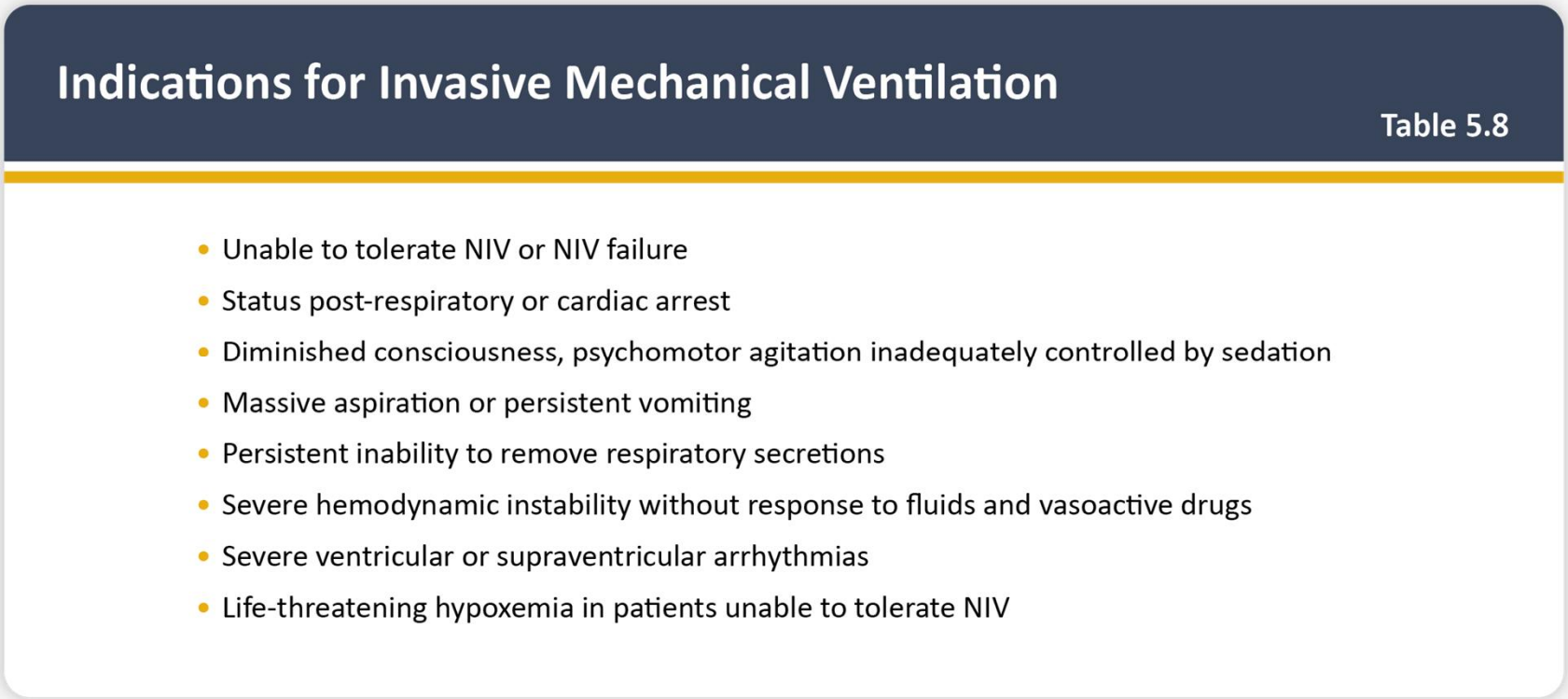
**Table 2**
Therapy failure.

| | HVNI, *n* = *34* | NIPPV, *n* = *31* | p-value |
|---|---|---|---|
| Intubation at 72 h, *n (%)* | 2 (5.9%) | 5 (16.1%) | 0.244 |
| Arm failure at 72 h, *n (%)* | 8 (23.5%) | 8 (25.8%) | 1.000 |
| Crossover at 72 h, *n (%)* | 8 (23.5%) | 4 (12.9%) | 0.346 |

Data is reported as number (%). Statistical significance ($p < 0.05$) determined by Fisher's Exact Test.

*Heart & Lung 49 (2020) 610-615*

# Indications for Invasive mechanical ventilation in AECOPD




GOLD 2023

## Summary

- Respiratory failure : lung failure, pump failure
- Acute hypoxemic respiratory failure
  - ✓ HFNC > COT or NIV
  - ✓ NIV : Acute cardiogenic pulmonary edema
- Acute hypercapnic respiratory failure
  - ✓ NIV > HFNC, COT
  - ✓ HFNC : hypercapnic AECOPD without respiratory acidosis


갸...감사합니다!
넙죽