NIV in hypoxemic respiratory failure

Cesare Gregoretti
Cesare.gregoretti @unicamillus.org

COI

Received fees for pesentations from:

- Philips
- Vivisol
- Airliquide

The most common ventilatory mode is a pressure targeted flow-cycling mode namely pressure support ventilation-PSV

Assisted Partial Support

$\mathbf{Papp.rs = P_{MUS} + P_{VENT}}$

In PSV the pressure switches between 2 levels of pressure namely an inspiratory (IPAP) and an end positive expiratory pressure (EPAP-PEEP)

Why NIV can be harmful in hypoxemic respiratory failure?

VILI

Lungs ignore if they are moved or overdistended by the muscles or by the ventilator: VILI depends on the level of power applied, not on its source.

Intensive Care Med (2017) 43:256–258
DOI 10.1007/s00134-016-4483-4

EDITORIAL

Ventilation-induced lung injury exists in spontaneously breathing patients with acute respiratory failure: We are not sure

Luciano Gattinoni*

Intensive Care Med 1988;15(1):8-14

Acute respiratory failure following pharmacologically induced hyperventilation: an experimental animal study

Mascheroni D., Kolobow T., Fumagalli R., Moretti MP,Chen V., Buckhold D.

National Institute of Health, Lab. Of Technical Development, Bethesda, Maryland,USA.

Hyperventilation on Spontaneous breathing:

- ↓ PaO2
- ↓ Cst,rs
- Abnormal chest Rx
- Abnormal lung pathology

From VILI to SILI

- In patients with “denovo” Acute Hypoxemic Respiratory Failure (AHRF) vigorous patient inspiratory effort generated by the diaphragm contraction during a spontaneous or assisted breath, may increase tidal volume and global dynamic lung stress (computed by transpulmonary driving pressure, ΔPL) potentially leading to lung injury recently termed as Self Inflicted Lung Injury (SILI)

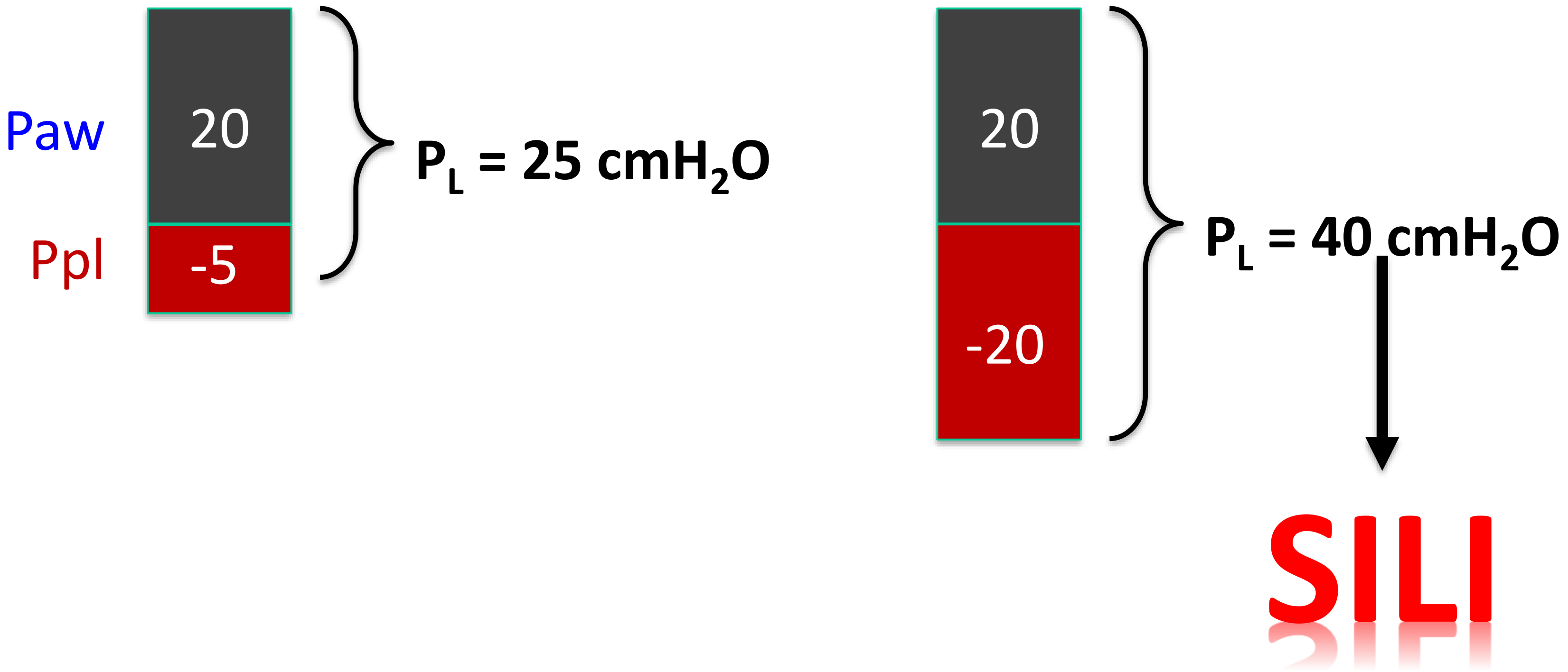
Yoshida T et al Spontaneous Breathing during Mechanical Ventilation Risks, Mechanisms, and Management Am J Respir Crit Care Med Vol 195, Iss 8, pp 985–992, Apr 15, 2017

Demoule A et al Intensive Care Medicine 2006 ; Carteaux G et al Critical Care Med 2015

Mechanisms of SILI: role of transpulmonary pressure (P_L)

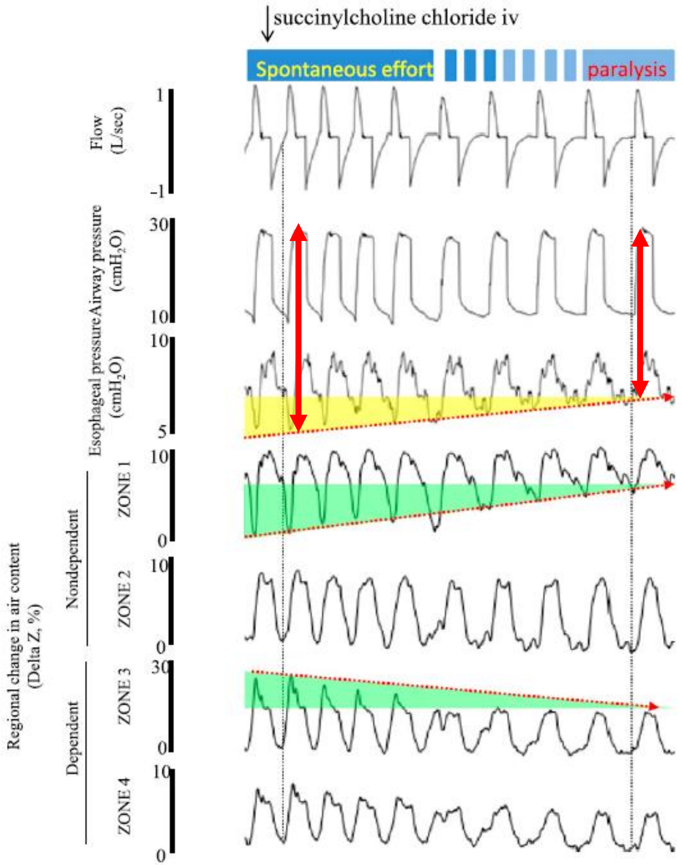
$$P_L = Paw - Ppl$$

(ventilator) *(muscles)*



Spontaneous effort increases regional lung stretch: the pendelluft concept

Spontaneous breathing effort during mechanical ventilation causes unsuspected overstretch of dependent lung … Even when not increasing tidal volume, strong spontaneous effort may potentially enhance lung damage.



Yoshida T et al. Am J Respir Crit Care Med 2013;188:1420-1427

Check for updates

ORIGINAL ARTICLE

Respective Effects of Helmet Pressure Support, Continuous Positive Airway Pressure, and Nasal High-Flow in Hypoxemic Respiratory Failure

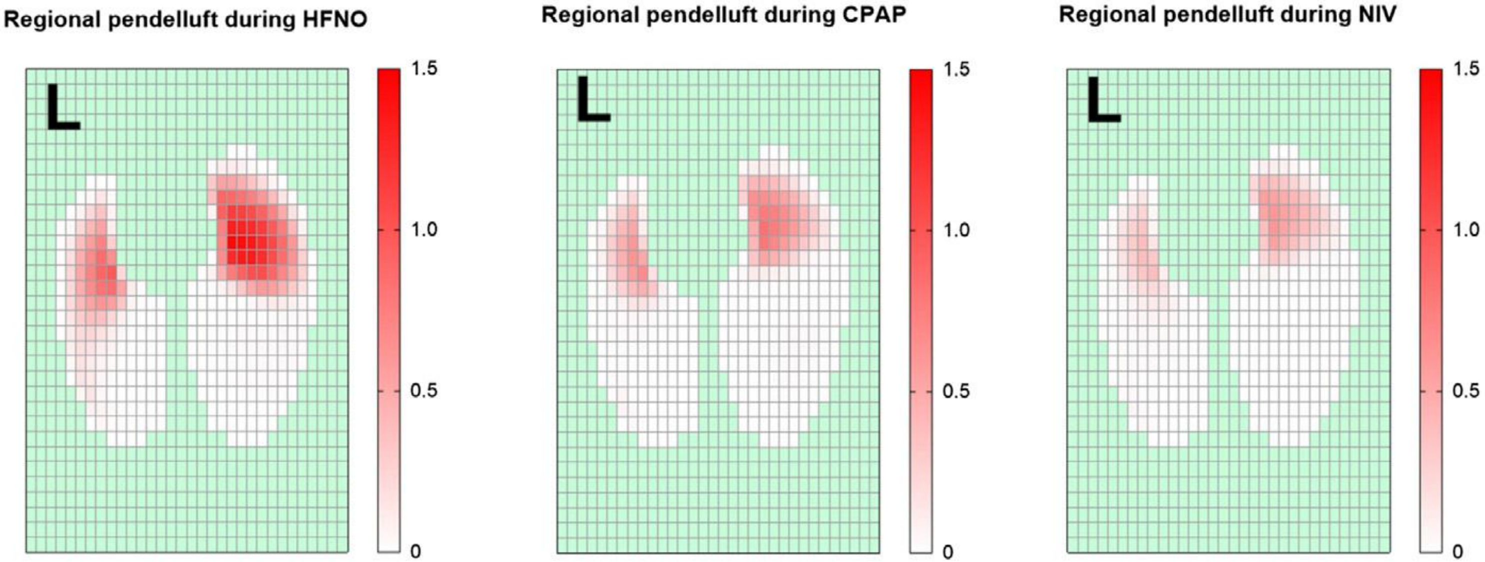
A Randomized Crossover Clinical Trial

Luca S. Menga[1,2*], Luca Delle Cese[1,2*], Tommaso Rosà[1,2], Melania Cesarano[1,2], Roberta Scarascia[1,2], Teresa Michi[1,2], Daniele G. Biasucci[1,2], Ersilia Ruggiero[1,2], Antonio M. Dell'Anna[1,2], Salvatore L. Cutuli[1,2], Eloisa S. Tanzarella[1,2], Gabriele Pintaudi[1,2], Gennaro De Pascale[1,2], Claudio Sandroni[1,2], Salvatore Maurizio Maggiore[3,4], Domenico L. Grieco[1,2], and Massimo Antonelli[1,2]

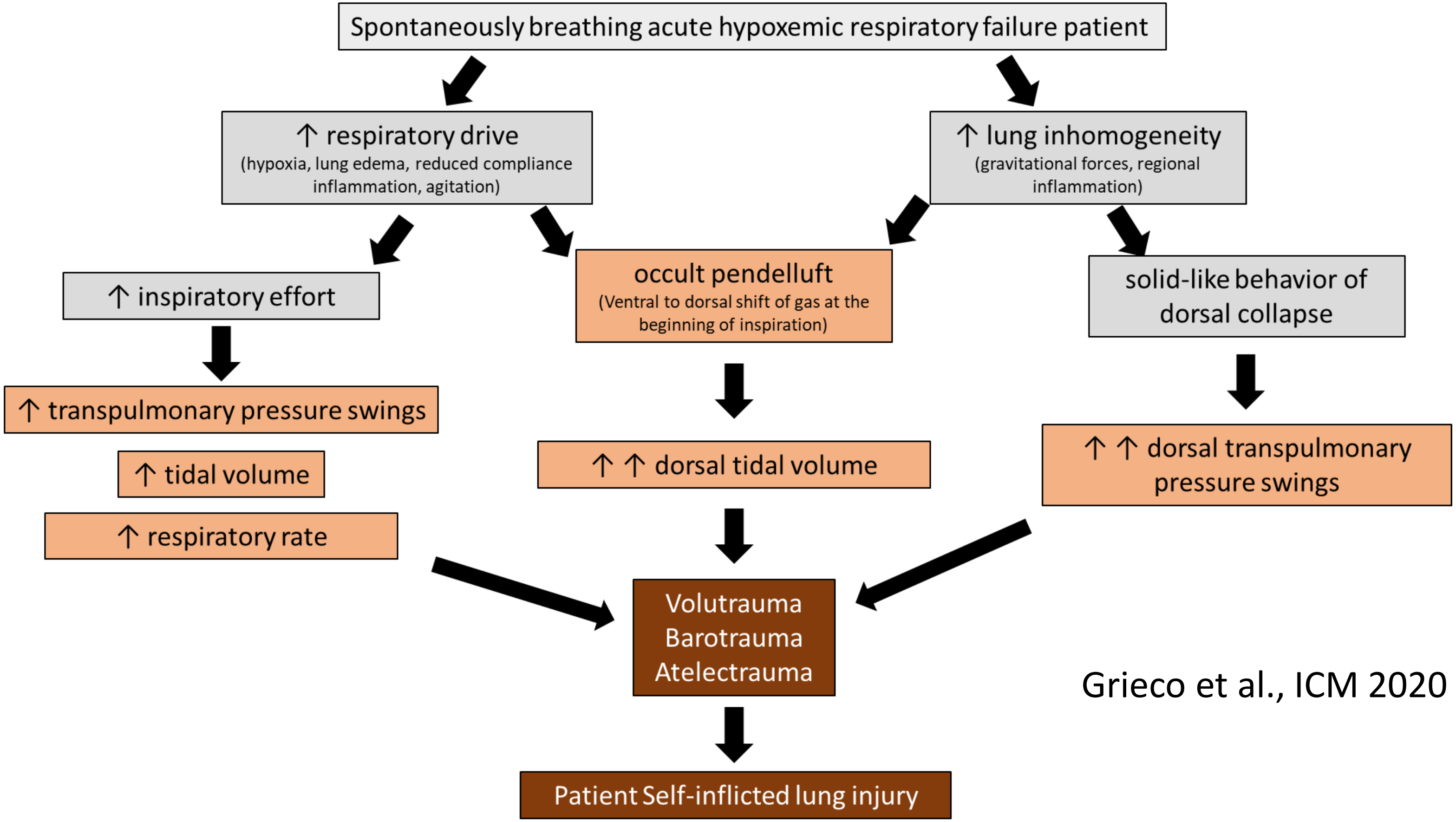
NIV, and to a lesser extent CPAP, mitigated pendelluft.

A high pendelluft percentage during HFNO (65% of VT), which progressively decreased with both helmet CPAP (38% of VT) and NIV (26% of VT)

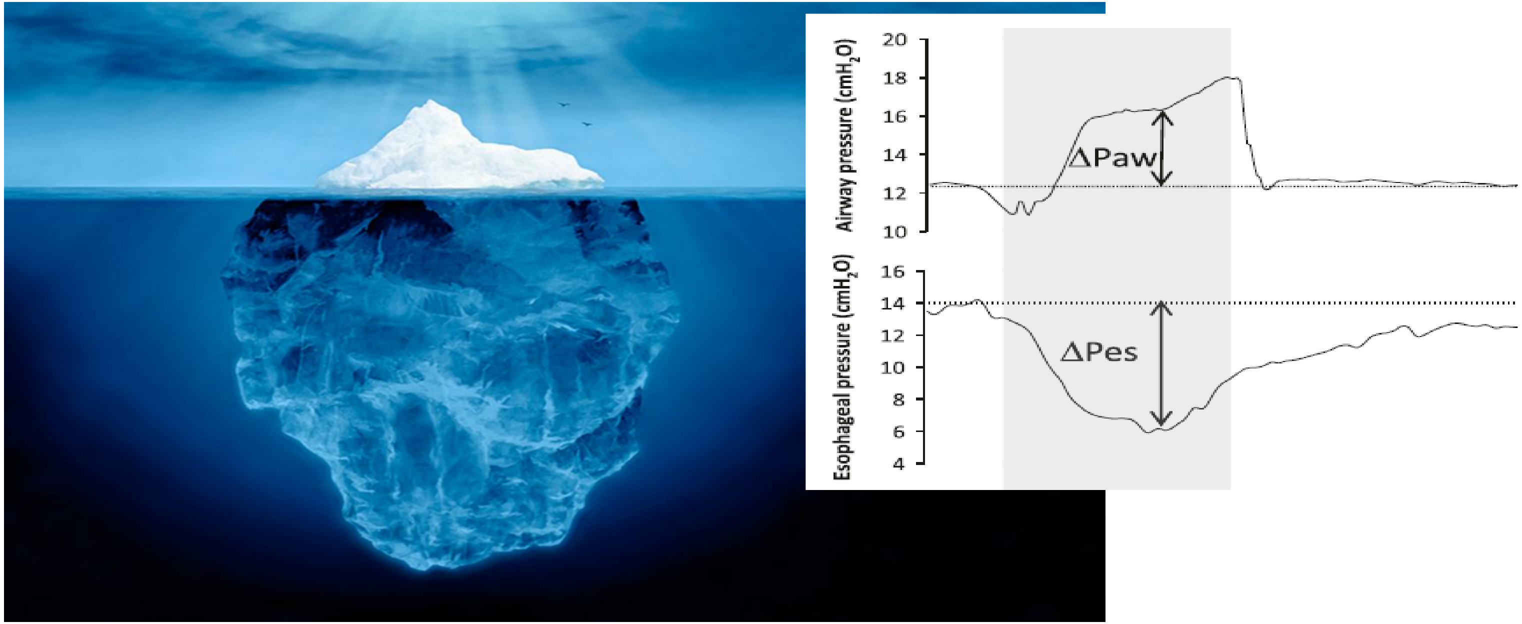
American Journal of Respiratory and Critical Care Medicine 2023; 207:10



Intrapulmonary distribution of air in one representative patient.


Spontaneously breathing acute hypoxemic respiratory failure patient
↑ respiratory drive
(hypoxia, lung edema, reduced compliance inflammation, agitation)
↑ lung inhomogeneity
(gravitational forces, regional inflammation)
↑ inspiratory effort
occult pendelluft
(Ventral to dorsal shift of gas at the beginning of inspiration)
solid-like behavior of dorsal collapse
↑ transpulmonary pressure swings
↑ tidal volume
↑ respiratory rate
↑ ↑ dorsal tidal volume
↑ ↑ dorsal transpulmonary pressure swings
Volutrauma
Barotrauma
Atelectrauma
Patient Self-inflicted lung injury
Grieco et al., ICM 2020

Sometimes pressures are hidden….



Unfortunately end inspiratory transpulmonary pressure is impossible to know during NIV, despite it can surrogated by dynamic transpulmonary pressure, whose measurement however requires esophageal baloon and is not clinically feasible in all patients

Courtesy G.Bellani

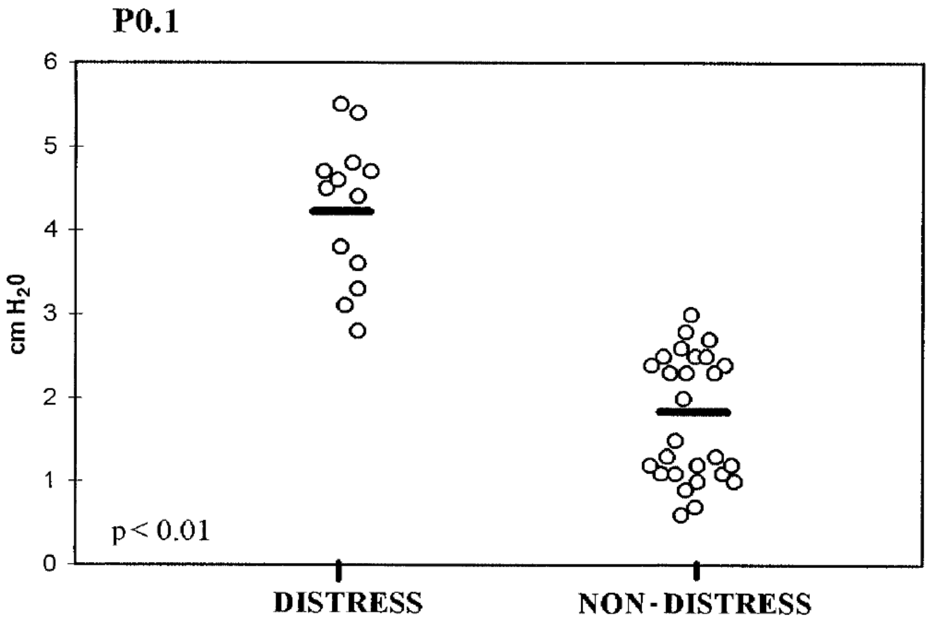
P0.1-Respiratory drive-Possible during facemask NIV

Intensive Care Med (1998) 24: 1277–1282

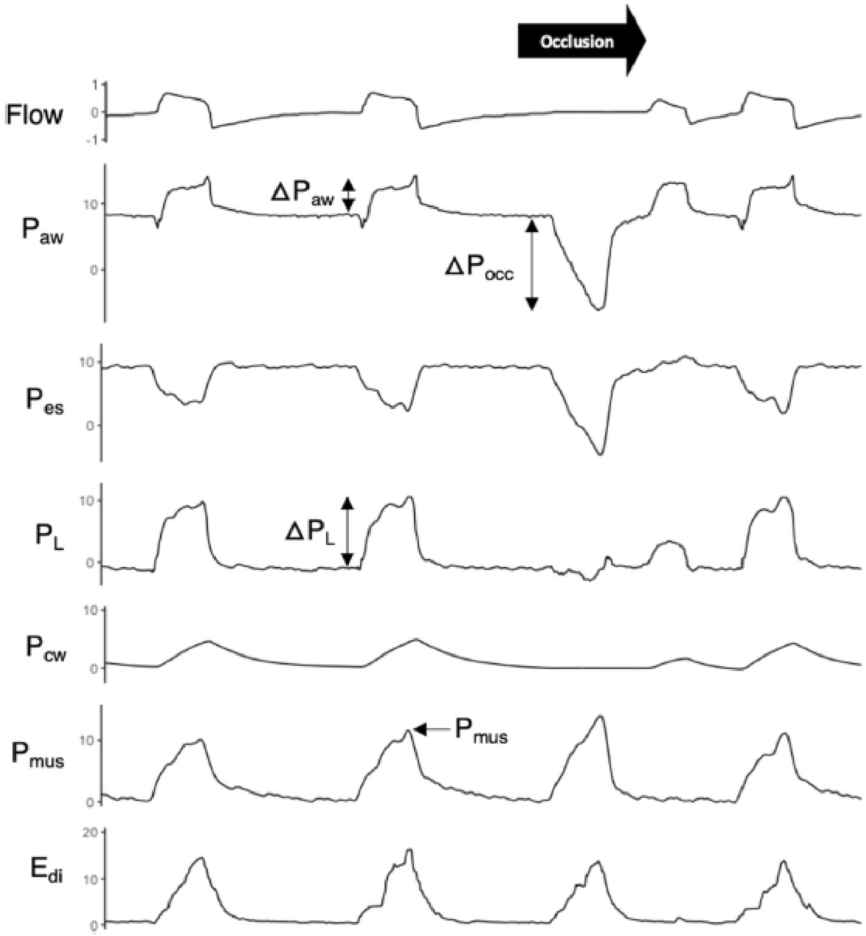
ORIGINAL

G. Hilbert
D. Gruson
L. Portel
F. Vargas
G. Gbikpi-Benissan
J.P. Cardinaud

Airway occlusion pressure at 0.1 s (P0.1) after extubation: an early indicator of postextubation hypercapnic respiratory insufficiency

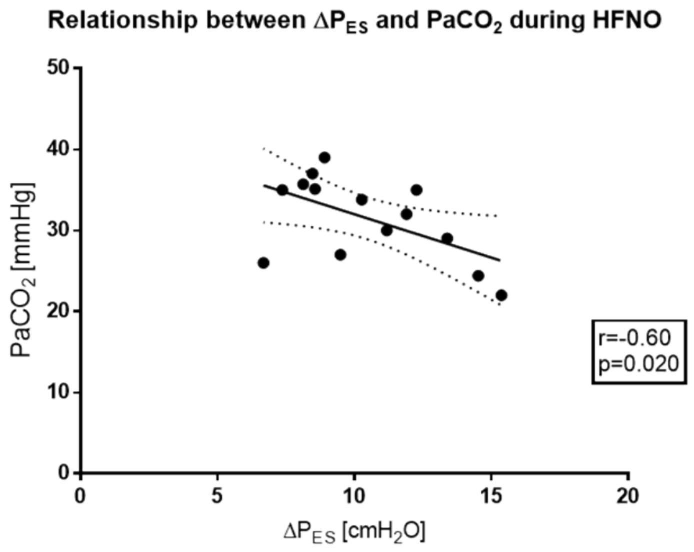


ΔPOCC: inspiratory effort-potentially possible during facemask NIV

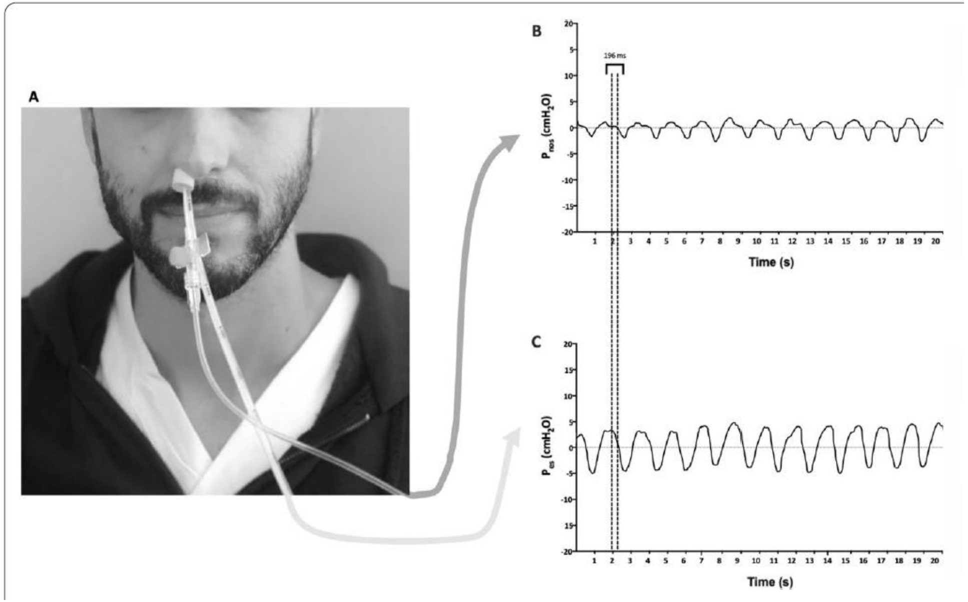


Bertoni Crit Care 2019

Estimation of effort

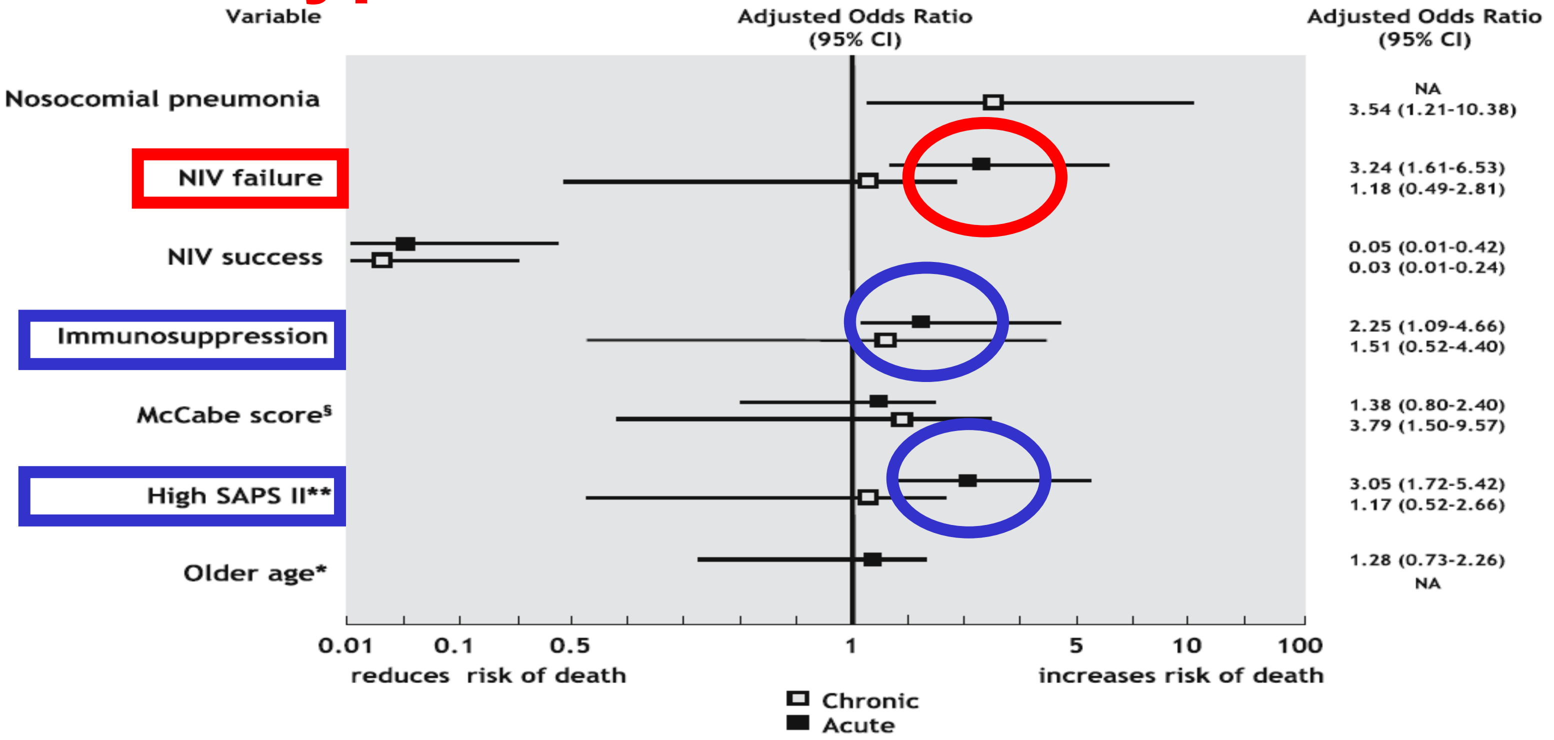


Menga AJRCCM 2023



Tonelli Crit Care 2020

NPPV failure increases the risk of death in hypoxemic “DENOVO” ARF

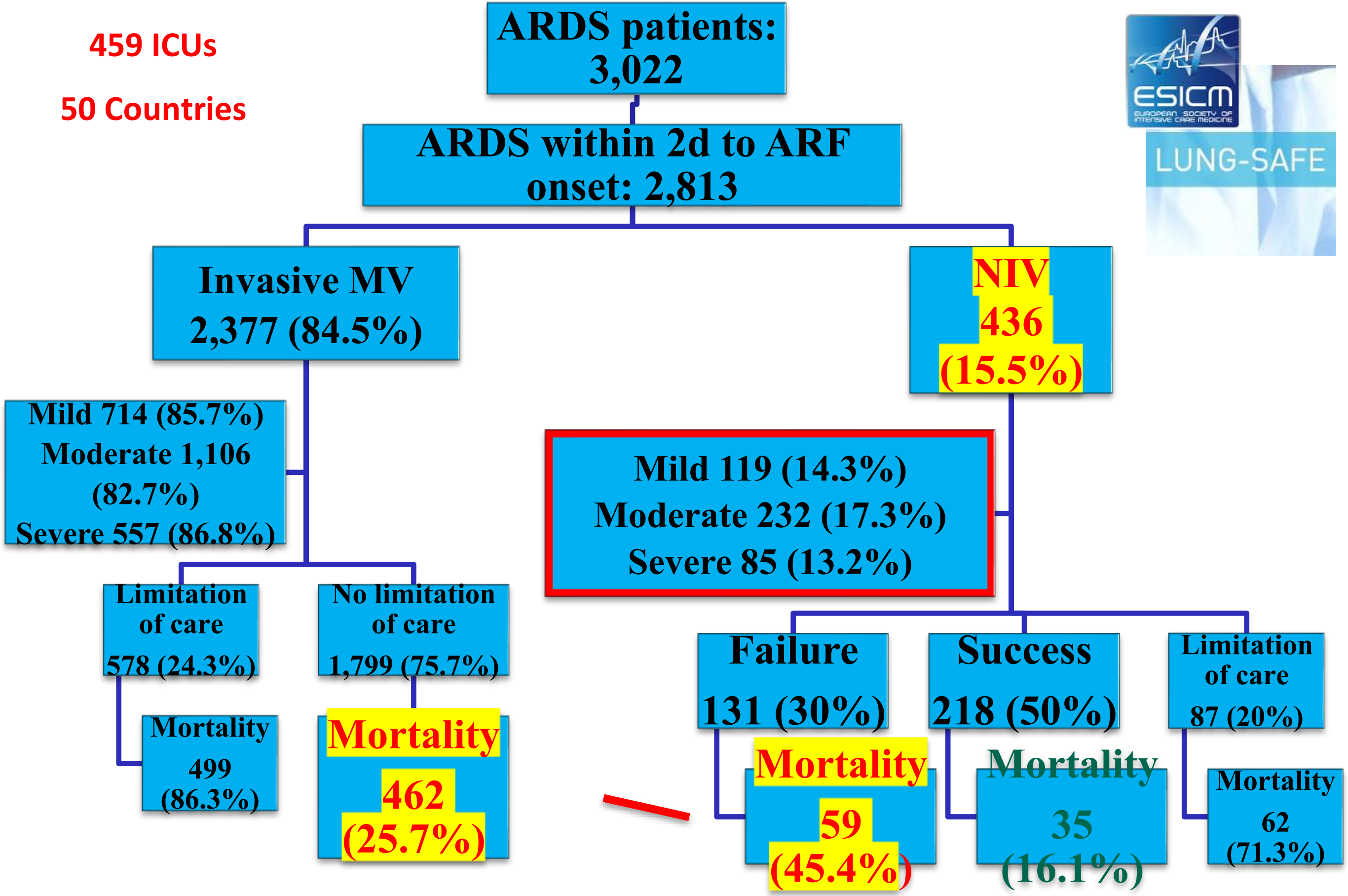


Demoule A et al Intensive Care Medicine 2006; 32:1756-1765

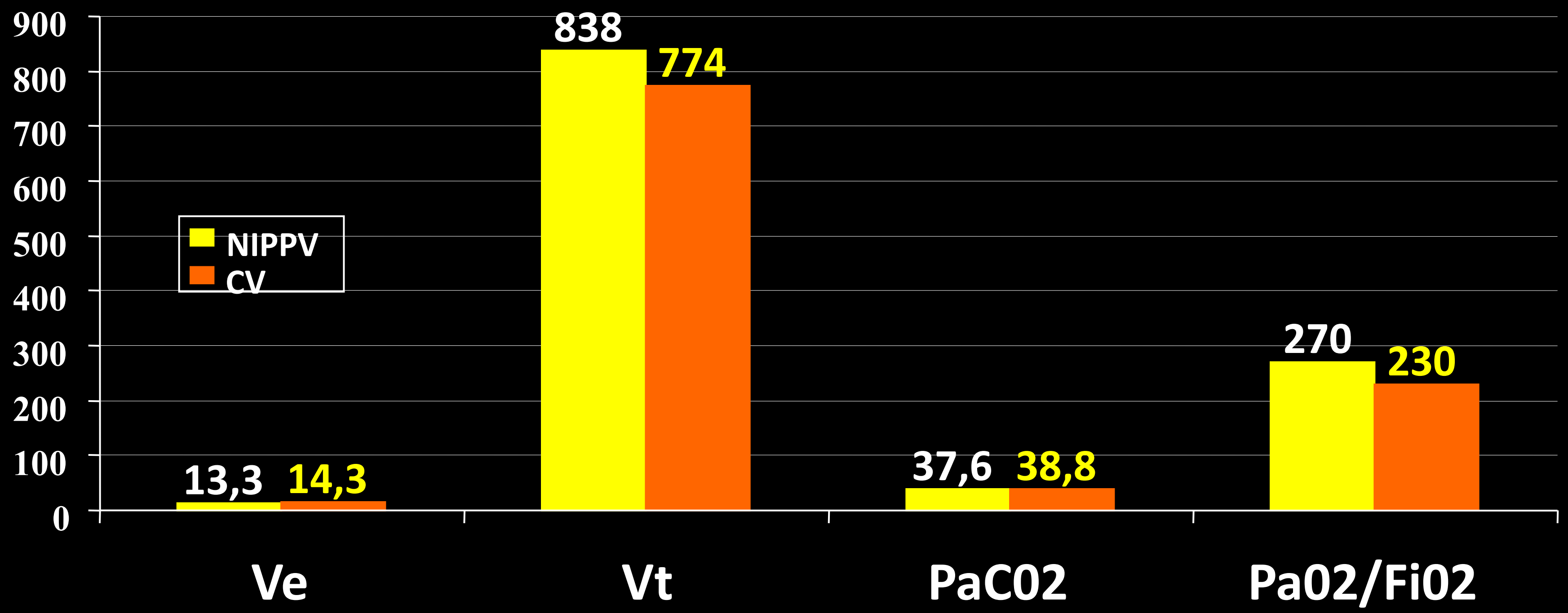
NIV in patients with ARDS: the LUNG-SAFE analysis

459 ICUs

50 Countries



Bellani G et al. Am J Resp Crit Care Med 2016;10.1164/rccm.201606-1306OC (18-October-2016)



Comparison of physiologic response between NIV and EIV. Gregoretti et al Intensive Care 1998; 24:785-90

All these interfaces skip the nasal bridge

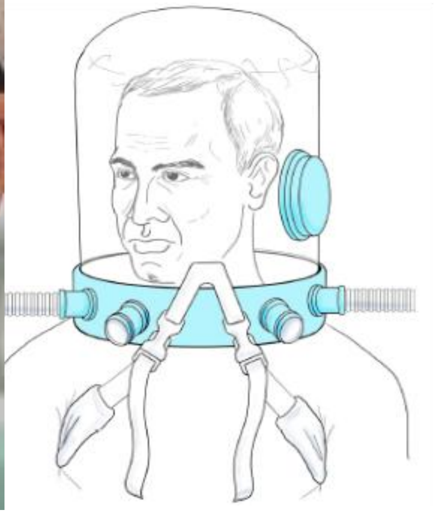
Noninvasive respiratory support for acute hypoxemic respiratory failure

Noninvasive ventilation: CPAP and Pressure Support Ventilation (PSV)

TOTAL FACE

HYBRID ORO NASAL

HELMET



Modified by D Grieco

Fig. 3 Trend of skin breakdown score in the conventional masks group (● conventional mask group patients). Skin breakdown score: 0= nil, 1= area of redness, 2= moderate skin breakdown, 3= skin ulcer, 4= skin necrosis

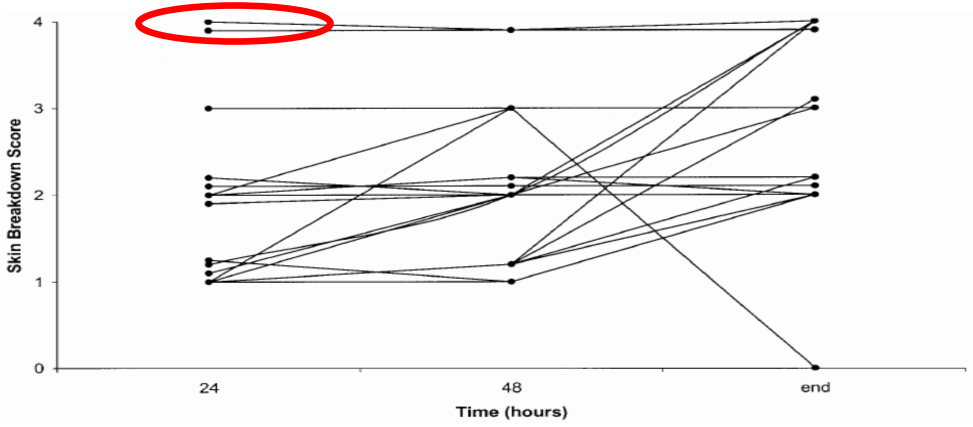
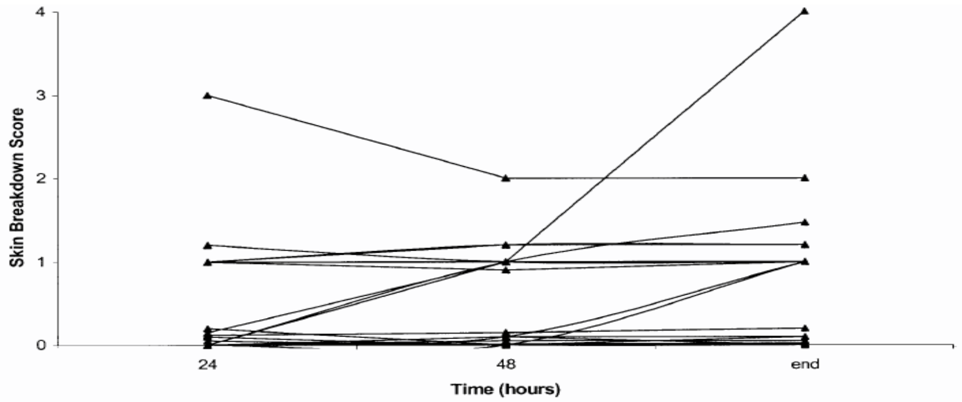


Fig. 4 Trend of skin breakdown score in the prototype mask group (black triangle = prototype mask group patients) Skin breakdown score: 0= nil, 1= area of redness, 2= moderate skin breakdown, 3= skin ulcer, 4= skin necrosis



Gregoretti C et al Intensive Care Med 2002

In patients with ARF undergoing NIV or CPAP, oronasal mask use for > 26 h was independently associated with development of skin break down

SB was observed in 48% of the subjects, with **transient erythema** in 18% (stageI), **prolonged erythema** in 23% (stage II), and **skin necrosis** in 3% (stage III). The overall prevalence of SB was lowern our study (14.4%), as well as stage I (13.1%) and stageII (1.3%)

QUICK LOOK

Current knowledge

Noninvasive ventilation (NIV) is associated with improved outcomes and lower mortality in exacerbations of COPD. Mask discomfort and skin breakdown (SB) are two of the most common reasons for NIV failure. The risk factors for SB are not well described.

What this paper contributes to our knowledge

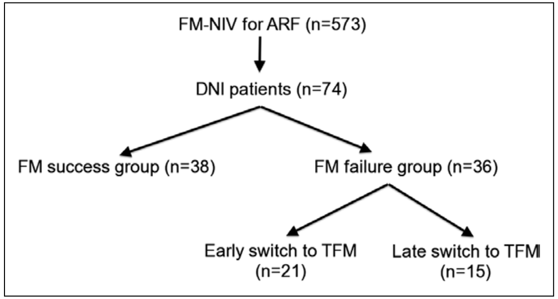
SB was associated with the use of an oronasal mask and prolonged application of NIV. Stage I SB occurred in 13% of subjects and stage II SB in only 1.3% of subjects. A total face mask had a lower incidence of SB.

European Pressure Ulcer Advisory Panel, National Pressure UlcerAdvisory Panel. Prevention and treatment of pressure ulcers: quick reference guide. 2009. http://www.epuap.org/guidehnes/Final_Quick_Prevention.pdf. Accessed May 14, 2014

Yamaguti W et al Respiratory Care 2014

TFM vs FFM:

TURBINE DRIVEN INTENTIONAL LEAK VENTILATOR



Rescue Therapy by Switching to Total Face Mask After Failure of Face Mask-Delivered Noninvasive Ventilation in Do-Not-Intubate Patients in Acute Respiratory Failure*

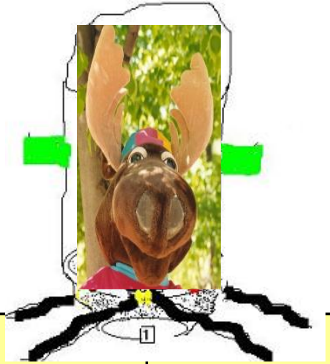
Malcolm Lemyze, MD[1]; Jihad Mallat, MD[1]; Olivier Nigeon, MD[2]; Stéphanie Barrailler, MD[1]; Florent Pepy, MD[1]; Gaëlle Gasan, MD[1]; Nicolas Vangrunderbeeck, MD[1]; Philippe Grosset, MD[2]; Laurent Tronchon, MD[1]; Didier Thevenin, MD[1]

Parameters	Switched Early to Total Face Mask (*n* = 21)	Switched Late to Total Face Mask (*n* = 15)	*p*
Pressure sore, *n* (%)	5 (24%)	13 (87%)	0.0002
Pressure sore score	0 [0–0]	1 [1–3]	<0.0001
Protective dressings, *n* (%)	2 (9.5)	8 (53.3)	0.007
Length of NIV during first 48 hrs (hrs)	44 [35–46]	34 [29–42]	0.05
Length of facial mask-delivered NIV during first 48 hrs (hrs)	2 [2–4]	20 [12–24]	<0.0001
Length of NIV (days)[a]	8 [5–10]	8 [5–10]	0.9

Lemyze et al Crit Care Med 2013; 41:481–488

New treatment of acute hypoxemic respiratory failure: Noninvasive pressure support ventilation delivered by helmet—A pilot controlled trial

Massimo Antonelli, MD; Giorgio Conti, MD; Paolo Pelosi, MD; Cesare Gregoretti, MD; Mariano Alberto Pennisi, MD; Roberta Costa, MD; Paolo Severgnini, MD; Maurizio Chiaranda, MD; Rodolfo Proietti, MD



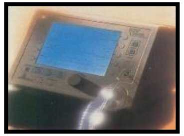
Crit Care Med 2002;30:602-608	HELMET	MASK	p
HOURS OF CONTINUOUS NIV	36 ± 29	26 ± 13	0.05
ETI BECAUSE OF INTOLERANCE	0	8	0.05
COMPLICATIONS RELATED TO NIV (Skin necrosis, Gastric Distension, Eye irritation)	0	14	0.002

Types of Ventilators: gas source

- **ICU HIGH PRESSURE (4 atm.) DRIVEN VENTILATORS.**
  They always ensure stable FiO2 (“blender”)

- **TURBINE OR PISTON DRIVEN VENTILATORS WITH O2 PROVIDED AT LOW PRESSURE**
  They do not ensure stable FiO2 (“no blender”)

- **TURBINE OR PISTON DRIVEN VENTILATORS WITH O2 PROVIDED At HIGH PRESSURE**
  They always ensure stable FiO2 (“blender”)



Severely hypoxemic patients need ventilators with high pressure O_2 inlet because:

- **stable FiO_2 is provided**
- **PaO_2/FiO_2 ratio is computed**

Intensive Care Med
https://doi.org/10.1007/s00134-023-07050-7

CONFERENCE REPORTS AND EXPERT PANEL

ESICM guidelines on acute respiratory distress syndrome: definition, phenotyping and respiratory support strategies

Giacomo Grasselli[1,2*], Carolyn S. Calfee[3], Luigi Camporota[4,5], Daniele Poole[6], Marcelo B. P. Amato[7], Massimo Antonelli[8,9], Yaseen M. Arabi[10,11,12], Francesca Baroncelli[13], Jeremy R. Beitler[14], Giacomo Bellani[15,16], Geoff Bellingan[17], Bronagh Blackwood[18], Lieuwe D. J. Bos[19], Laurent Brochard[20,21], Daniel Brodie[22], Karen E. A. Burns[21,23,24,25], Alain Combes[26,27], Sonia D'Arrigo[8], Daniel De Backer[28], Alexandre Demoule[29,30], Sharon Einav[31], Eddy Fan[21], Niall D. Ferguson[32,33], Jean-Pierre Frat[34,35], Luciano Gattinoni[36], Claude Guérin[37,38], Margaret S. Herridge[39], Carol Hodgson[40,41], Catherine L. Hough[42], Samir Jaber[43], Nicole P. Juffermans[44], Christian Karagiannidis[45], Jozef Kesecioglu[46], Arthur Kwizera[47], John G. Laffey[48,49], Jordi Mancebo[50], Michael A. Matthay[51], Daniel F. McAuley[18,52], Alain Mercat[53], Nuala J. Meyer[54], Marc Moss[55], Laveena Munshi[56], Sheila N. Myatra[57], Michelle Ng Gong[58,59], Laurent Papazian[60,61], Bhakti K. Patel[62], Mariangela Pellegrini[63], Anders Perner[64], Antonio Pesenti[1,2], Lise Piquilloud[65], Haibo Qiu[66], Marco V. Ranieri[67,68], Elisabeth Riviello[69], Arthur S. Slutsky[21,24], Renee D. Stapleton[70], Charlotte Summers[71], Taylor B. Thompson[72], Carmen S. Valente Barbas[73,74], Jesús Villar[24,75,76], Lorraine B. Ware[77], Björn Weiss[78], Fernando G. Zampieri[79,80], Elie Azoulay[81] and Maurizio Cecconi[82,83] on behalf of the European Society of Intensive Care Medicine Taskforce on ARDS

Recommendation 3.1

We **recommend** that non-mechanically ventilated patients with AHRF not due to cardiogenic pulmonary edema or acute exacerbation of COPD receive HFNO as compared to conventional oxygen therapy to reduce the risk of intubation
Strong recommendation; moderate level of evidence in favor

We are **unable to make a recommendation** for or against the use of HFNO over conventional oxygen therapy to reduce mortality
No recommendation; high level of evidence of no effect

This recommendation applies also to AHRF from COVID-19
Strong recommendation; low level of evidence in favor for intubation and no recommendation: moderate level of evidence of no effect for mortality, for indirectness.

Recommendation 3.2

We are **unable to make a recommendation** for or against the use of HFNO compared to continuous positive airway pressure (CPAP)/NIV to reduce intubation or mortality in the treatment of unselected patients with acute hypoxemic respiratory failure not due to cardiogenic pulmonary edema or acute exacerbation of COPD.
No recommendation; moderate level of evidence for mortality, low level of evidence for intubation, not in favor nor against.

We **suggest** that CPAP/NIV can be considered instead of HFNO for the treatment of AHRF due to COVID-19 to reduce the risk of intubation (*weak recommendation, high level of evidence*), but **no recommendation** can be made for whether CPAP/NIV can decrease mortality compared to HFNO in COVID-19.
No recommendation; high level of evidence of no effect.

EUROPEAN RESPIRATORY JOURNAL
ERS OFFICIAL DOCUMENTS
S. OCZKOWSKI ET AL.

Eur Respir J. 2022 Apr 14;59(4):2101574

ERS clinical practice guidelines: high-flow nasal cannula in acute respiratory failure

Simon Oczkowski[1,2,26], Begüm Ergan[3,26], Lieuwe Bos[4,5], Michelle Chatwin[6], Miguel Ferrer[7], Cesare Gregoretti[8,9], Leo Heunks[10], Jean-Pierre Frat[11,12], Federico Longhini[13], Stefano Nava[14,15], Paolo Navalesi[16,17], Aylin Ozsancak Uğurlu[18], Lara Pisani[14,15], Teresa Renda[19], Arnaud W. Thille[11,12], João Carlos Winck[20], Wolfram Windisch[21], Thomy Tonia[22], Jeanette Boyd[23], Giovanni Sotgiu[24] and Raffaele Scala[25]

TABLE 2 Population, intervention, comparison, outcomes (PICO) questions and recommendations

1. Should HFNC or COT be used in patients with acute hypoxaemic respiratory failure?	The ERS task force suggests the use of HFNC over COT in patients with acute hypoxaemic respiratory failure (conditional recommendation, moderate certainty of evidence)
2. Should HFNC or NIV be used in patients with acute hypoxaemic respiratory failure?	The ERS task force suggests the use of HFNC over NIV in acute hypoxaemic respiratory failure (conditional recommendation, very low certainty of evidence)

TABLE 3 Key research recommendations

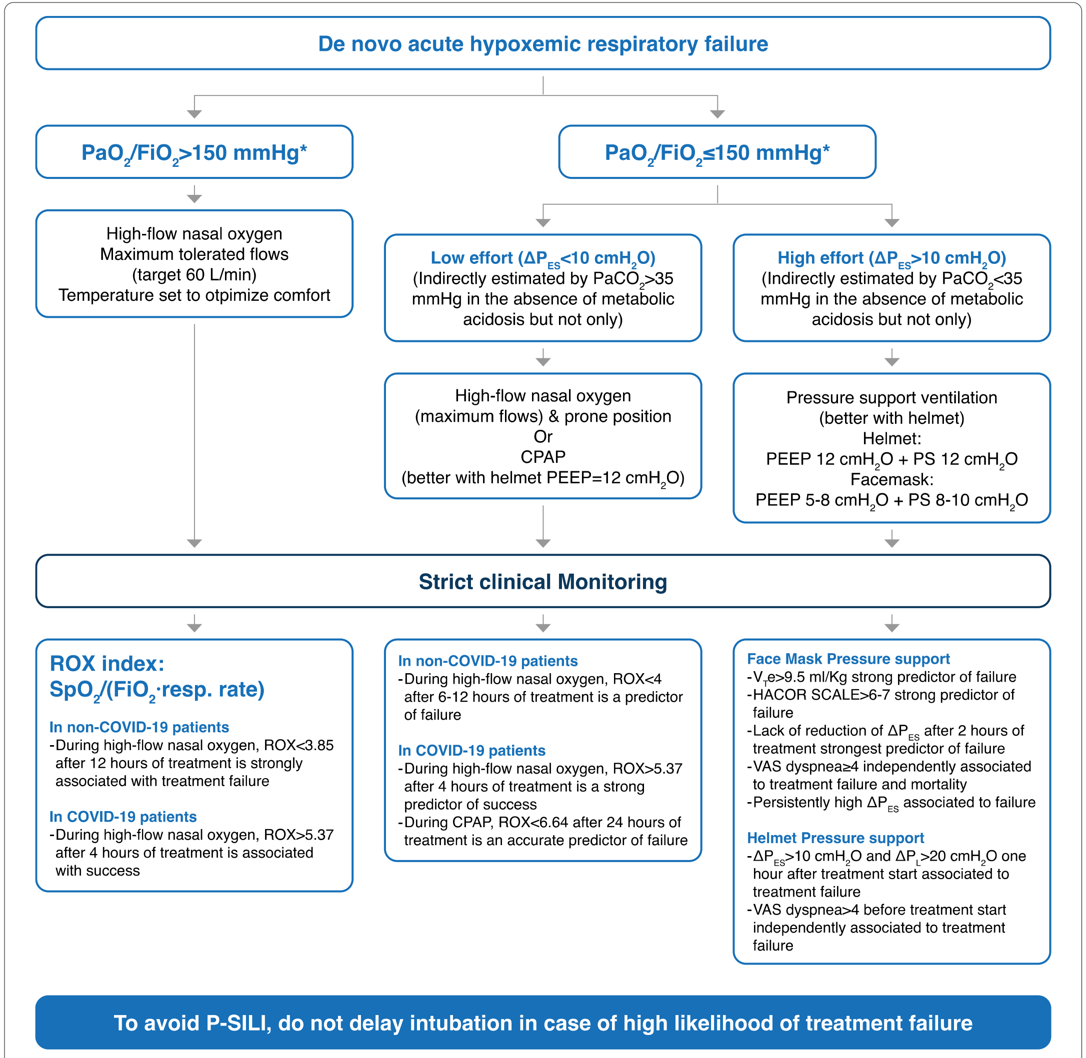
1. Should HFNC or COT be used in patients with acute hypoxaemic respiratory failure?	More evidence is needed to identify patients at high risk of deterioration and therefore more likely to benefit from HFNC. Which treatment (HFNC or COT) results in aerosolisation of infectious particles in COVID-19, and what are the clinical implications of this?
2. Should HFNC or NIV be used in patients with acute hypoxaemic respiratory failure?	More evidence is needed to assess the impact of HFNC *versus* NIV in COVID-19 and other viral illnesses, as well as in patients at different risk of induced lung injury and different P_{aO_2}/F_{iO_2} ratio severity. More evidence is needed regarding effectiveness of HFNC *versus* NIV in both helmet and facemask forms. Which treatment (HFNC or COT) results in aerosolisation of infectious particles in COVID-19, and what are the clinical implications of this?

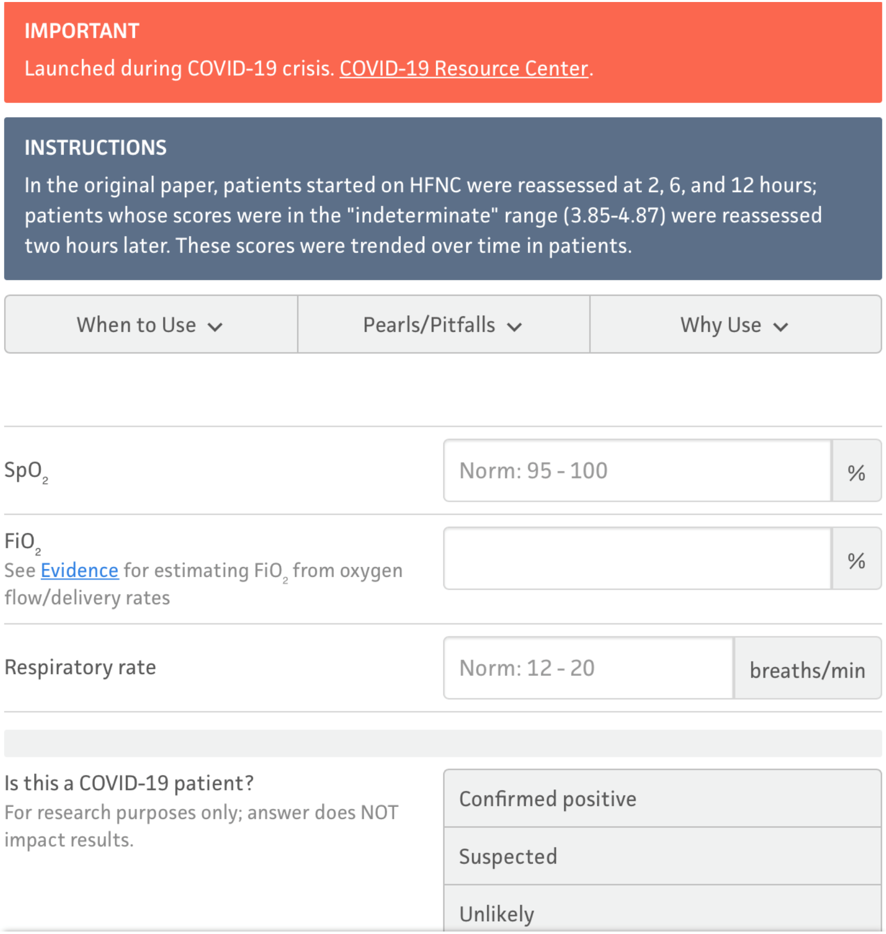
Intensive Care Med
https://doi.org/10.1007/s00134-023-07048-1

EDITORIAL

Personalized noninvasive respiratory support for acute hypoxemic respiratory failure

Domenico Luca Grieco[1,2*], Laveena Munshi[3,4] and Lise Piquilloud[5]





ROX index

Predictors of intubation

ROX defined as the ratio of SpO2/FIO2 to respiratory rate for determining HFNT outcome (need or not for intubation).

ROCA O et al AJRCCM 2018

Duan *et al. Ann. Intensive Care* (2019) 9:108
https://doi.org/10.1186/s13613-019-0585-9

Annals of Intensive Care

RESEARCH Open Access

Early prediction of noninvasive ventilation failure in COPD patients: derivation, internal validation, and external validation of a simple risk score

Jun Duan[1*†], Shengyu Wang[2†], Ping Liu[3†], Xiaoli Han[1], Yao Tian[2], Fan Gao[2], Jing Zhou[2], Junhuan Mou[3], Qian Qin[3], Jingrong Yu[3], Linfu Bai[1], Lintong Zhou[1] and Rui Zhang[1]

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

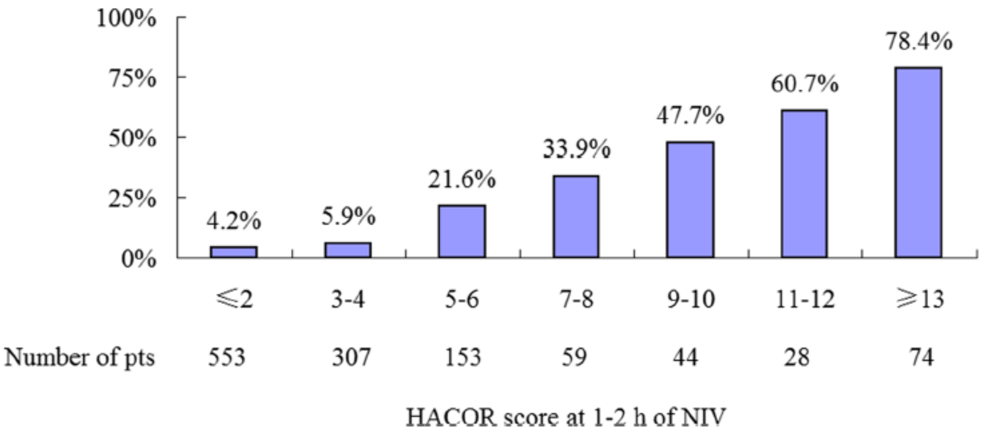


Fig. 2 NIV failure rates in patients with different HACOR scores. *Pts* patients, *NIV* noninvasive ventilation, *HACOR* heart rate, acidosis, consciousness, oxygenation, and respiratory rate

In all patients with HACOR score > 5, the NIV failure rate was 50.2%.

Take home messages

Combined effects of **high ΔP_{ES}**, high ΔP_L, high V_T and pendelluft may genatrate **P-SILI**
Spontaneous breathing may be dangerous in case $PaO_2/FiO2<200$ and thus strict monitoring of inspiratory Effort is needed
In nonintubated patients, monitor inspiratory effort and response to interventions.
Signs of high inspiratory effort-increased risk of failure are:

-VT>9 ml/kg

-ΔPes>10 cmH2O

-Pocc (inspiratory effort)>13-15 cmH2O

-P0.1 (respiratory drive)>4 cmH2O

courtesy of D.Grieco

-$PaCO_2$<35 mmHg

-VAS dyspnea>4