108 年機械通氣重症繼續教育課程(北區)

NON-INVASIVE VENTILATION (INCLUDING HIGH FLOW NASAL CANNULA)

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Outline

- **NIV: past , Present**
- Basic principles of ventilators :mode and setting
- Indications and patient s selection
- Choosing the interface
- Humidification and aerosol therapy in NIV
- Monitoring in acute NIV
- Patient-ventilator asychrony
- Complications of NIV
- Guideline introduction

Figure 2. Multitier iron lung used in poliomyelitis epidemics. Reproduced from Kacmarek (2011) Respir Care; *56: 1170–1180 with permission from the publisher.*

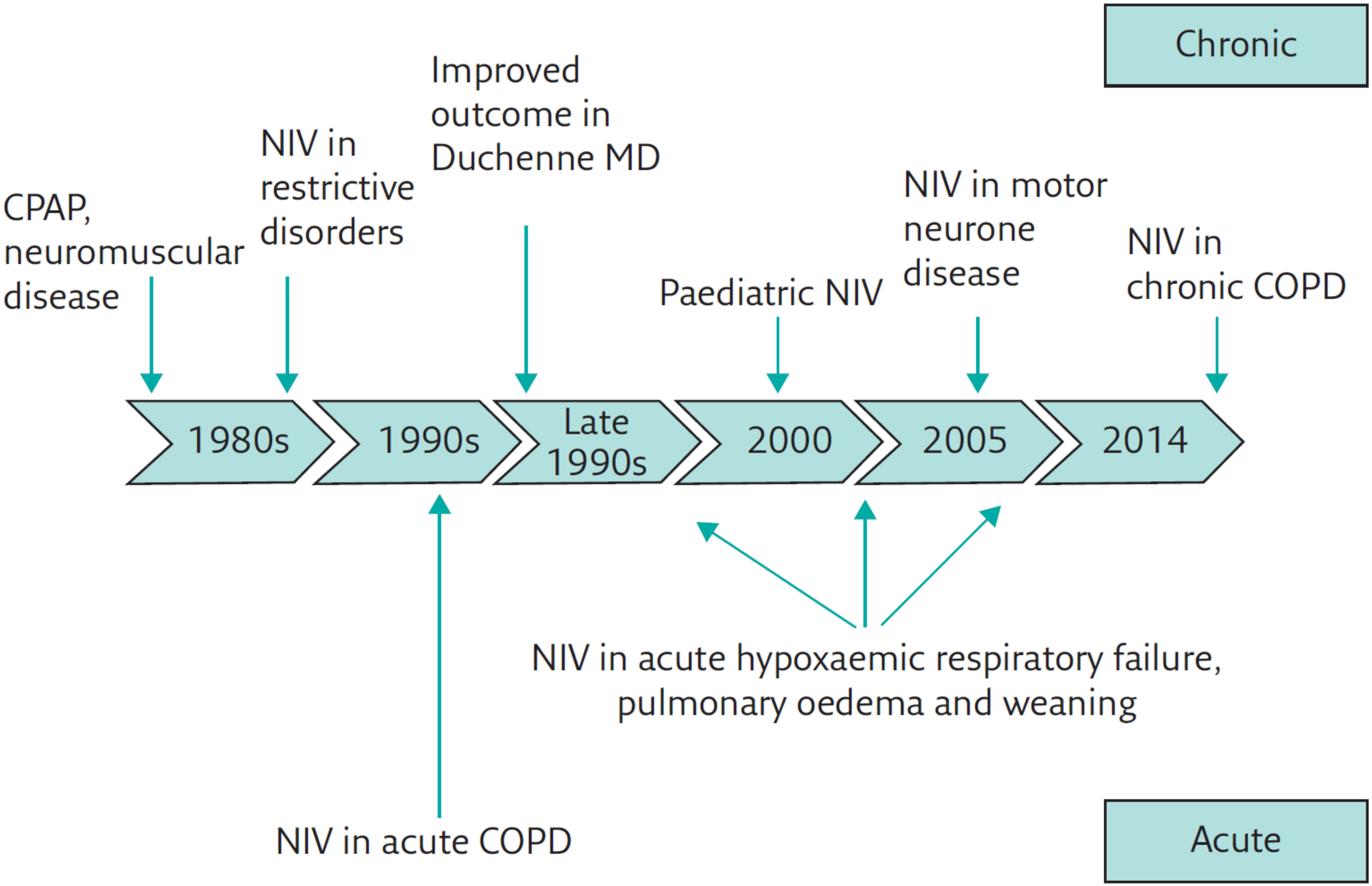

Figure 3. Timeline of developments in NIV from the 1980s to the present day. MD: muscular dystrophy.

Fig. 1. A patient with COPD using noninvasive ventilation in addition to supplemental oxygen. (From Reference 51, with permission.)

Respiration 2009;78(2):154-160.

Noninvasive mechanical ventilation in acute respiratory failure: trends in use and outcomes

- 1997年至2011年期間需要通氣支持急性呼吸衰竭的重症患者的多中心數據庫研究(法國,14 ICU)
- 在3,163例患者中，1,232例（39%）接受了NIV。
- 第一線使用NIV從29%增加到42%，NIV成功率從69%增加到84%。
- 與第一線插管相比，第一線使用NIV有更好的60天存活率和更少的ICU院內感染。
- NIV在acute-on-chronic respiratory failure 和 immunocompromised的患者有存活益處

Intensive Care Med. 2014 Apr;40(4):582-91

Current Status of Noninvasive Ventilation Use in Korean Intensive Care Units: A Prospective Multicenter Observational Study.

- **20 ICUs** of university hospitals from June 2017 to February 2018
- **156 patients** treated with NIV were enrolled (mean age, 71.9±11.6 years)
- **Acute hypercapnic respiratory failure** and **post-extubation respiratory failure** were the most common indications
- The main device for NIV was an **invasive mechanical ventilator with an NIV module (61.5%)**
- majority of patients (87.2%) used an **oronasal mask**
- Overall NIV success was achieved in **68.5% of** patients, with the lowest rate in patients with *de novo* respiratory failure(27.3%)
- ICU and hospital mortality rates were **8.9% and 15.3%**

Tuberc Respir Dis (Seoul). 2019 Feb 28.

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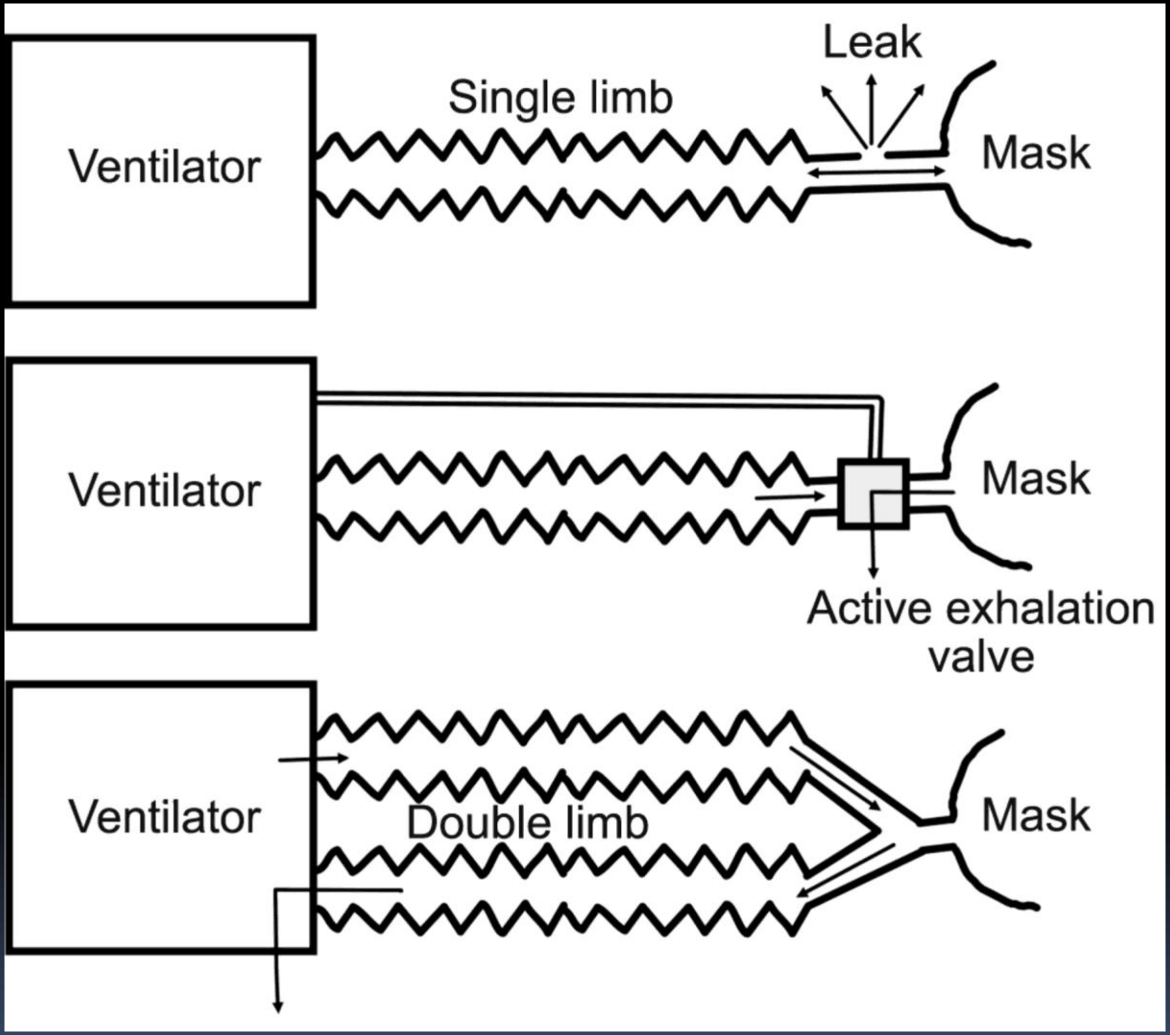
Types of NIV

- **Negative pressure NIV**
  - Main means of NIV during the 1st half of the 20th century
  - Extensively used during polio epidemics
  - **Tank ventilator "iron lung"**
  - **Cuirass, Jacket ventilator,** Hayek oscillator
- **Positive pressure NIV**
  - Positive pressure delivered through mask
  - **CPAP & BiPAP**

Ventilators for NIV

- **Volume controlled home ventilators**
  - First machines to be used
  - Limited ability to compensate for leaks
- **Bilevel ventilators**
  - Most commonly used
  - EPAP & IPAP
  - Single limb circuit
  - Good efficiency & leak compensation
- **ICU ventilators**
  - Limited leak compensation

Circuit configurations for noninvasive ventilation.



Dean R Hess Respir Care 2013;58:950-972

Table 2. A comparison of ventilator designs for NIV.

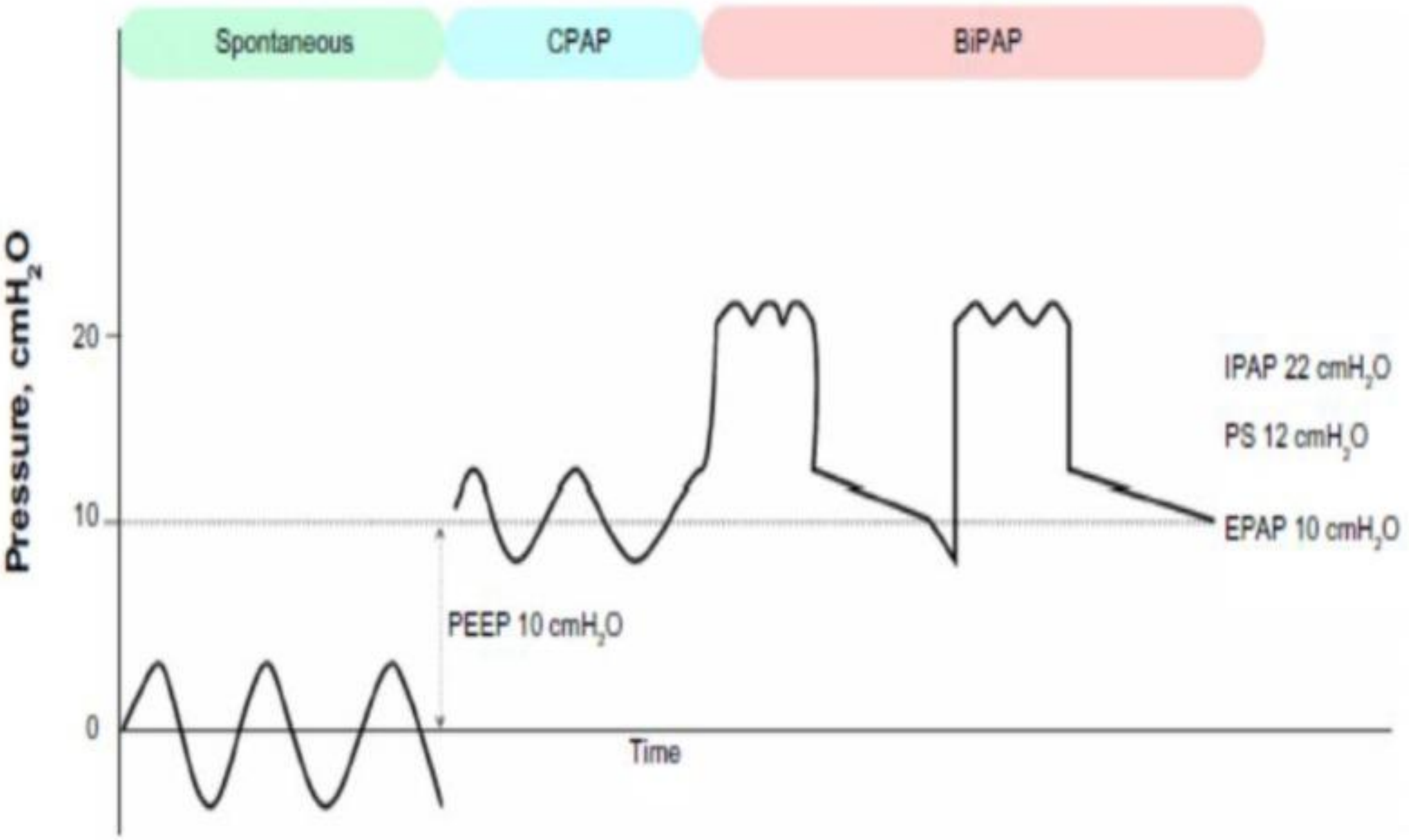
Design	Description
Bilevel ventilator	Bilevel ventilators use internal blowers to generate flow through a single limb circuit during both inhalation and exhalation. A passive leak port, either in the circuit or the interface, is open throughout the respiratory cycle. An active exhalation valve is not needed because the exhaled gas passes through the leak port.
Intermediate ventilator	These ventilators are most commonly used for patient transport or home care ventilation. They utilize a single limb circuit with either an active exhalation valve near the patient or a passive leak port. In the past, these devices have been leak intolerant. However, newer designs offer leak compensation.

	compensation.
Critical care ventilator without NIV mode	In the past, critical care ventilators were designed primarily for invasive ventilation. As such, they were leak intolerant. Although these ventilators have been used for NIV, the absence of leak compensation often resulted in asynchrony and much clinician time and effort to minimize leak.
Critical care ventilator with NIV mode	Newer generation critical care ventilators have NIV modes, with dual limb circuits that separate the inspiratory from expiratory gases. NIV modes offer leak compensation, but the ability of the ventilator to compensate for leaks varies among manufacturers. Additional embellishments available from some manufactures include an adjustable flow termination and a maximum inspiratory time during pressure support, both of which improve synchrony with pressure support in the presence of leak. Some manufactures also provide leak compensation in all modes, including

Modes of NIV

- **Pressure modes**
  - Better tolerated than volume-cycled vents
  - Constant positive airway pressure **(CPAP)**
  - Bilevel or biphasic positive airway pressure **(BiPAP)**
  - Pressure support ventilation **(PSV)**
- **Volume modes**
  - Initial tidal volumes range from 10 to 15 mL/kg
  - **Control**
  - **Assist control**
  - **Proportional assist control**

Pressure/time curves in spontaneous, continuous positive airway pressure (CPAP) and BiPAP



Ventilator Modes and Settings for NIV

- In an epidemiologic survey conducted in the US, over **90%** of NIV applications used bilevel type pressure-limited ventilators
- only 5% used critical care ventilators.

Chest 2014: 145(5): 964-971.

Continuous positive airway pressure (CPAP)

- a single selected pressure applied via a noninvasive interface to the upper airway.
- mainly for cardiogenic pulmonary edema or prophylactically for postoperative patients.
- disadvantage of CPAP is that it provides **no active respiratory assistance** during inspiration,

Bilevel positive airway pressure (bilevel NIV)

- consists of a higher inspiratory pressure (IPAP) and lower expiratory pressure (EPAP).
- When treating patients with **hypoxemic respiratory failure,** higher pressures may be necessary
- as **higher EPAP is used to improve oxygenation** and higher pressure support to increase tidal volume and reduce dyspnea.

Pressure support ventilation (PSV)

- similar to bilevel NIV but is provided on **critical care ventilators** or a few dedicated NIV ventilators.
- Ventilator settings in PSV are essentially the same as with bilevel NIV
- terminology is different; EPAP equals PEEP, but **IPAP equals pressure support plus PEEP**.

Pressure Control Ventilation (PCV)

- flow triggered and uses preset inspiratory and expiratory pressures
- PCV is the same as with PSV, but **inspiratory time is set** using absolute time or an I:E ratio.
- improve expiratory synchrony when inspiratory pressure is prolonged in the face of **air leaks**
- or a delayed drop in inspiratory flow as may be seen in COPD patients.

Average Volume Assured Pressure Support (AVAPS)

- automatically adjust **inspiratory airway** pressure to achieve a target tidal volume.
- sets a target tidal volume, range of inspiratory pressures, EPAP and a backup rate

Volume-targeted modes

- set tidal volumes of 6 - 8 mL/kg PBW.
- chief limitation of volume-targeted modes has been an **inability to compensate for leaks**
- possible **auto-cycling** as the persisting leak triggers **premature breaths.**

Practical advice for the application of NIV in patients with acute respiratory failure

Crit Care Clin. 2018 Jul;34(3):395-412.

Considerations in the Selection of a Ventilator for Noninvasive Ventilation

Leak compensation
Trigger and cycle coupled to patient's breathing pattern
Rebreathing
Oxygen delivery (acute care)
Monitoring
Alarms (safety vs nuisance)
Portability (size, weight, battery)
Tamper-proof
Cost

(Data from reference 114.)

Respir Care 2012;**57**(6):900-918; discussion 918-920

Protocol for initiation of noninvasive positive pressure ventilation

1. Appropriately monitored location, oximetry, respiratory impedance, vital signs as clinically indicated
2. Patient in bed or chair at >30-degree angle
3. Select and fit interface
4. Select ventilator
5. Apply headgear; avoid excessive strap tension (one or two fingers under strap)
6. Connect interface to ventilator tubing and turn on ventilator
7. Start with low pressure in spontaneously triggered mode with backup rate; pressure limited: 8 to 12 cmH_2O inspiratory pressure; 3 to 5 cmH_2O expiratory pressure
8. Gradually increase inspiratory pressure (10 to 20 cmH_2O) as tolerated to achieve alleviation of dyspnea, decreased respiratory rate, increased tidal volume (if being monitored), and good patient–ventilator synchrony
9. Provide O_2 supplementation as needed to keep O_2 saturation >90 percent
10. Check for air leaks, readjust straps as needed
11. Add humidifier as indicated
12. Consider mild sedation (eg, intravenously administered lorazepam 0.5 mg) in agitated patients
13. Encouragement, reassurance, and frequent checks and adjustments as needed
14. Monitor occasional blood gases (within 1 to 2 hours) and then as needed

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Evidence-based indications for noninvasive positive-pressure ventilation (NPPV)

Stage of ARF

Likelihood of NPPV success		Not established	Mild-moderate (early)	Severe (late)
	High	• Extubation failure in high-risk hypercapnic patients (*i.e.* COPD)	• COPD exacerbations • Immunocompromised patients • ACPE	• Weaning from invasive ventilation (only COPD)
	Moderate	• Post-abdominal surgery	• Post-operative lung resection • Fibre-optic bronchoscopy • Do-not-intubatate order • Chest trauma • CAP	• COPD exacerbations • Pre-intubation oxygenation
	Low	• COPD exacerbations	• Extubation failure • Hypoxaemic (ARDS) • Asthma exacerbations	• Hypoxaemic (ARDS/CAP) • Do-not-intubate order
	Goals of NPPV	To prevent ARF	To prevent intubation	Alternative to invasive ventilation

Goals of NPPV

Eur Respir Rev. 2018 Jul 11;27(149)

Indications for NIV

Acute NIV

- COPD Exacerbation
- Cardiogenic Pulmonary Edema
- Weaning ventilator and Post-Extubation
- Immunocompromised Patients
- ARDS
- Acute Asthma
- Community-Acquired Pneumonia
- Palliative care and at the end of life
- Pre-oxygenation Before Intubation
- Post-Operative Respiratory Failure
- Obesity Hypoventilation Syndrome
- Bronchoscopy

Long term NIV

- Neuromuscular disorders
- Sleep apnea
- Motor neurone disease/ALS
- Chest wall disorders
- Chronic COPD

Fig. 2. Bronchoscope inserted through the swivel adaptor of a face mask for noninvasive ventilation. (From Reference 88.)

Respir Care 2012;**57**(11):1927-1936

Contraindications of NIV

- Coma, seizures, or severe central neurologic disturbances**(例外:hypercapnic encephalopathy)**
- Inability to protect the airway or clear respiratory secretions
- Unstable hemodynamic conditions (blood pressure or rhythm instability)
- Upper airway obstruction
- Severe upper gastrointestinal bleeding
- Recent facial surgery, trauma, burns, deformity, or inability to fit the interface
- Recent gastroesophageal surgery
- Undrained pneumothorax
- Recurrent vomiting

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Desirable Characteristics of an Interface for Noninvasive Ventilation.

Low dead space
Transparent
Lightweight
Easy to secure
Adequate seal with low facial pressure
Disposable or easy to clean
Non-irritating (non-allergenic)
Inexpensive
Variety of sizes
Adaptable to variations in facial anatomy
Ability to be removed quickly
Anti-asphyxia mechanism
Compatible with wide range of ventilators

(Data from reference 114.)

Dean R Hess Respir Care 2013;58:950-972

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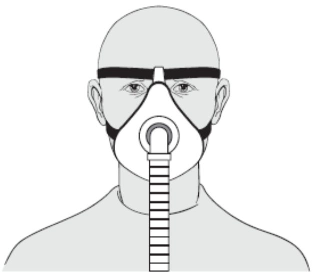
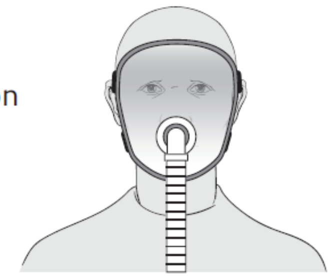


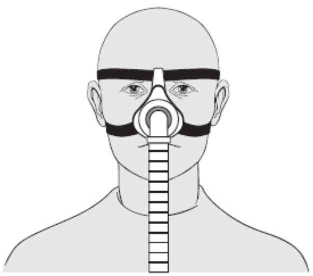
Oronasal mask#

Covers mouth and nose
Special subtype: hybrid masks (a combination of nasal pillows and an oral mask)
With or without forehead spacer



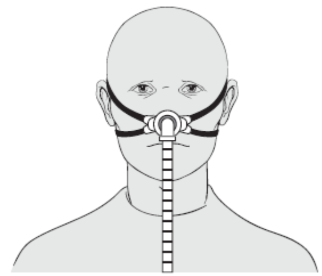
Full face mask#

Also called total face mask, cephalic or integral mask
Covers mouth, nose and eyes and seals around the perimeter of the face



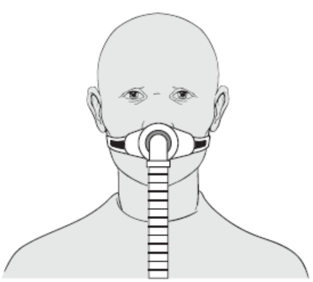
Nasal mask#

Covers the whole nose but not the mouth
With or without forehead spacer



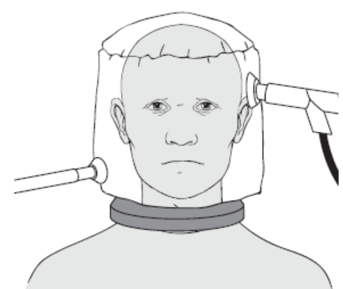
Nasal pillows

Subtype of nasal mask, also nasal plugs or nasal slings
Applied externally to the nares



Oral masks and mouthpieces

Placed between the patient's lips
Mouthpieces have various degrees of flexion and are held in place by a lip seal or the teeth
Oral masks can also have headgear as a securing system



Helmet

Transparent hood with collar
Covers the whole head and all or part of the neck, no contact with the head
Has at least two ports
Most helmets have an anti-asphyxia valve

Figure 1. The six main interface types for NIV. #: available as a vented or non-vented version. Image of the human head by Patrick J. Lynch reproduced from Wikimedia Commons under CC BY 2.5 licence.

ERS Practical Handbook of Noninvasive Ventilation
Edited by Anita K. Simonds 2015

HFNCO

Nasal mask

Oronasal Mask

Crit Care Clin. 2018 Jul;34(3):395-412

Nasogastric tube positioned through the oronasal mask

Full-face mask.

Helmet

Crit Care Clin. 2018 Jul;34(3):395-412

Physiological effects of different interfaces during noninvasive ventilation for acute respiratory failure*

Amanda Tarabini Fraticelli, MD; François Lellouche, MD; Erwan L'Her, MD; Solenne Taillé, BioMedEng; Jordi Mancebo, MD; Laurent Brochard, MD

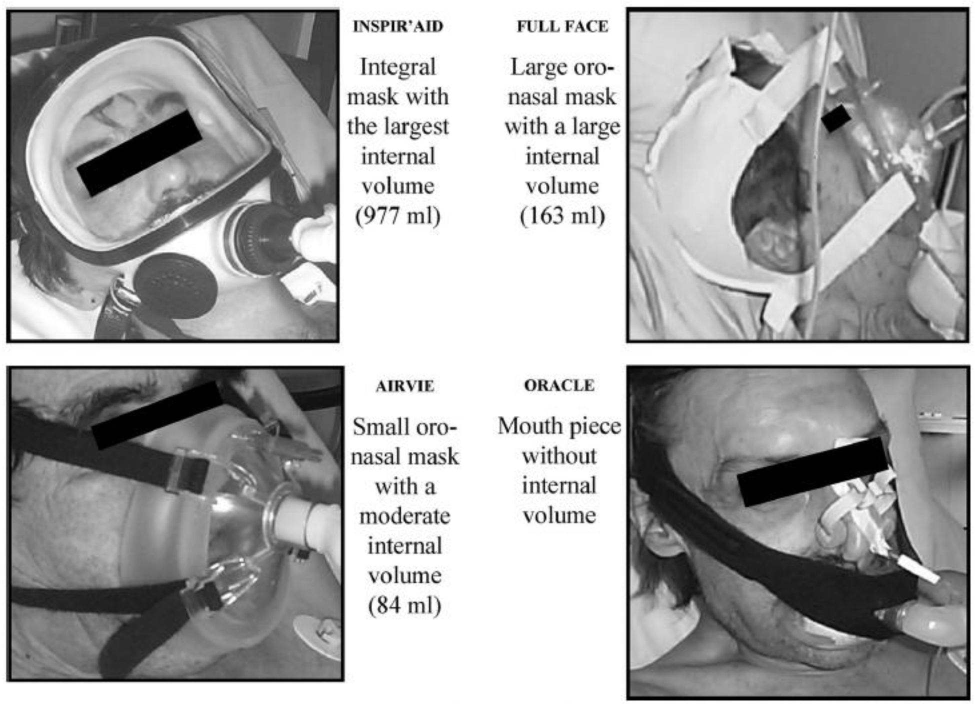


Figure 1. The four different interfaces studied: Inspir'aid (integral mask, 977 mL of internal volume), Full-face (large oronasal mask, 163 mL of internal volume), Airvie (small oronasal mask, 84 mL of internal volume), and Oracle (mouthpiece, no internal volume).

(Crit Care Med 2009; 37:939–945)

Table 2. Indexes of effort and ventilatory parameters in all patients (n = 14), in hypercapnic subgroup (n = 7) and in hypoxemic subgroup (n = 7) at baseline and under noninvasive ventilation with the different interfaces studied (median [25th–75th])

Parameter	Baseline	Inspir'aid Integral Mask	Full Face Large Oronasal Mask	Airvie Small Oronasal Mask	Oracle Mouthpiece	p^a
Work of breathing (J/L)						
All	0.83 (0.63–1.22)	0.59 (0.37–0.72)	0.57 (0.42–0.74)	0.56 (0.49–0.63)	NA	0.29
Hypercapnic	0.66 (0.59–0.91)	0.40 (0.34–0.51)	0.53 (0.38–0.61)	0.53 (0.44–0.56)	0.52 (0.43–0.56)	0.91
Hypoxemic	0.94 (0.83–1.33)	0.65 (0.59–0.81)	0.75 (0.55–0.77)	0.62 (0.54–0.67)	NA	0.25
Pdi (cm H_2O)						
All	11.3 (8.9–15.6)	4.6 (3.4–7.5)	4.4 (2.2–9.8)	5.7 (2.3–8.9)	6.9 (4.8–9.4)	0.96
Hypercapnic	8.3 (5.0–11.5)	3.3 (2.4–4.4)	2.0 (1.5–4.2)	2.2 (1.5–4.2)	4.8 (1.9–0.56)	0.74
Hypoxemic	15.1 (11.3–17.7)	7.5 (6.0–10.4)	9.9 (4.4–12.2)	9.0 (6.2–10.2)	9.7 (6.7–9.9)	0.86
PTPes × RR (cm $H_2O \cdot sec \cdot min^{-1}$)						
All	179 (158–285)	91 (65–143)	105 (76–159)	111 (84–135)	109 (89–159)	0.84
Hypercapnic	158 (132–166)	64 (60–80)	94 (64–98)	82 (81–97)	89 (78–99)	0.75
Hypoxemic	257 (192–330)	145 (112–166)	166 (120–173)	136 (126–159)	140 (104–172)	0.61
RR (breath/min)						
All	27 (22–31)	24 (19–30)	26 (20–32)	25 (19–33)	23 (20–28)	0.29
Hypercapnic	22 (20–29)	20 (18–26)	23 (19–32)	19 (19–26)	23 (21–25)	0.15
Hypoxemic	29 (27–31)	26 (24–31)	27 (23–31)	27 (25–33)	27 (19–30)	0.24
V_F min (L/min)						
All	9.7 (7.7–17.7)	11.7 (8.9–16.3)	11.1 (8.3–16.2)	9.9 (6.4–17.0)	NA	0.14
Hypercapnic	8.4 (5.7–9.5)	10.1 (9.2–11.7)	9.4 (7.0–11.0)	6.5 (6.0–10.3)	8.3 (6.8–8.9)	0.36
Hypoxemic	18.5 (12.5–21.9)	16.3 (12.3–20.7)	16.0 (13.2–19.2)	17.3 (9.9–18.5)	NA	0.28
PEEPi (cm H_2O)						
All	0.2 (0.1–0.5)	0.4 (0.1–0.5)	0.4 (0.1–0.6)	0.3 (0.1–0.8)	0.1 (0.1–0.4)	0.05
Hypercapnic	0.1 (0.1–0.2)	0.1 (0.1–0.4)	0.2 (0.1–0.5)	0.2 (0.1–0.4)	0.2 (0.1–0.4)	0.74
Hypoxemic	0.5 (0.3–1.2)	0.5 (0.4–1)	0.6 (0.3–0.9)	0.4 (0.3–0.9)	0.1 (0.0–0.5)	0.12

ΔPdi, tidal swings in transdiaphragmatic pressure; PTPes, esophageal pressure-time product; RR, respiratory rate; V_E, minute ventilation; PEEPi, intrinsic positive end-expiratory pressure; NA, not available because of excessive leaks.

The statistical comparisons concern the differences between the interfaces during noninvasive ventilation.

^{a}p values for the Friedman non-parametric test; comparisons with baseline are not shown in the table.

(Crit Care Med 2009; 37:939–945)

Table 4. Asynchronies, leaks, and comfort in all patients (n = 14) under noninvasive ventilation with the different interfaces studied (median [25th–75th])

	Inspir'aid Integral Mask	Full Face Large Oronasal Mask	Airvie Small Oronasal Mask	Oracle Mouthpiece	p^a
Asynchronies (/10 min)	2 (0–7)	4 (0–21)	1 (0–5)	12 (1–70)	0.04
Leaks (%)	18 (12–44)	31 (22–60)	34 (18–45)	68 (50–73)	0.0001
Comfort Visual Assessment Score (0–10)	6 (5–8)	5 (3–5)	5 (4–7)	2 (0–5)	0.02

[a] p values for the Friedman nonparametric test; comparison with baseline are not shown in the table.

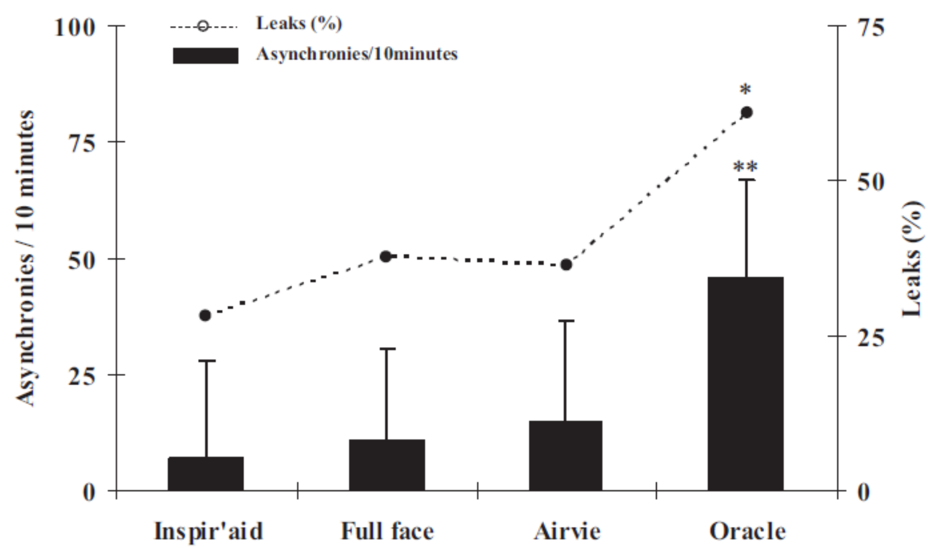


Figure 2. Comparison of the effects of noninvasive ventilation with the different studied interfaces on the percentage of leaks and the frequency of patient-ventilator asynchronies during a 10-minute period. The percentage of leaks [$100 \times (V_{ti}-V_{te})/V_{ti}$] was significantly larger with the mouthpiece than with the other interfaces (*$p < 0.0001$). The frequency of patient-ventilator asynchronies was also significantly more important with the mouthpiece (**$p = 0.04$). There were no differences in the percentage of leaks or in the frequency of asynchronies amo

(Crit Care Med 2009; 37:939–945)

Measurements and Main Results: Despite differences in internal volume, no apparent dead space effect was observed on minute ventilation, work of breathing, or arterial CO_2 levels. Compared with baseline, NIV was uniformly successful in reducing indexes of respiratory effort: the pressure–time product of the respiratory muscles decreased from a median (25th–75th interquartile range) of 179 (158–285) cm $H_2O \cdot sec \cdot min^{-1}$ to values between 91 and 111 during NIV, with no differences between masks ($p = 0.84$). Few differences were observed in terms of arterial blood gases and breathing pattern. Leaks and patient-ventilator asynchronies were greater with the mouthpiece, and comfort with this interface was deemed poor for most patients.

Conclusion: The internal volume of the masks had no apparent short-term dead space effect on gas exchange, minute ventilation, or patient's effort, suggesting that, with the exception of mouthpiece, interfaces may be interchangeable in clinical practice provided adjustment of the ventilatory device parameters are performed. (Crit Care Med 2009; 37:939–945)

Oronasal VS nasal mask

- 口鼻面罩應該是高碳酸血性急性呼吸衰竭初始治療的第一線策略（鼻罩組氣漏較大）
  ------ Girault，Crit Care Med2009; 37（1）：124-131
- 鼻面罩的耐受性低於口鼻面罩
  ------ Kwok H，Crit Care Med2003; 31（2）：468-473。
- COPD急性發作使用口鼻面罩的呼吸速率有較大的下降，其他沒有差異。
  ----- Anton A，Respir Care2003; 48（10）：922-925。

- 通過口腔洩漏常見於鼻罩。 這會影響舒適度，導致口乾和通氣效率降低，影響 patient-ventilator interaction (trigger and cycle) ，擾亂睡眠結構
----- Respir Care2011; 56（2）：153-165
- 吸入性肺炎是口鼻面罩的可能風險，但這種情況較少見
------ Eur Respir J 2004; 23（4）：605-609

Oronasal mask VS Total face mask

- total face mask was more comfortable than the oronasal mask and suggested that the total face mask should be available as an option in units where NIV is routinely applied
----- Respiration2011;**82**(5):426-430.
- total face mask avoided pain on the bridge of the nose and presented no air leaks around the eyes and mouth
---- J Bras Pneumol2009;**35**(2):164-173.

Helmit

- Helmit有一個透明的罩子和柔軟的邊緣，密封在頸部.頭盔有兩個端口，一個通過氣體進入，另一個通過氣體排出，並通過腋帶固定在患者身上。美國食品和藥物管理局尚未認可任何可用頭盔，但它們已在其他一些國家獲得批准，並且在歐洲和南美洲的某些地方很受歡迎

Respir Care 2009;**54**(1):71-84

Critical Care
2004 9:98

- Helmit的體積大於潮氣量，其中吸入的CO2分壓的增加是重要的問題。
- 頭盔中的PCO2取決於患者呼出的二氧化碳量以及沖刷頭盔的新鮮氣體流量.
- 需要高氣流**（40-60升/分鐘）**來降低二氧化碳分壓。
- 與口鼻面罩相比，Racca發現使用頭盔傳遞PSV會增加吸氣肌力和異步性，呼吸困難加重。
- Costa等比較氣管內管和口鼻面罩或頭盔作為界面。他們發現，氣管插管的患者 – 呼吸機同步性明顯優於面罩或頭盔。他們還發現**頭盔導致更差的同步性**。

J Appl Physiol 2005;**99**(4):1262-1271.
Intensive Care Med 2008;**34**(6):1102-1108

- 應用NIV治療急性呼吸衰竭，界面的首選應該是**口鼻面罩**。
- 現有證據表明，**全面罩**可能也是合理首選。
- 如果患者不能忍受口鼻面罩或全面罩，或者出現面部皮膚破裂等併發症，則應提供其他介面。
- 美國和歐洲的調查結果表明，臨床醫生最常使用**口鼻面罩**治療急性呼吸衰竭患者

Respir Care 2009;**54**(10):1306-1312
Eur Respir J 2010;**36**(2):362-369.

Advantages and Disadvantages of Various Interfaces for NIV

Interface	Advantages	Disadvantages
Nasal mask	Less risk for aspiration Easier secretion clearance Less claustrophobia Easier speech May be able to eat Easy to fit and secure Less dead space	Mouth leak Higher resistance through nasal passages Less effective with nasal obstruction Nasal irritation and rhinorrhea Mouth dryness
Oronasal mask	Better oral leak control More effective in mouth breathers	Increased dead space Claustrophobia Increased aspiration risk Increased difficulty speaking and eating Asphyxiation with ventilator malfunction
Mouthpiece	Less interference with speech Very little dead space May not require headgear	Less effective if patient cannot maintain mouth seal Usually requires nasal or oronasal interface at night Potential for orthodontic injury
Total face mask	May be more comfortable for some patients Easier to fit (one size fits all) Less facial skin breakdown	Potentially greater dead space Potential for drying of the eyes Cannot deliver aerosolized medications
Nasal pillows	Advantages of nasal mask, but more comfortable Less risk of facial skin breakdown than nasal mask	Same as nasal mask

Respir Care 2012;57(6):900–918.

Table 2. Comparison of oronasal# and nasal masks

Aspect	Oronasal mask	Nasal mask
Mouth leak	No	Yes
Mouth breathing	Possible	Decreases NIV quality
Dead space	Higher	Low
First choice interface	Acute care	Chronic care
Communication	Reduced	Possible
Eating and drinking	No	Possible
Expectoration	No	Possible
Risk of aspiration	Elevated	Reduced
Risk of aerophagia	Elevated	Reduced
Claustrophobia	Elevated	Reduced
Comfort	Lower	Higher

#: sometimes also known as facial or face masks. Reproduced and modified from Storre *et al.* (2008), with permission from the publisher.

Table 2. Characteristics of the different interfaces

	Oronasal mask	Total face mask	Helmet	Nasal mask	Nasal prongs	Mouth pieces
Acute setting	●	●	●	○	○	○
Use outside HDU/ICU	●	●		●	●	●
Chronic setting	●	●		●	●	●
Less claustrophobic		○	○	●	●	●
More likely to have leaks in the acute setting	●			●	●	●
Nasal patency required				●	●	
Coughing and expectoration is easier				●	●	
Useful for prominent facial anatomy		●	●		●	●
High level of noise			●			
No pressure on the nasal bridge		●	●		●	●
High gas flow required			●			
Chance of eye irritation	●	○	○	●		
Speaking is easier			●	●	●	

HDU: high-dependency unit; closed circles: applicable to the interface; open circles: an alternative, but less common or less frequent option. Reproduced and modified from Brill (2014) with permission from the publisher.

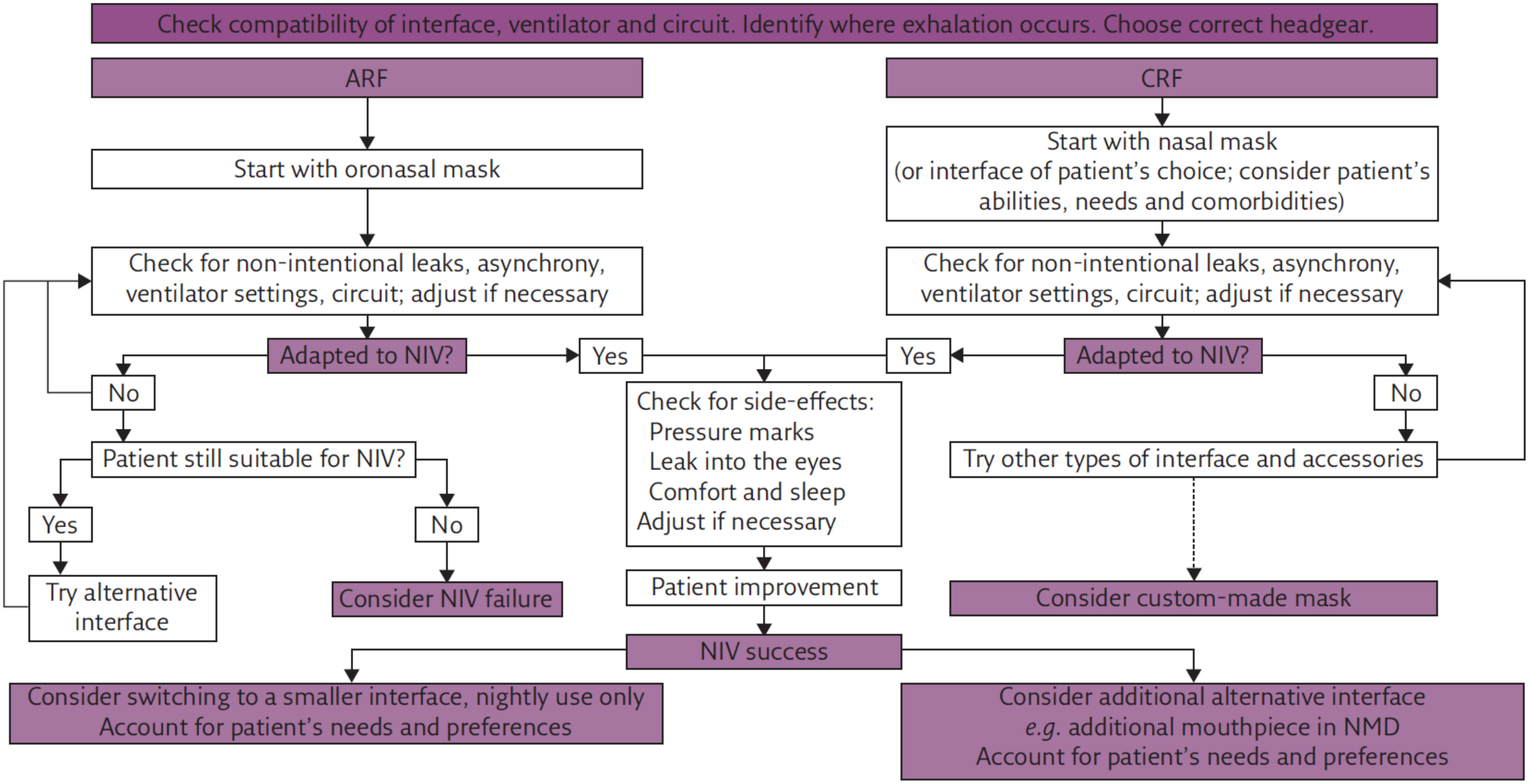


Figure 2. Interface strategies for NIV in adult patients with ARF and chronic respiratory failure (CRF). NMD: neuromuscular disease.

ERS Practical Handbook of Noninvasive Ventilation
Edited by Anita K. Simonds 2015

Outline

- NIV: past , Present
- Basic principles of ventilators :mode and setting
- Indications and patients selection
- Choosing the interface
- **Humidification and aerosol therapy in NIV**
- Monitoring in acute NIV
- Patient-ventilator asychrony
- Complications of NIV
- Guideline introduction

Humidification

- 在nasal mask的口腔洩漏的情況下，單向氣體流動會干燥上呼吸道並增加鼻氣道阻力。
- 上呼吸道乾燥會導致不適並可能影響NIV的耐受性.
- 加濕水平不需要與插管患者一樣大；在約30℃下**100%的相對濕度**通常是足夠的
- 不推薦使用heat and moisture exchanger與NIV一起使用，因為額外的死腔會減少二氧化碳的排除，特別是對於高碳酸血症患者

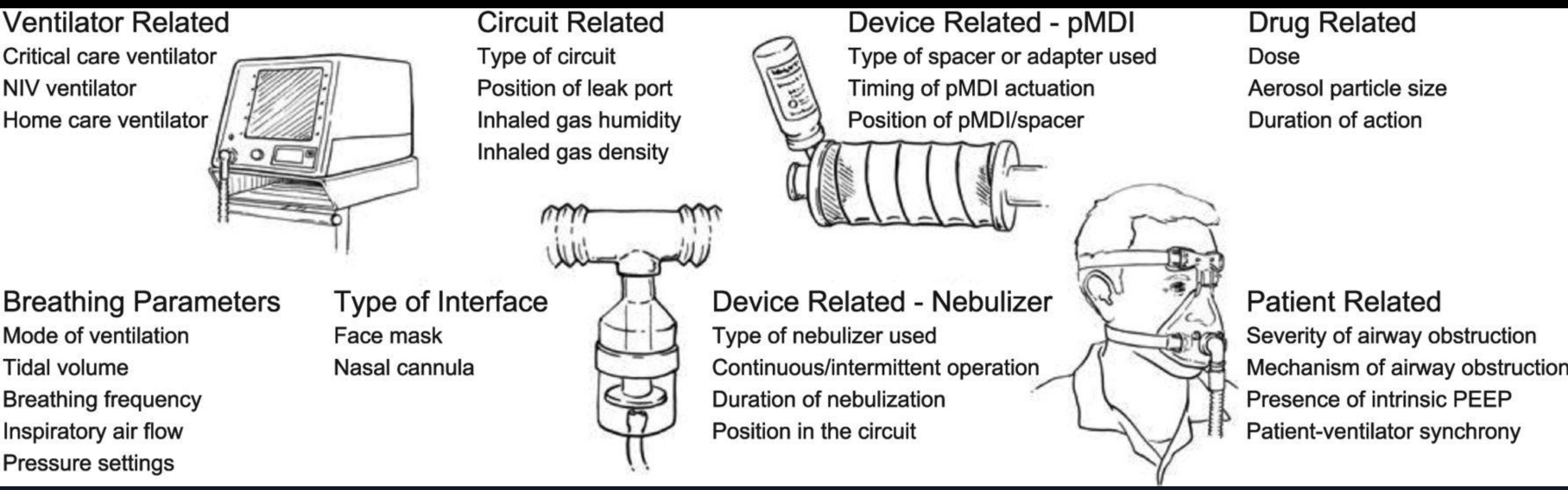
Respir Care2010;**55**(2):209-216

Inhaled aerosol therapy

- 接受NIV的阻塞性肺病患者可受益於吸入性支氣管擴張劑治療
- Aerosol therapy可以通過pressurized metered-dose inhaler with a spacer or nebulizer有效地傳遞.
- 患者也可以中斷NIV ，並以常規方式給予吸入藥物
- Galindo-Filho報導，儘管在哮喘急性發作期間nebulization並未改善radio-aerosol肺部沉積，但確實導致了這些患者肺功能的臨床改善。

Respir Care 2013;58(2):241-249

Factors influencing aerosol delivery during noninvasive ventilation (NIV). pMDI = pressurized metered-dose inhaler.



Dean R Hess Respir Care 2013;58:950-972

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Risk Factors for Noninvasive Ventilation Failure

Acute hypercapnic respiratory failure
- Poor neurologic score: Glasgow Coma Score < 11
- Tachypnea: > 35 breaths/min
- pH < 7.25
- Acute Physiology and Chronic Health Evaluation score > 29
- Asynchronous breathing
- Edentulous
- Excessive air leak
- Agitation
- Excessive secretions
- Poor tolerance
- Poor adherence to therapy
- No initial improvement within first 2 h of noninvasive ventilation
- No improvement in pH
- Persistent tachypnea
- Persistent hypercapnia

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 P_{aO_2}/F_{IO_2}
- Simplified Acute Physiology Score II > 34
- Failure to improve oxygenation within first hour of noninvasive ventilation: $P_{aO_2}/F_{IO_2} > 175$ mm Hg

(Data from reference 99.)

Dean R Hess Respir Care 2013;58:950-972

Acute NIV monitoring

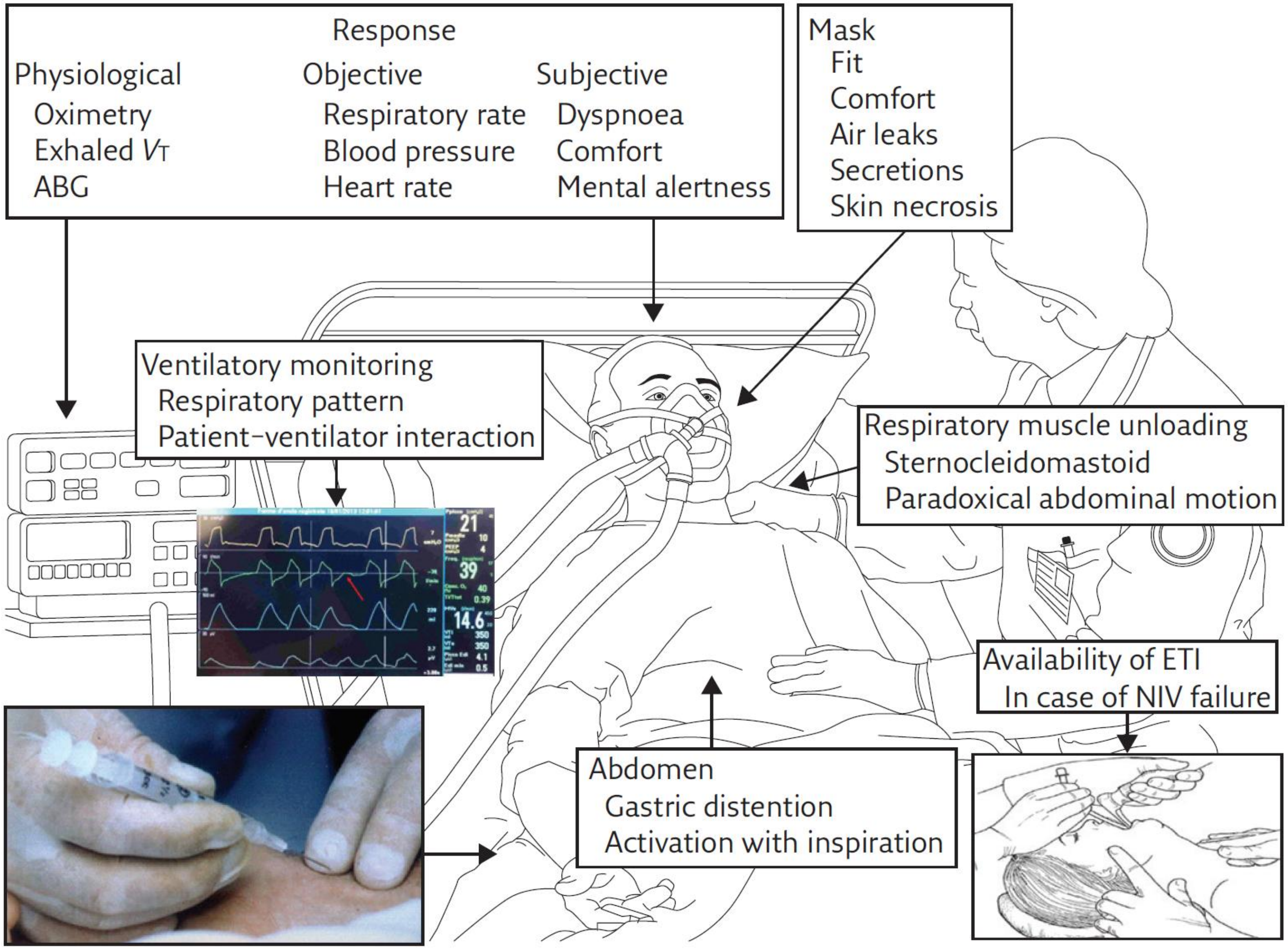

Figure 1. Key points for monitoring of patients undergoing NIV for ARF. ABG: arterial blood gas. Reproduced and modified from Umberto Meduri (1996) Clin Chest Med; *17: 513–553, with permission from the publisher.*

Monitoring of NIV

- . Level of consciousness
- . Comfort
- . Chest wall motion
- . Accessory muscle recruitment
- . Patient-ventilator synchrony
- . Respiratory rate
- . Exhaled tidal volume
- . Flow and pressure waveforms
- . Heart rate
- . Blood pressure
- . Continuous electrocardiography
- . Continuous oximetry
- **. Arterial blood gas at baseline, after 1 hour to 2 hours, and as clinically indicated**

Crit Care Clin. 2018 Jul;34(3):395-412

Criteria used to perform ETI

- . Patient intolerance
- . Inability to improve gas exchange
- . Inability to improve dyspnea or respiratory muscle fatigue
- . Appearance of severe hemodynamic or electrocardiographic instability
- . Severe neurologic deterioration

Crit Care Clin. 2018 Jul;34(3):395-412

Optimal location for NIV

- 需要考慮患者的監測需求
- 單位的監測能力
- 可用的技術和人力資源（護理和呼吸治療）
- 照護者的技能和經驗

- 在許多醫院，NIV在急診室開始，之後患者被轉到ICU。
- 由於ICU床位非常昂貴，許多醫院在普通病房治療NIV的患者。
- 如果病房醫護人員接受了足夠的技術培訓，並且在24小時內都有人支援，通過適當的監測，穩定的患者可在病房照護。
- NIV病人的理想照護位置因國家和醫院而異，具體取決於當地因素。

Eur Respir J2002;**19**(6):1159-1166

Noninvasive Ventilation Outside the Intensive Care Unit From the Patient Point of View: A Pilot Study

Luca Cabrini MD, Elena Moizo MD, Elisa Nicelli MD, Gloria Licini MD, Stefano Turi MD, Giovanni Landoni MD, Paolo Silvani MD, and Alberto Zangrillo MD

- **方法**：採訪在ICU外以NIV成功治療急性呼吸衰竭的患者。
- **結果**：45名患者納入研究。只有20%的人參與了NIV參數的初始設置。超過**40%**的人表示他們從未有過討論NIV治療。**百分之八十從未被要求嘗試其他界面**。所有受試者都知道如何尋求幫助，但只有四分之一的人接受過去除面罩的培訓，22%的受訪者表示如果需要的話根本無法去除面罩。一半的受試者報告說在需要時立即得到了幫助，但15%的受試者等待超過3分鐘。所有受試者均報告併發症，18%報告病情惡化。
- **結論**：受試者報告NIV治療的初始設置參與程度低，與護理人員溝通的滿意度低，以及緊急情況下的安全水平不理想

Respiratory Care May 2012, 57 (5) 704-709

- 大多數患者報告他們從未被要求嘗試另一種界面
- 界面選擇對於患者舒適度和NIV成功至關重要。
- 可能RT對NIV患者照護的時間不足，或缺乏深入了解界面選擇或在不同界面之間轉換的培訓。
- 如果患者對面罩不耐受，很可能導致NIV失敗
- 而用止痛鎮靜，以提高患者耐受NIV ，在普通病房的設置是不安全的
- 大多數受試者表示，他們沒有接受過去除面罩的培訓，或者根本無法將其移除。
- 應注意病人在嘔吐的情況或呼吸器失效時，是否有及時移除呼吸面罩的能力。

如何優化普通病房的NIV治療

- 使用實際NIV設備和全尺寸人體模型培訓參與者相關技能。
- 與患者的良好溝通，花足夠的時間來獲得他/她的合作
- 持續關注他/她的需求，以及選擇最舒適的界面
- 設置最佳通氣參數提高成功率。
- 持續或定期收集患者對NIV治療的看法以及對於NIV的常規數據收集

Checklist at initiation of NIV

First Huddle, at initiation of NIV

	Yes	No
Is NIV being used in lieu of intubation?	☐	☐
Does the patient have hypoxemic respiratory failure? (not related to cardiogenic edema or immunocompromise)	☐	☐
Will the patient be intubated if NIV fails?	☐	☐
Are relative contraindications for NIV present? (altered mental status, airway protection, aspiration risk, copious secretions)	☐	☐
Is patient tolerating NIV poorly/appearing uncomfortable?	☐	☐
Is much coaching required for patient to tolerate NIV?	☐	☐
Will frequent titration of settings be required?	☐	☐
Is patient hemodynamically unstable?	☐	☐
Does patient remain hypoxemic? ($SpO_2 < 92\%$ or $FIO_2 > 0.6$)	☐	☐

A "yes" response to any of the above should prompt consideration of transfer to ICU.

What is the goal for NIV in this patient?

How will we decide if NIV is failing?

What is the alternative if NIV fails?

Has pulmonary medicine been consulted? _____ yes _____ no

(Massachusetts General Hospital)

Checklist after 2 hours of NIV

Second Huddle, after 2 hours of NIV

	Yes	No
Has gas exchange and dyspnea improved in past 2 hours?	☐	☐
Is the goal of NIV being met?	☐	☐
Does patient tolerate removal of the mask for at least 30 minutes?	☐	☐
Is patient tolerating NIV and comfortable?	☐	☐
Is $SpO_2 > 92\%$ and $FIO_2 < 0.6$?	☐	☐
Is patient hemodynamically stable?	☐	☐
Does patient tolerate NIV without excessive coaching?	☐	☐
Is patient stable on IPAP ≤ 15 cm H_2O?	☐	☐

A "no" response to any of the above should prompt consideration of transfer to the ICU.

Will patient be moved to ICU? _____ yes _____ no

If no, has pulmonary medicine been consulted? _____ yes _____ no

Has the medical attending been notified? _____ yes _____ no

(Massachusetts General Hospital)

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Patient-ventilator asynchrony

- NIV失敗率（需要插管）可能高達40%。其中一些失敗可能與**asynchrony**有關。
- 在一項研究中，43%的受試者在NIV期間發生了高比率的**asynchrony** 。
- NIV期間**Patient-ventilator asynchrony**與潛在的疾病過程和**air leak**的存在有關
- 減少與接面的**air leak**並使用具有良好**air leak**補償的呼吸器可降低**Patient-ventilator asynchrony**

Respir Care2011;**56**(2):153-165;

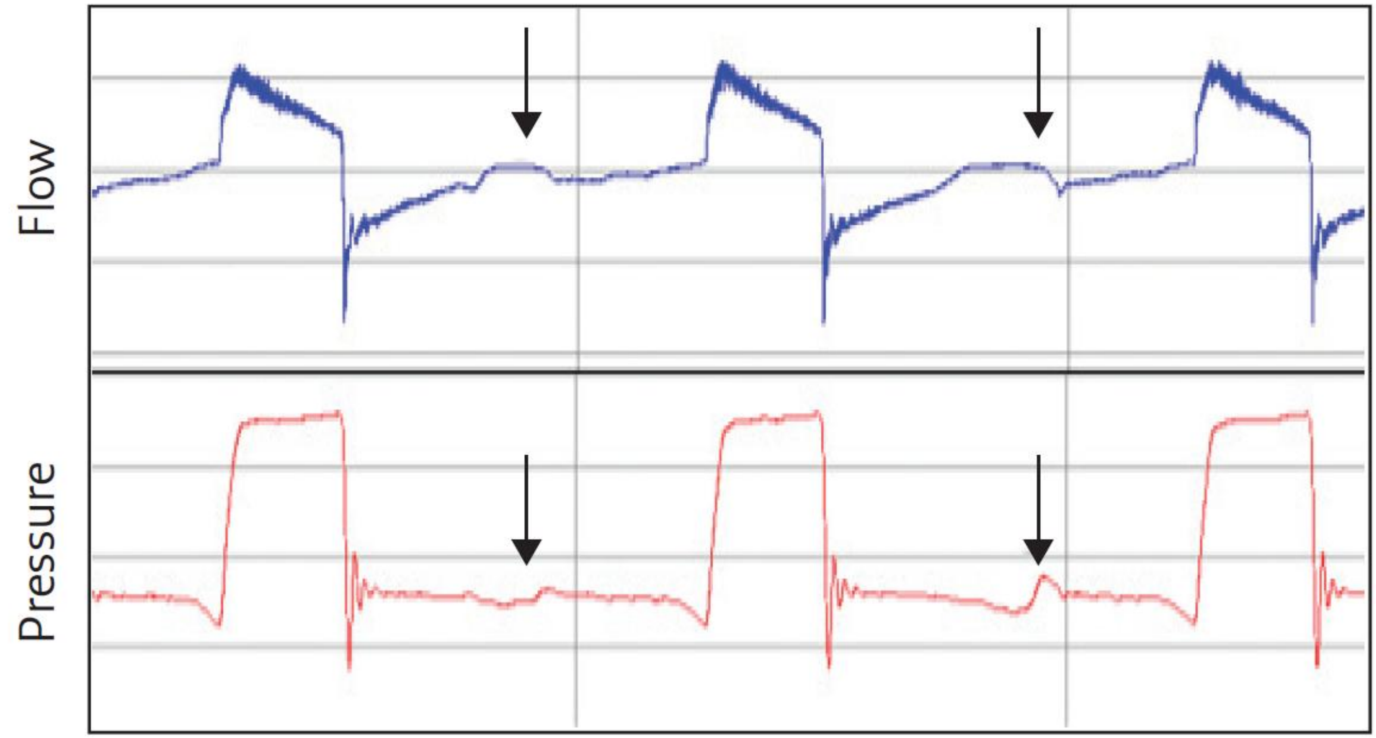

Figure 3. A typical patient–ventilator asynchrony pattern due to ineffective efforts during NIV that may be easily identified by looking at the flow–pressure curves of the ventilator. Arrows indicate the wasted efforts performed by the patient to successfully trigger the ventilator. Reproduced from Vignaux et al. *(2009)* Intensive Care Med; *35: 840–846, with permission from the publisher.*

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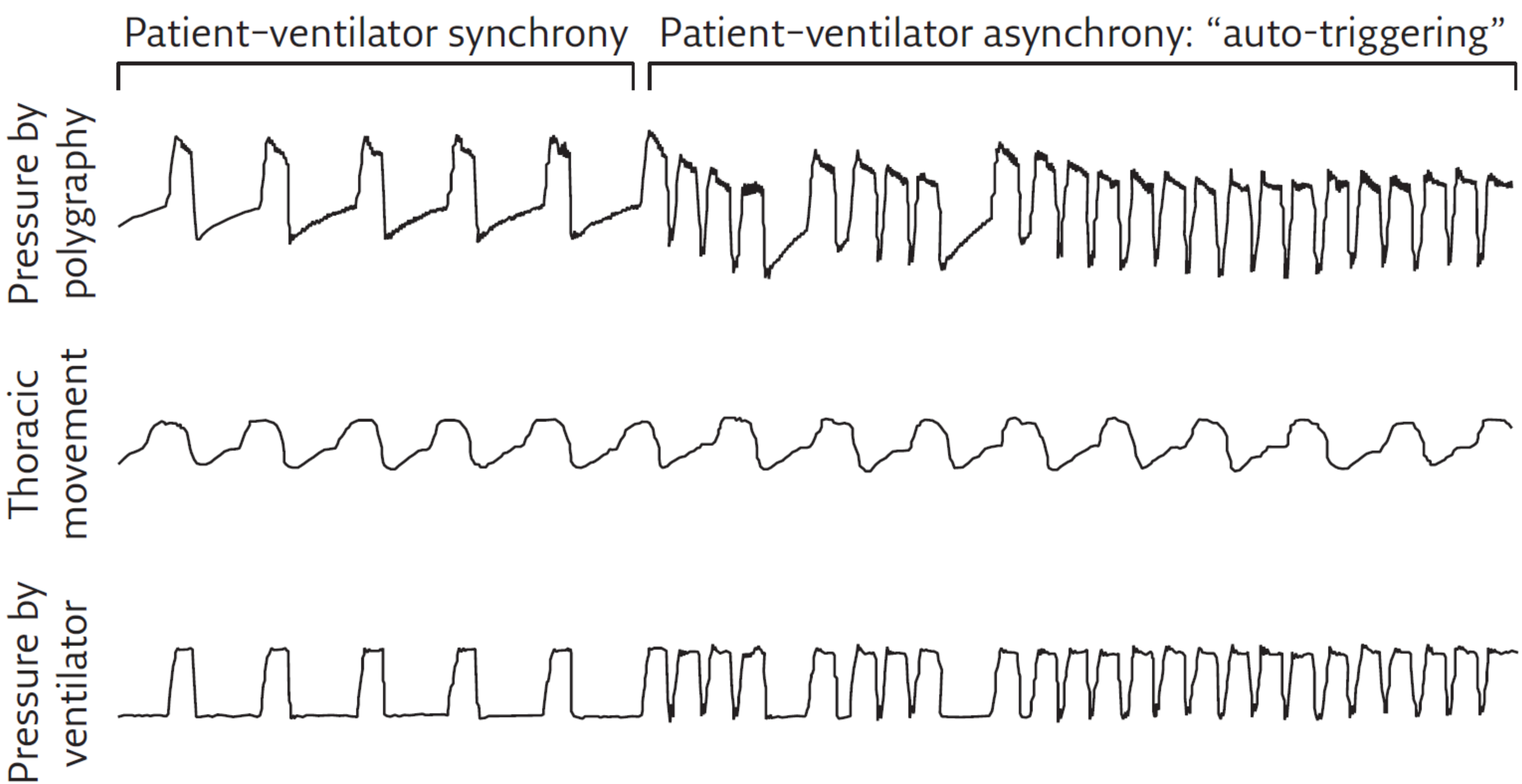

Figure 3. Patient–ventilator asynchrony during mechanical ventilation after five regular breaths. Periodic breathing patterns by the subject (thoracic movements) are not detected by the ventilator and breathing frequency (pressure curves) is increased without patient effort (so-called “auto-triggering”). Reproduced and modified from Storre et al. *(2014a), with permission from the publisher.*

Sedation for interface intolerance

- 15%, 6%, and 28% never used **sedation, analgesia, or hand restraints** for patients receiving NIV.
- Sedation, analgesia, and hand restraints were more commonly used in **North America** than in Europe.
- A **benzodiazepine** alone was the most preferred (33%), followed by an opioid alone (29%)

Crit Care Med2007;**35**(10):2298-2302

When to sedate

- **NIV failure due to patient refusal to continue NIV because of discomfort, claustrophobia or marked agitation.**

exclusion criteria were:

- poor respiratory state requiring immediate intubation
- severely altered consciousness
- any patient requiring an immediate lifesaving intervention such as cardiopulmonary resuscitation, airway control, cardioversion or inotropic support

(Intern Med 51: 2299-2305, 2012)

Remifentanil(starting at 0.025 μg/kg/min and titrating up to 0.12 μg/kg/min as needed).

- a **potent short-acting synthetic opioid** used for pain relief and sedation
- sedated to a Ramsay scale of 2–3 by a continuous infusion of remifentanil during NIV.
- tolerance improved
- P_{aO_2}/F_{IO_2} increased
- breathing frequency decreased
- P_{aCO_2} decreased

Intensive Care Med 2007;33(1):82-87
Intensive Care Med 2010;36(12):2060-2065

esth Analg 2008;**107**(1):167-170

Dexmedetomidine（1 mcg/kg的初劑量, 0.2 至0.7 mcg/kg/hr的維持劑量）

- an ideal pharmacologic agent for sedation of patients intolerant of NIV
- a prospective clinical investigation in 10 subjects in whom NIV was difficult because of agitation.
- All subjects were successfully weaned from NIV, and the respiratory state was not worsened

Anesth Analg 2008;**107**(1):167-170

J Anesth 2009;23(1):147-150

Respir Care 2012;57(11):1967-1969

Dexmedetomidine Versus Midazolam for the Sedation of Patients with Non-invasive Ventilation Failure

Intern Med 51: 2299-2305, 2012

Zhao Huang, Yu-sheng Chen, Zi-li Yang and Ji-yun Liu

Table 2. Primary and Secondary End Points in Patients Treated with Dexmedetomidine VS. Midazolam

Outcome	Midazolam	Dexmedetomidine	p value
Primary end point			
No. of endotracheal intubations/total (%)	13/29(44.8)	7/33(21.2)	0.043
Mean time to ETI (h)	17.8±1.9	27.6±4.7	0.024[a]
Cause of ETI			0.565
Severe hypoxemia No.(%)	4/13(30.8)	2/7(28.6)	
Copious tracheal secretions No.(%)	5/13(38.5)	1/7(14.3)	
Severe hemodynamic instability No.(%)	1/13(7.7)	2/7(28.6)	
Vomiting No.(%)	3/7(23.1)	2/7(28.6)	
Secondary end point			
Length of ICU stay (days)	8.5±4.6	4.9±4.3	0.042
ICU Mortality(%)	3/29(10.3)	2/33(6.1)	0.658
Length of NIV in patients who never required ETI(h)	(n=16)	(n=26)	
	93.4±12.4	57.5±7.9	0.010[a]
Physiology at 24h after sedation			
Oxygen saturation (%)	96.6±4.6	97.5±3.7	0.476
Arterial pH	7.4±0.05	7.5±0.19	0.781
PaO_2/FiO_2	271.4±36.0	289.9±25.2	0.397
Average dosage of sedative (mg.kg-1)	0.07±0.004	0.10±0.03	

[a] Calculated using Kaplan-Meier survival analysis, with differences between treatment groups assessed by the logrank test.

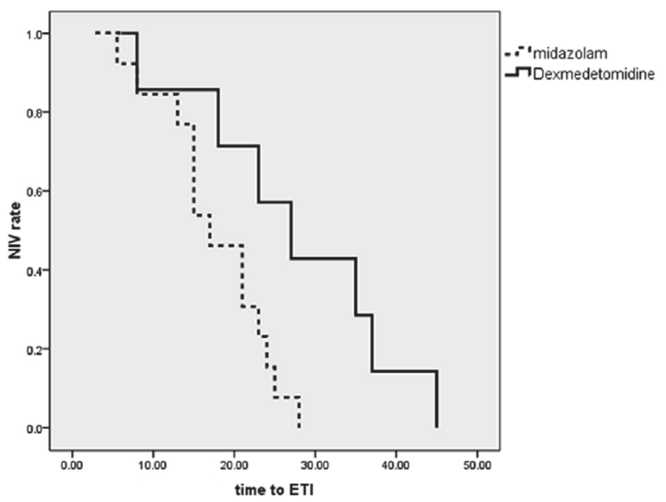

Figure 2. The Kaplan-Meier curve of the time (hours) until ETI in patients under midazolam (n=13) or dexmedetomidine (n=7) sedation (the y-axis shows the percentage of patients with NIV) in the patients who required ETI. The difference was significant (p=0.024).

Table 3. Safety Outcomes during Treatment with Dexmedetomidine VS. Midazolam

Outcome	Midazolam (n= 29)	Dexmedetomidine (n= 33)	p value
Cardiovascular			
Bradycardia	0/29(0)	6/33(18.2)	0.016
Bradycardia with intervention	0/29(0)	1/33(0)	1.000
Hypotension	5/29(17.2)	4/33(12.1)	0.772
Hypotension with intervention	1/29(3.4)	1/33(3.0)	0.927
Delirium NO.(%)	5/29(13.8)	1/33(3.0)	0.089
Vomiting No.(%)	9/29(31)	2/33(6.1)	0.010
Gastric aspiration No.(%)	3/29(10.3)	2/33(6.1)	0.658
Respiratory infections No.(%)	10/29(31.0)	3/33(9.1)	0.026

Intern Med 51: 2299-2305, 2012

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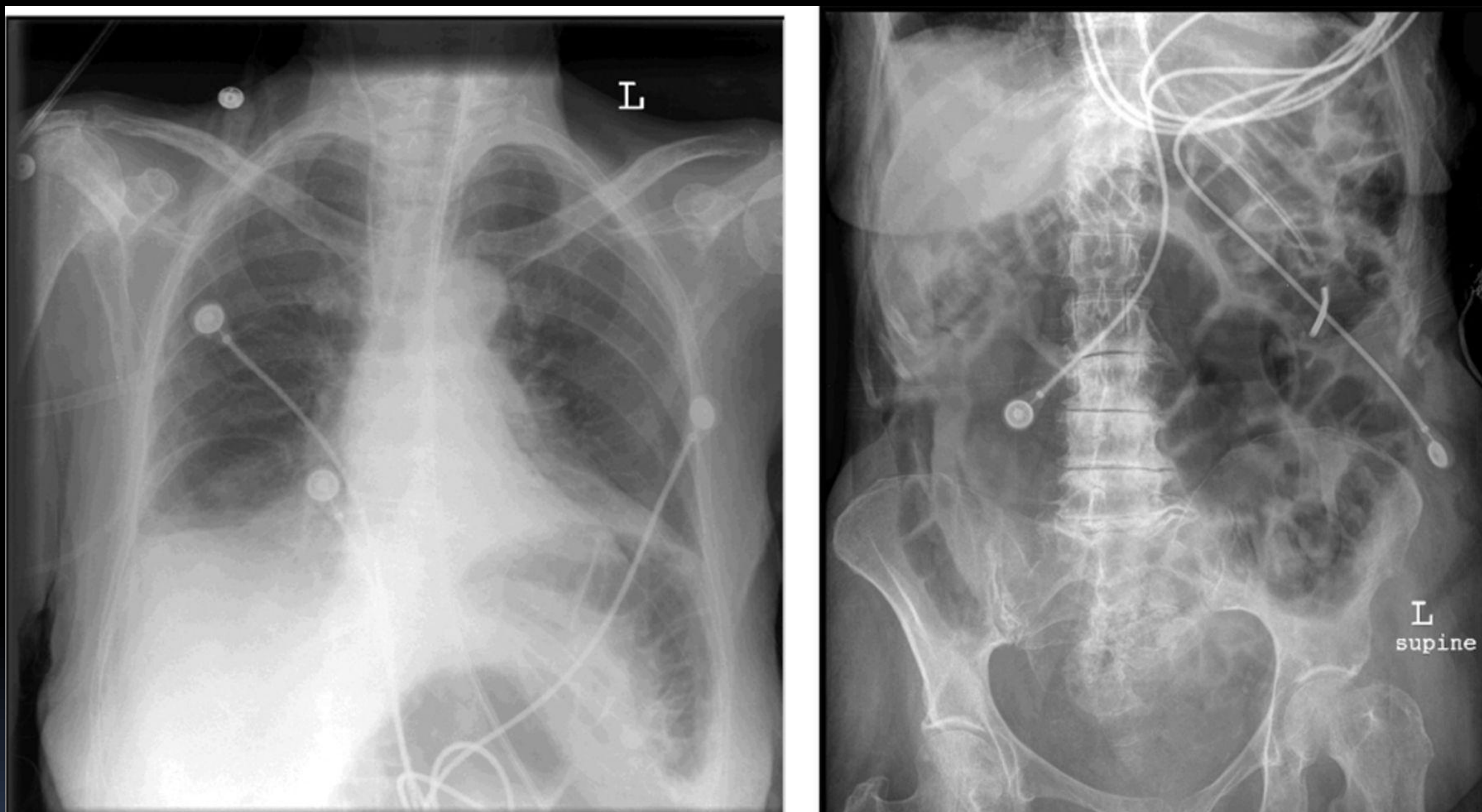
Chest and abdomen radiographs of a patient who developed severe gastric insufflation while receiving noninvasive ventilation.



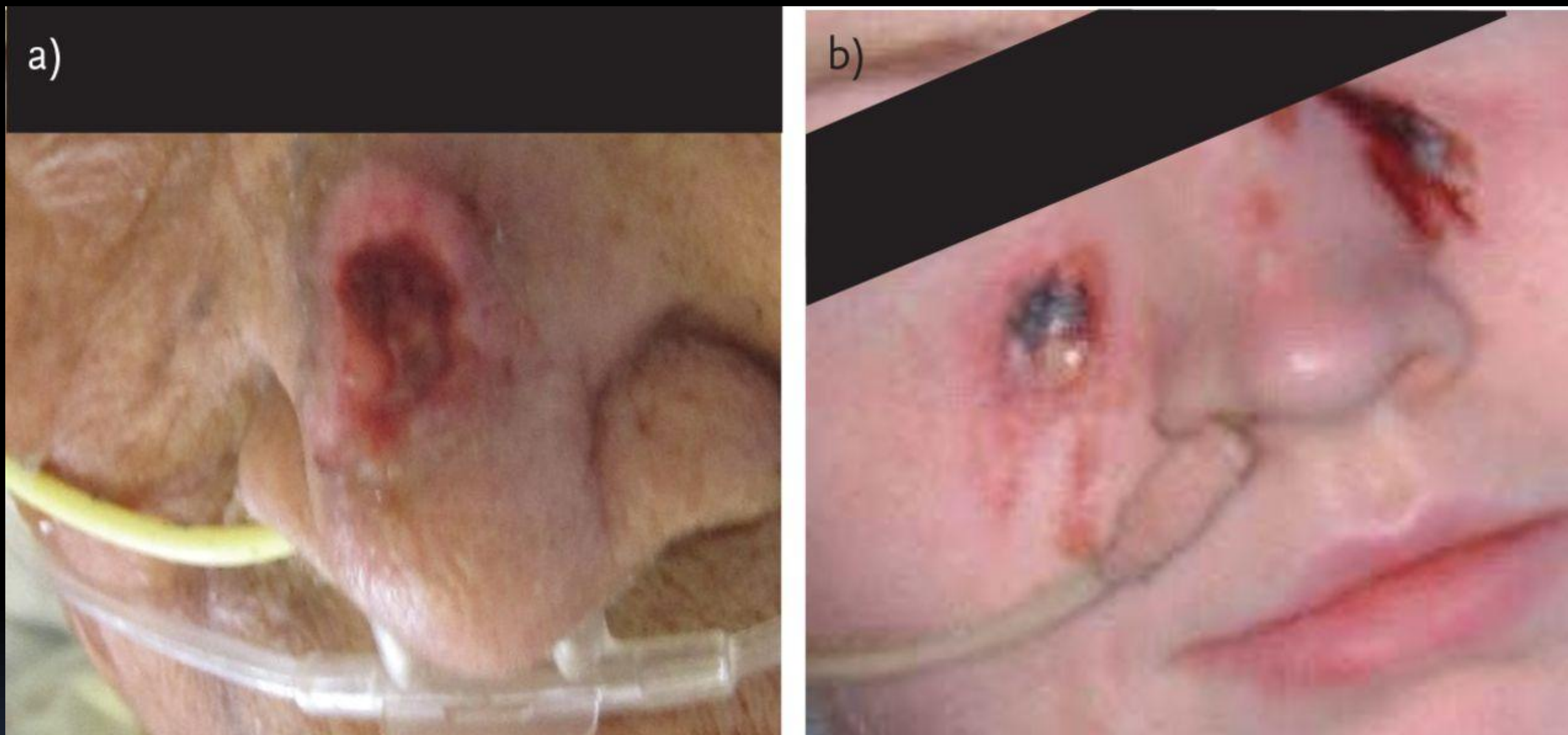
Dean R Hess Respir Care 2013;58:950-972

- NIV通常會出現食道注氣(aerophagia)，但這通常是良性的，因為氣道壓力低於食管開口壓力。
- 胃注氣可能很嚴重，但這通常是吸氣壓力設置過高的結果。
- 對於面罩通氣，通常不需要胃管。

facial skin breakdown

- A potential problem with **nasal and oronasal masks**
- most commonly occurs on the **bridge** of the nose.
- Nasal skin breakdown has been estimated to occur in **5–20%** of applications of NIV
- the most important approach to prevent skin breakdown is to **avoid strapping the mask too tight**

a) Grade III pressure ulcer on the nasal bridge b) grade II pressure ulcers on the cheeks



Anne-Kathrin Brill Breathe 2014;10:230-242

The two-finger rule: when the headgear is attached it should be possible to pass two fingers beneath it [30].

Anne-Kathrin Brill Breathe 2014;10:230-242

Example for skin protection: a self-cut foam (Mölnlycke Health Care, Göteborg, Sweden) dressing on a head model.

Anne-Kathrin Brill Breathe 2014;10:230-242

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New Guidelines on Noninvasive Ventilation
A Few Answers, and Several More Questions

- Mehta及其同事進行的分析評估了加州醫院使用NIV的適應症。作者假設NIV的最常見用途是COPD和心臟衰竭，與最佳現有證據一致，但**肺炎**是接受NIV的患者中更常見的診斷。
- 此外，Bellani及其同事研究了LUNG SAFE中的NIV使用情況，發現多達**六分之一**的ARDS患者在其病程早期接受NIV治療，其使用與死亡率增加相關

Ann Am Thorac Soc [online ahead of print] 25 May 2017
Am J Respir Crit Care Med 2017;195:67–77

Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure

Bram Rochwerg [1], Laurent Brochard [2,3], Mark W. Elliott [4], Dean Hess [5], Nicholas S. Hill [6], Stefano Nava [7] and Paolo Navalesi [8] (members of the steering committee); Massimo Antonelli [9], Jan Brozek [1], Giorgio Conti [9], Miquel Ferrer [10], Kalpalatha Guntupalli [11], Samir Jaber [12], Sean Keenan [13,14], Jordi Mancebo [15], Sangeeta Mehta [16] and Suhail Raoof [17,18] (members of the task force)

Eur Respir J 2017; 50:

Indications of NIV

- **Strong recommendation**

  -Hypercapnia with COPD exacerbation

  -Cardiogenic pulmonary edema

- **Conditional recommendation**

  -Immunocompromised

  -Post-operative

  -Palliative care

  -Trauma

  -Weaning in hypercapnic patients

  -Post-extubation in high risk patient

- **No recommendation**

  -*De novo* respiratory failure

  - Acute asthma exacerbation

HYPERCAPNIA WITH COPD EXACERBATION

COPD with hypercapnia

PH>7.35
- Condition against

PH:7.25-7.35
- Strong recommend

PH<7.25
- Strong recommend

COPD post-extubation

Weaning
- Condition recommend

Prevention
- Condition recommend

Failure treat
- Condition against

ERS/ATS guideline 2017

Table 2. Selection of Patients With Acute Hypercapnic Respiratory Failure for Noninvasive Ventilation

Selection Criteria
1. Determine the need for ventilatory assistance
Moderate-to-severe dyspnea
Tachypnea (≥24 breaths/min)
Increased accessory muscle use
Thoracoabdominal paradox
$pH < 7.34$; $P_{aCO_2} > 45$ mm Hg
2. Determine the presence of contraindications
Medical instability, including hypotensive shock, massive gastrointestinal bleed, acute ST elevation myocardial infarction
Agitation, uncooperativeness
Inability to protect the airway
Inability to accommodate the mask

Respir Care 2019;64(6):647–657.

NIV in Asthma Exacerbations

- IPAP:14 :cmH2O + EPAP: 6 cmH2O➔ a 20% improvement in FEV1 (*P*< *.05).*

----Intern Med 2008;47(6):493-501.

- A Cochrane review considered NIV for asthma promising but controversial.

------Cochrane Database Syst Rev 2012;12

- some patients can deteriorate rapidly and develop very-severe obstruction
- European Respiratory Society/American Thoracic Society guideline

➔**no recommendation** due to a lack of evidence.

Decompensated Obesity-Hypoventilation Syndrome

- BiPAP initiated in a monitored setting
- BiPAP successfully averts endotracheal intubation in over 90 percent of patients
- Volume-cycled positive pressure ventilation (VCPPV) for insufficient alveolar ventilation with BiPAP.

Am J Respir Crit Care Med 2012;186(12):1279-1285.

HFNC in Acute Hypercapnic Respiratory Failure

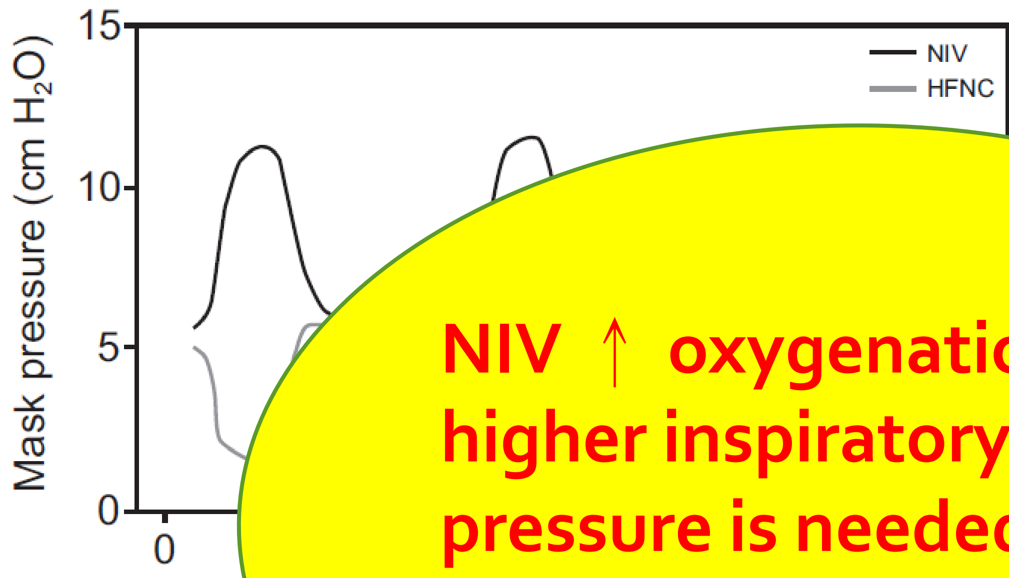


Fig. 1. Mask pressu…
by using a bi-level vent…
and expiratory pressure o…
tracing during high-flow nasa…
60 L/min. Expiratory pressures are…
(declining during expiration as patie… …y flow diminishes),
but during inspiration, pressure rises … …e set 12 cm H_2O during
NIV and drops to 2 cm H_2O during HFNC. Data are from ventilator
tracings and Reference 60. Illustration was by W. Hill.

NIV ↑ oxygenation when higher inspiratory pressure is needed such as COPD exacerbations or pulmonary edema.

Respir Care 2019;64(6):647–657.

NIV IN CARDIOGENIC PULMONARY EDEMA

Physiological effect of NIV

Table 2 Main physiologic effects of positive intrathoracic pressure

Cardiovascular
↓ Venous return → ↓ RV preload → ↓ LV preload
↑ Pulmonary vascular resistance → ↑ RV afterload → RV enlargement →↓ LV Compliance
↓ LV afterload (↓ systolic wall stress)
↓ Systemic blood pressure → ↓ Cardiac output[a]
Respiratory
Recruitment of collapsed alveoli → ↑Functional residual capacity
Maintenance continuously opened alveoli→ Gas exchange during the whole respiratory cycle
Intra-alveolar pressure against oedema
↓ Work of breathing
↑ Oxygenation

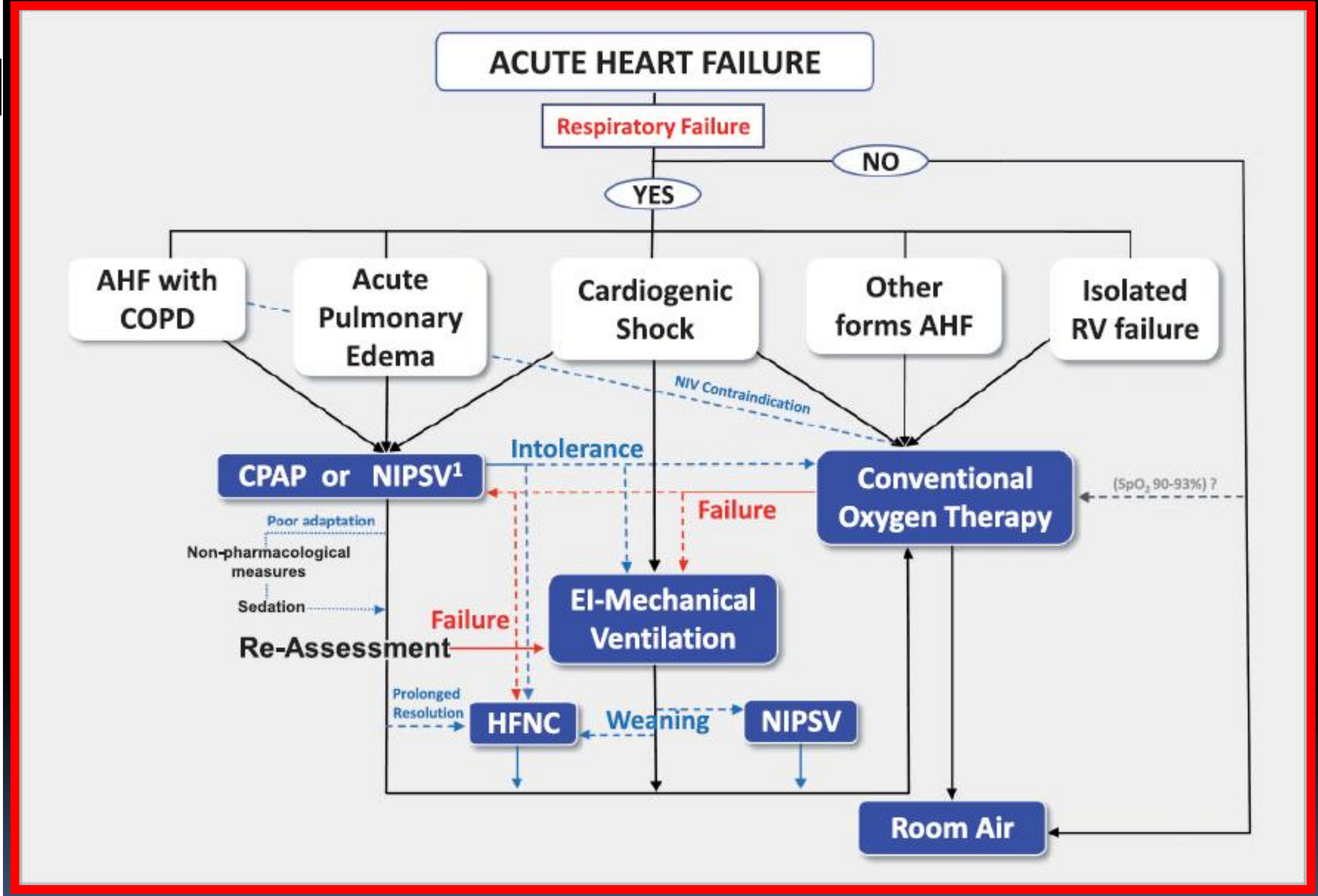
ERS/ATS guidelines

- We recommend either bilevel NIV or CPAP for patients with ARF due to cardiogenic pulmonary edema
- acute coronary syndrome or cardiogenic shock excluded
- (Strong recommendation, moderate certainty of evidence.)

Guidelines

Society	Recommendation	Evidence
ERS/ATS 2017	We recommend either bilevel NIV or CPAP for patients with ARF due to cardiogenic pulmonary oedema.	Strong recommend, moderate evidence
ESC 2016	Non-invasive positive pressure ventilation (CPAP, BiPAP) should be considered in patients with respiratory distress (**respiratory rate >25** breaths/min**, SpO2 <90%)** and started as soon as possible in order to decrease respiratory distress … **Blood pressure** should be monitored regularly when this treatment is used.	Class: IIa LOE: B
AHA 2013	(No NIV description)	
TSOC 2012	….It is recommended that non-invasive ventilation should be initiated as early as possible in acute heart failure patients with dyspnea and respiratory distress if no obvious contraindication….	No grading

Eur Respir J 2017; 50:1602426
Eur Heart J. 2016;37:2129–2200
Acta Cardiol Sin 2012;28:161-195



Eur Heart J. 2018 Jan 1;39(1):17-25

SHOULD NIV BE USED IN DE NOVO ARF?

De novo respiratory failure

- Respiratory failure occurring without prior chronic respiratory disease.
- Most patients are hypoxeamic respiratory failure

-hypoxaemia ($PaO_2/FIO_2 \leqslant 200$)

-tachypnea (RR >30 35 /min)

- Nearly three quarters of the cases are pneumonia
- 10-15% of patients with de novo acute respiratory failure or ARDS used NIV

Limitation of NIV in de novo RF

- Lack of efficacy in reducing work of breathing
- Need sufficient pressure support
- High inspiratory demand→ large transpulmonary pressures→ large tidal volumes→ VILI
- High inspiratory pressure →increase air leaks, gastric insufflation and patient intolerance
- Difficult for low tidal volume
- Spontaneous ventilation → VILI in severe lung injury

TASK FORCE REPORT
ERS/ATS GUIDELINES

Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure

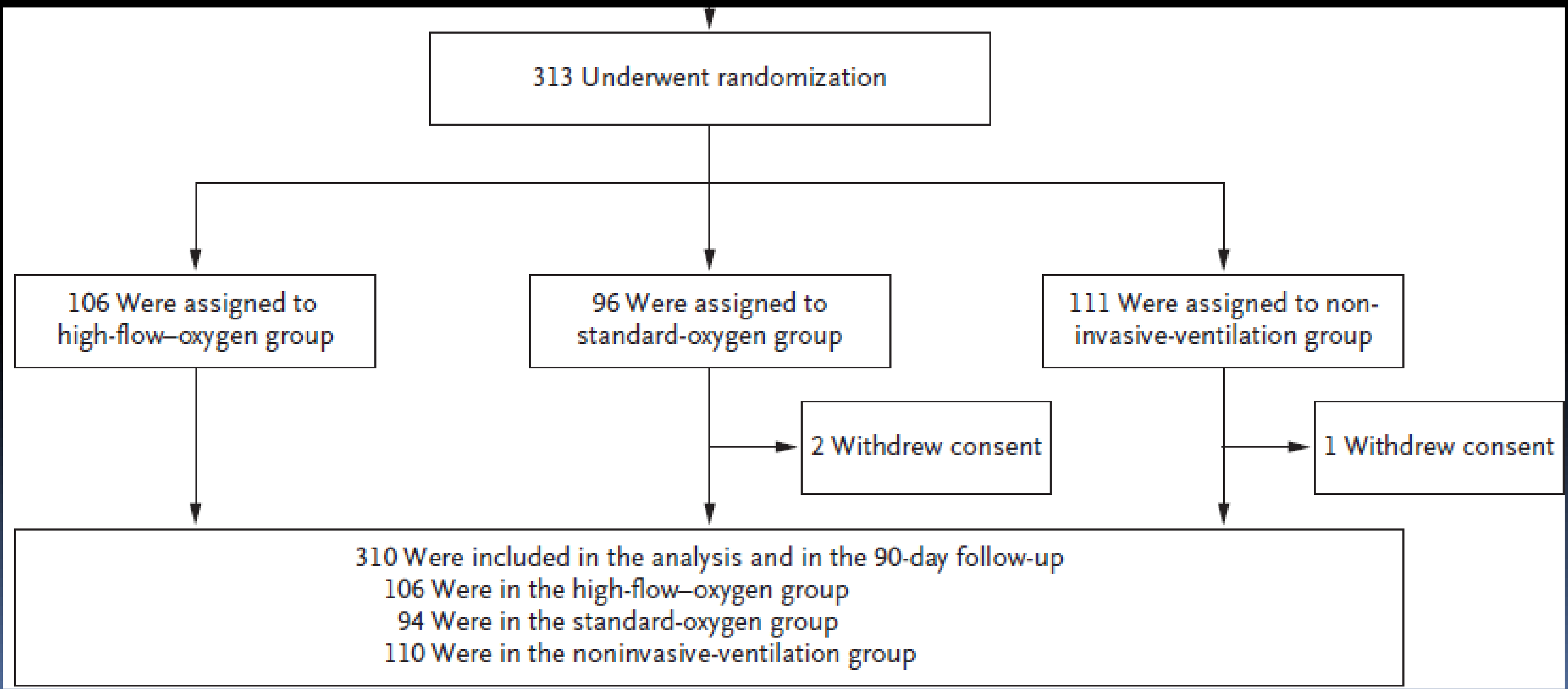
Bram Rochwerg[1], Laurent Brochard[2,3], Mark W. Elliott[4], Dean Hess[5], Nicholas S. Hill[6], Stefano Nava[7] and Paolo Navalesi[8] (members of the steering committee); Massimo Antonelli[9], Jan Brozek[1], Giorgio Conti[9], Miquel Ferrer[10], Kalpalatha Guntupalli[11], Samir Jaber[12], Sean Keenan[13,14], Jordi Mancebo[15], Sangeeta Mehta[16] and Suhail Raoof[17,18] (members of the task force)

- NIV in patients with de novo respiratory failure remains debated
- No recommendations for its use in this setting

The NEW ENGLAND JOURNAL of MEDICINE

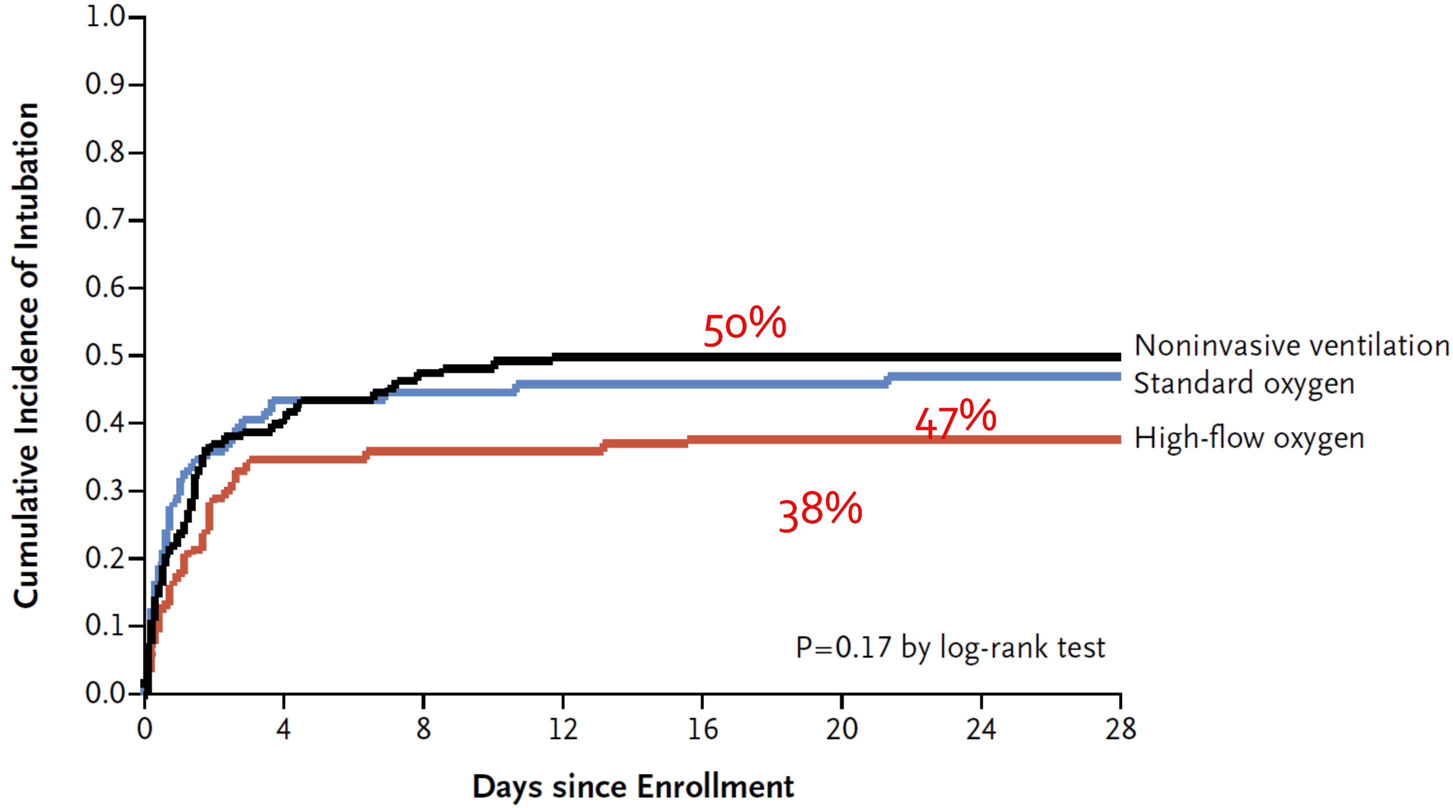
ORIGINAL ARTICLE

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



Intubation rate

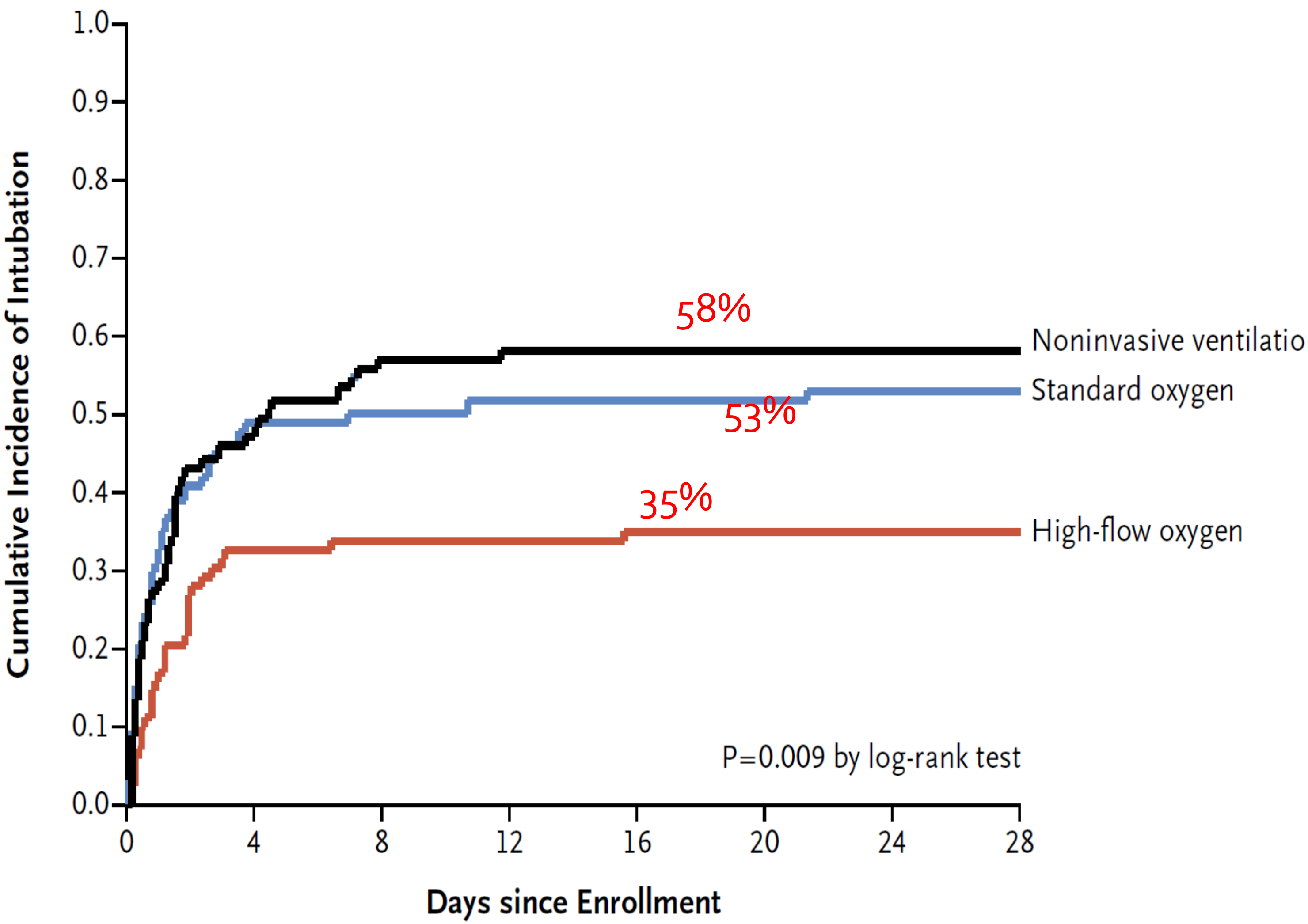
A Overall Population



No. at Risk

High-flow oxygen	106	68	67	67	65	65	65	65
Standard oxygen	94	52	50	49	49	49	48	48
Noninvasive ventilation	110	64	57	53	53	53	53	52

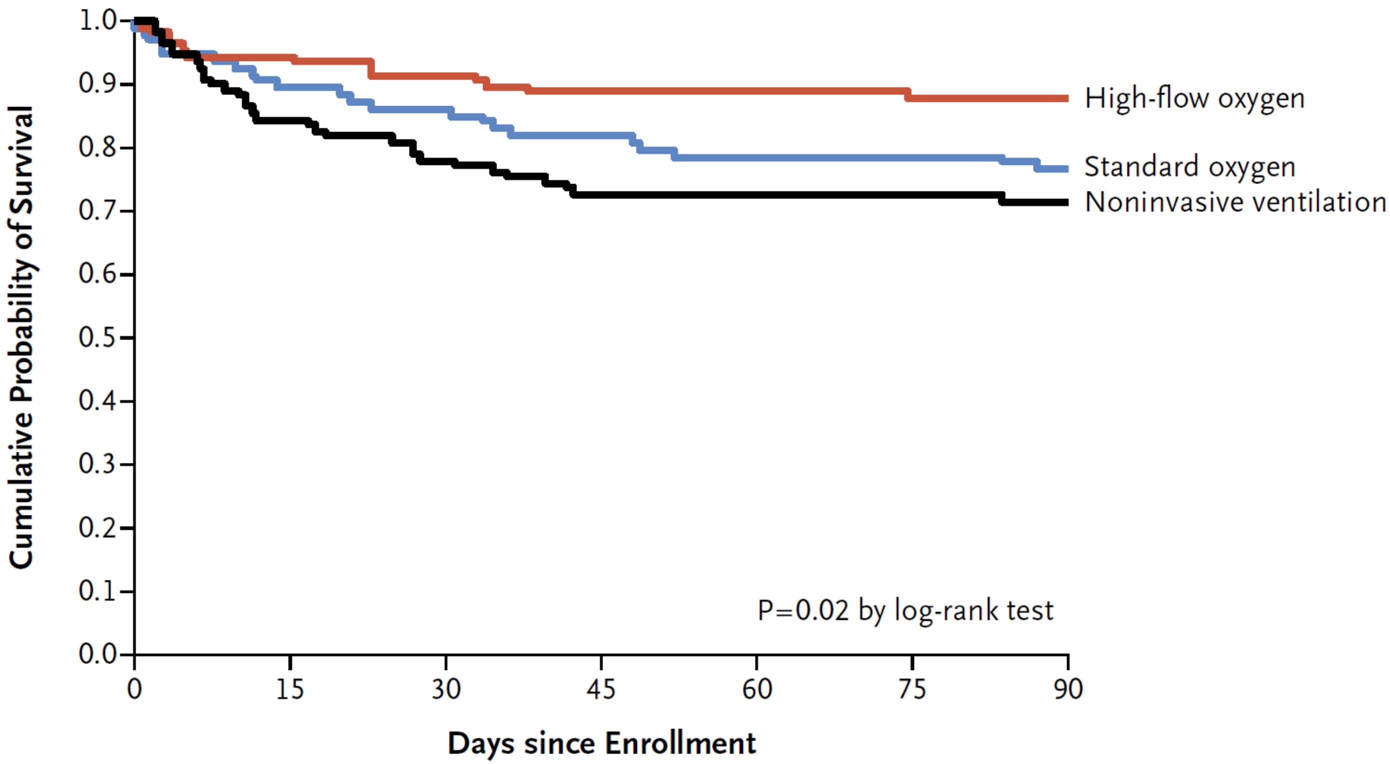
B Patients with a PaO_2:FIO_2 ≤200 mm Hg



No. at Risk

High-flow oxygen	83	55	54	54	53	53	53	53
Standard oxygen	74	37	35	34	34	34	33	33
Noninvasive ventilation	81	41	34	32	32	32	32	32

D90 Survival



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

Figure 3. Kaplan–Meier Plot of the Probability of Survival from Randomization to Day 90.

Predictors of Intubation in Patients With Acute Hypoxemic Respiratory Failure Treated With a Noninvasive Oxygenation Strategy*

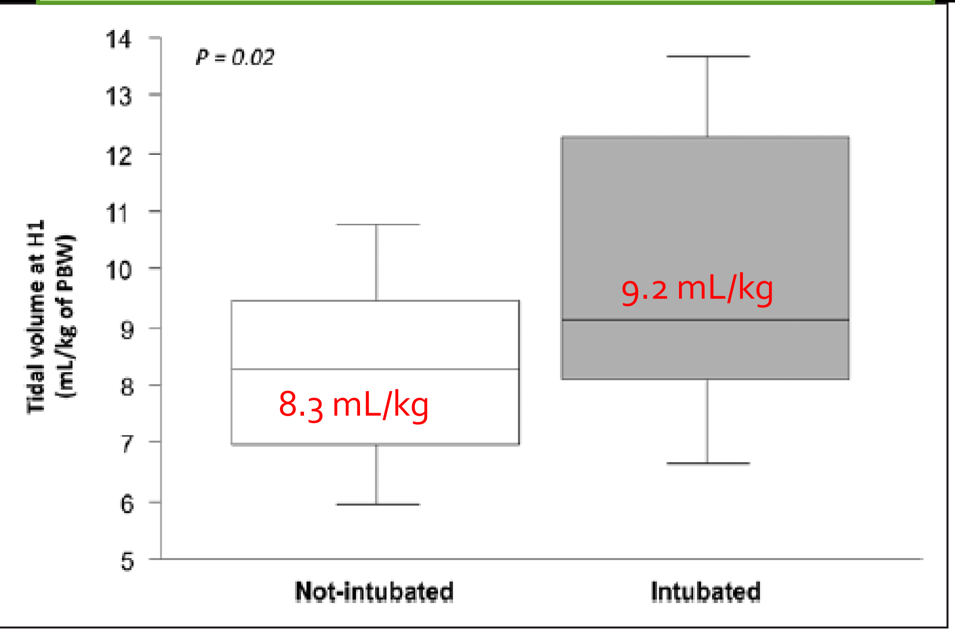
Jean-Pierre Frat, MD[1,2,3]; Stéphanie Ragot, PhD[4,5,6]; Rémi Coudroy, MD[1,2,3]; Jean-Michel Constantin, PhD[7]

TABLE 3. Multivariate Logistic Regression Analyses of Factors Associated With Intubation

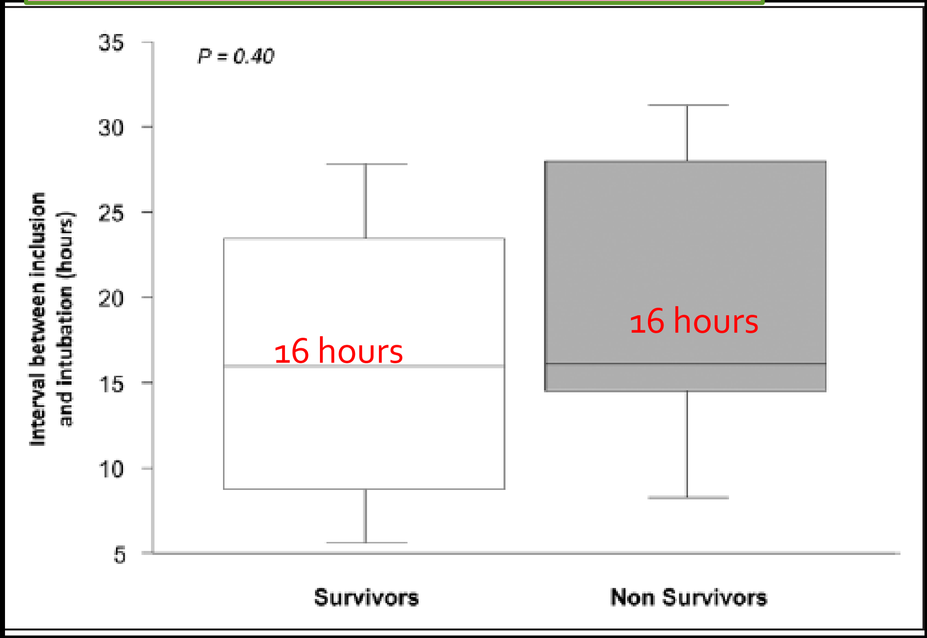
Risk Factors	OR (95% CI)	*p*
In patients treated with conventional O_2 therapy by nonrebreathing mask[a]		
Respiratory rate ≥ 30 breaths/min at H1	2.76 (1.13–6.75)	0.03
In patients treated with high-flow nasal cannula oxygen therapy[a]		
Heart rate at H1 (per beat/min)	1.03 (1.01–1.06)	< 0.01
In patients treated with noninvasive ventilation[ab]		
Tidal volume > 9 mL/kg of predicted body weight at H1	3.14 (1.22–8.06)	0.02
Pao_2/Fio_2 ≤ 200 mm Hg at H1	4.26 (1.62–11.16)	0.003

Crit Care Med 2018; 46:208–215

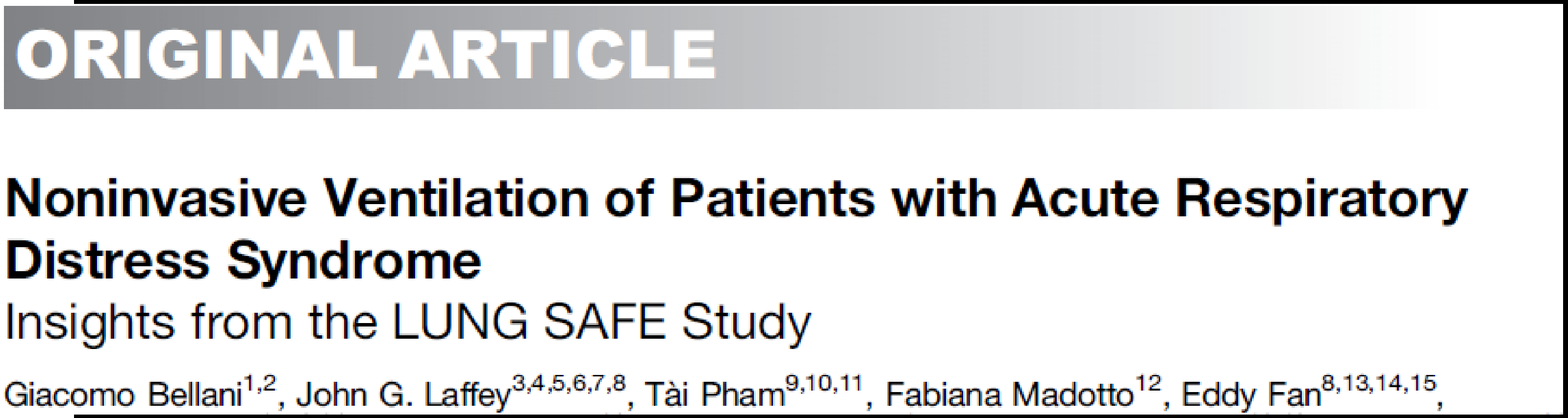
Tidal Volume



Interval before intubation



- ✓ **Predictors of intubation : TV>9 ml/Kg ; PF ratio < 200**
- ✓ **Poor outcomes were not because of delayed intubation**


ORIGINAL ARTICLE

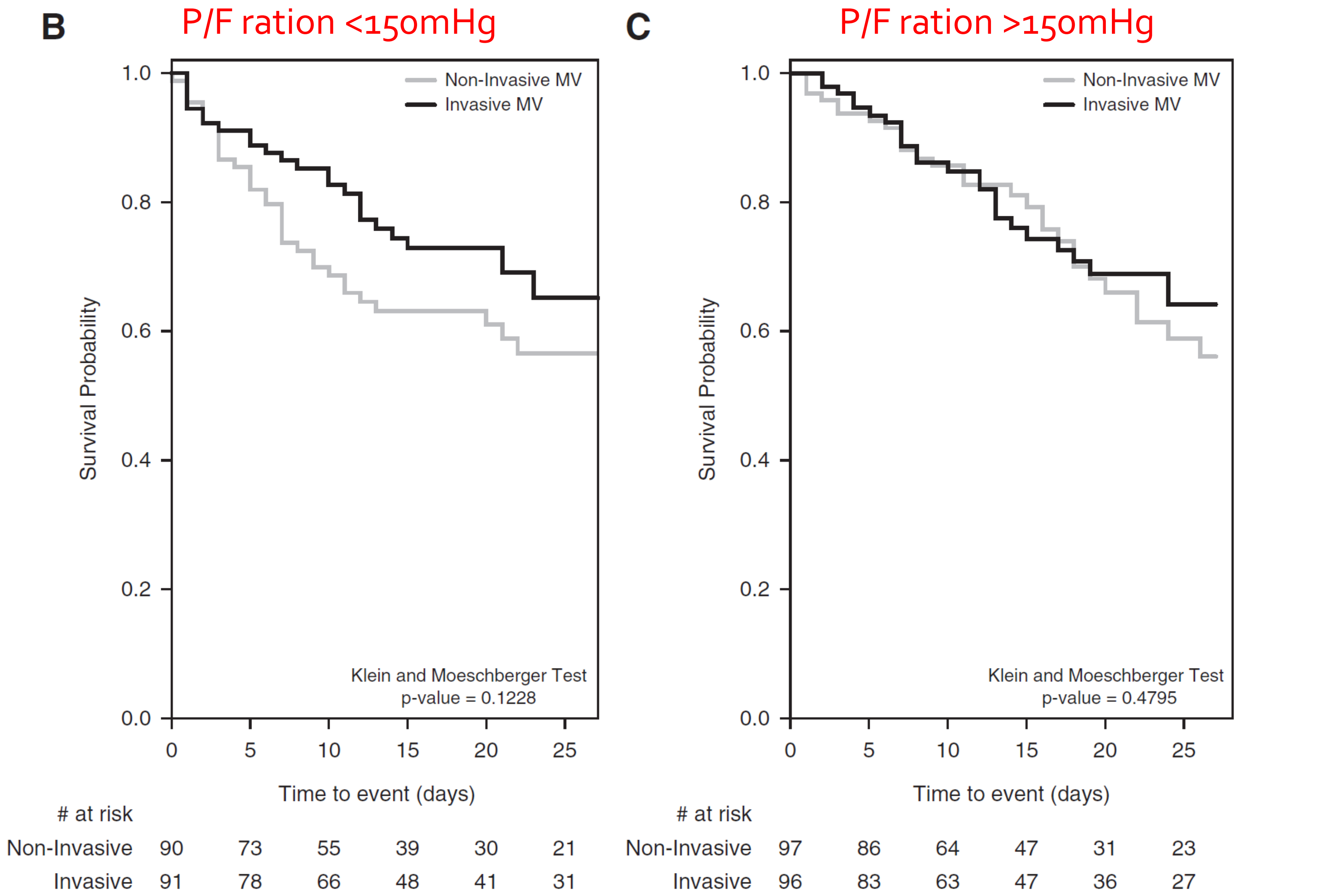
Noninvasive Ventilation of Patients with Acute Respiratory Distress Syndrome

Insights from the LUNG SAFE Study

Giacomo Bellani[1,2], John G. Laffey[3,4,5,6,7,8], Tài Pham[9,10,11], Fabiana Madotto[12], Eddy Fan[8,13,14,15],

- NIV was used in 15% of ARDS patients
- NIV failure rate : 22.2% of mild, 42.3% of moderate, and 47.1% of severe ARDS

Am J Respir Crit Care Med 2017; 195

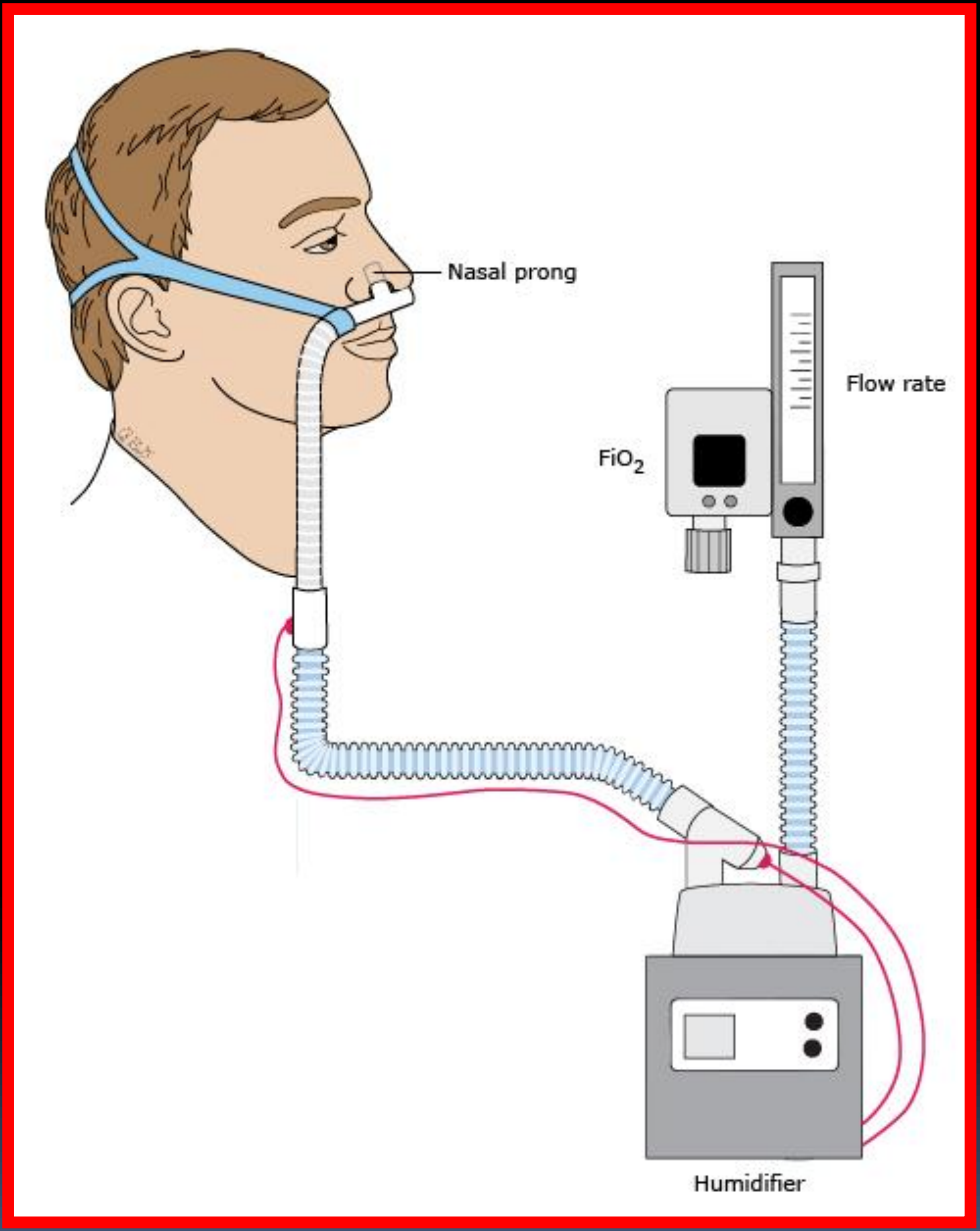


Higher ICU mortality in patients with a PaO2/FIO2 lower than 150 mm Hg received NIV than invasive-MV

Am J Respir Crit Care Med 2017; 195

High flow nasal cannula

- 急性呼吸衰竭患者產生的吸氣峰值平均值為30-40 L/min，更嚴重的可達到120 L / min
- 傳統氧療設備如nasal cannula, simple mask, Venturi mask, and non-rebreathing mask provide a maximum oxygen flow of 6－15 l/min
- 吸入氧氣與室內空氣混合，從而減小FiO2，其FiO2 通常不超過0.7
- **High-flow nasal cannula (HFNC) deliver up to 100 % heated and humidified oxygen via a wide-bore nasal cannula at a maximum flow of 60 l/min**



A typical set up for oxygen delivery through high flow nasal cannulae.

HFNC作用機轉

- 加熱和加濕增強舒適度
- 增加粘液的含水量促進分泌物去除，避免乾燥和上皮損傷
- 呼吸代謝成本降低，減少呼吸工作
- 高流量氧氣減少空氣的吸入;提高FIO_2
- 清除上呼吸道死腔中CO2，提高通氣效率
- 提供呼氣末正壓(PEEP)
- recruitment of alveoli➔increase FRC➔減少呼吸作工

CHEST 2015; 148(1):253-261

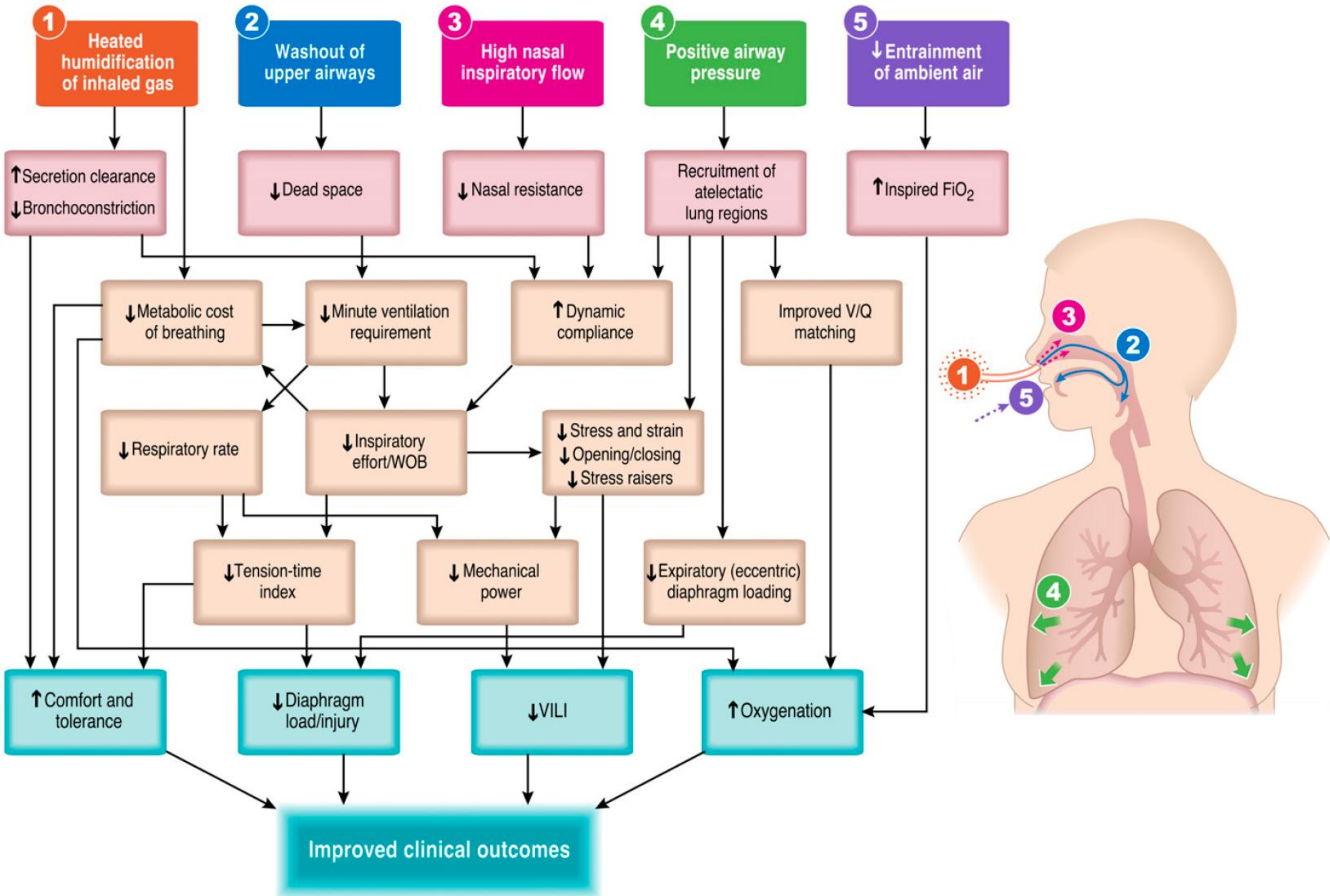
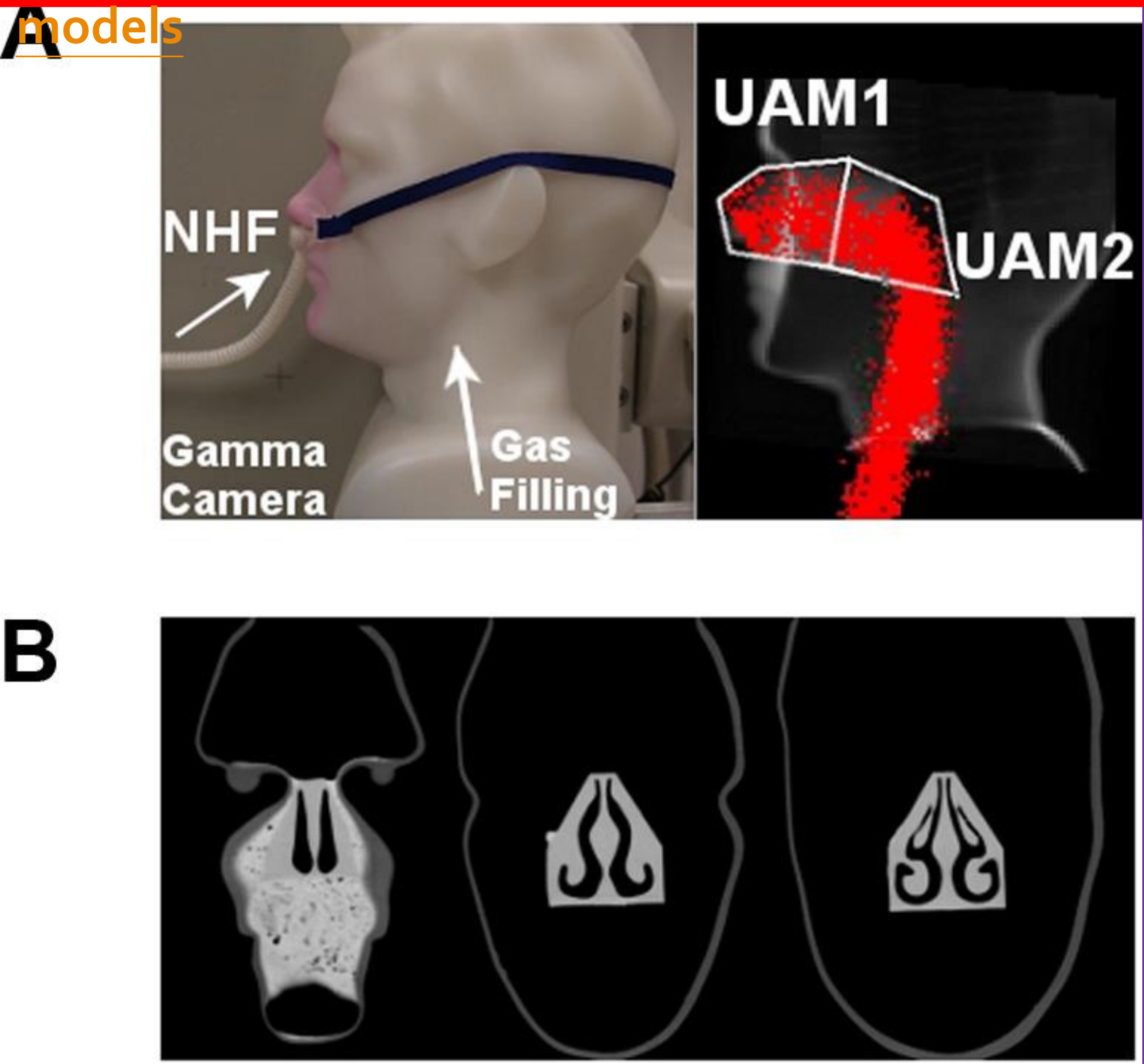
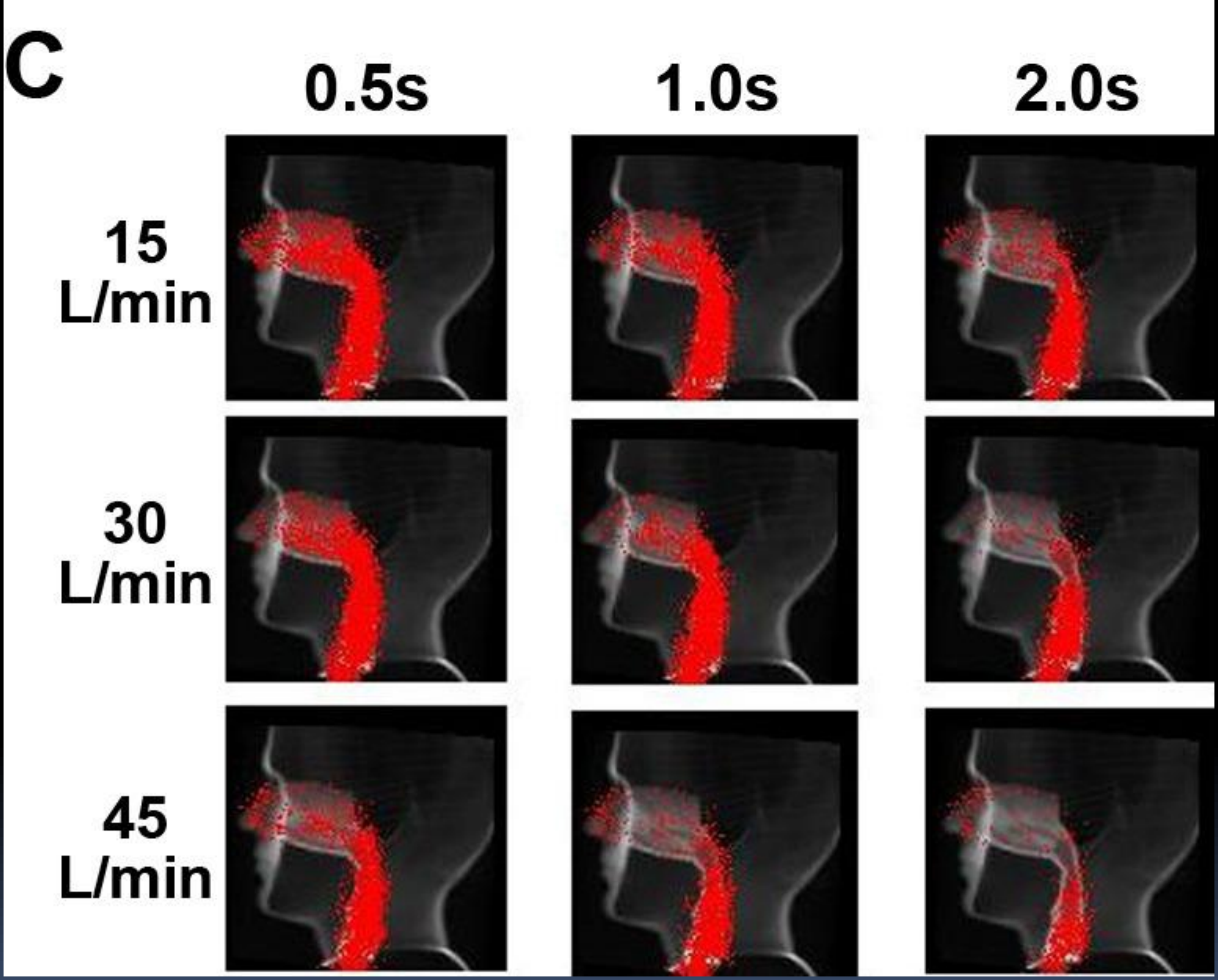


Figure 1. Mechanisms of action of high flow nasal cannula (HFNC) in acute hypoxemic respiratory failure. HFNC exerts a range of important and interdependent physiological effects on a variety of factors that may determine clinical outcomes for patients with acute respiratory failure. VILI = ventilator-induced lung injury; V/Q = ventilation/perfusion; WOB = work of breathing. Illustration by Jacqueline Schaffer.

Nasal high flow clears anatomical dead space in upper airway models



J Appl Physiol . 2015 June 15; 118(12): 1525–1532.



Winfried Möller, *et al.* J Appl Physiol . 2015 June 15; 118(12): 1525–1532.

Mean airway pressure increased in each increase of 10 L/min

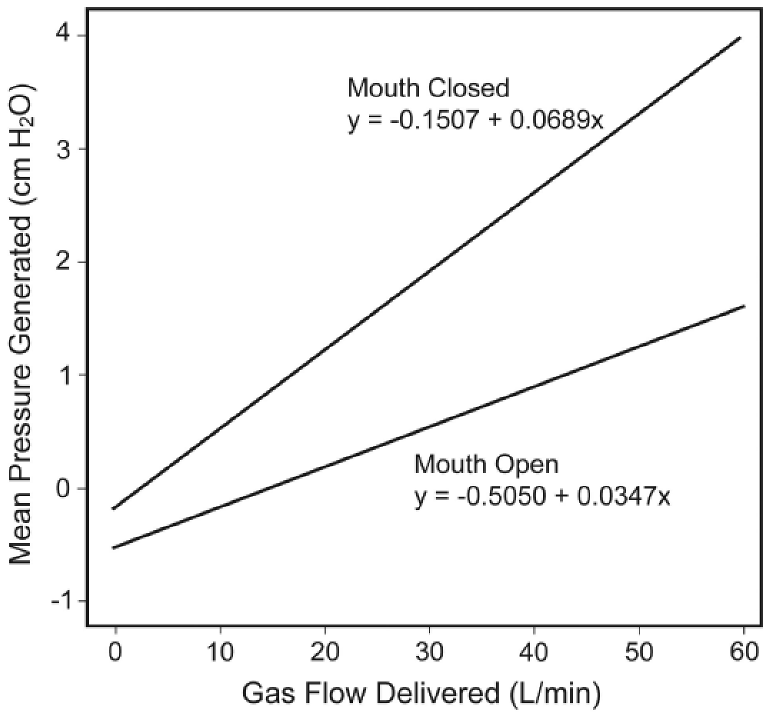


Fig. 3. Regression analysis of mean nasopharyngeal pressure during high-flow oxygen therapy, with mouth open or closed.

- 0.69 cm H_2O ($P < .01$) when mouths closed
- 0.35 cm H_2O ($P < .03$) when mouths open.

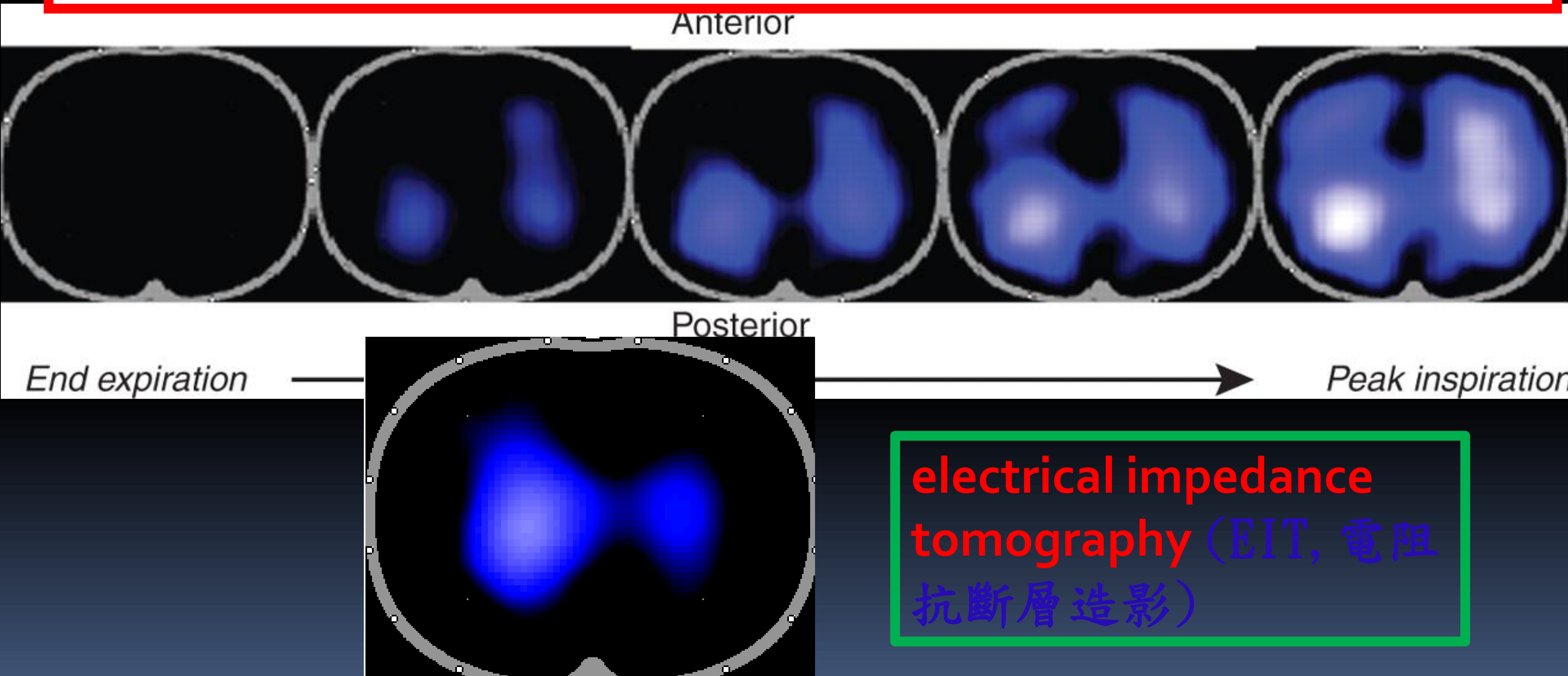
RL Parke, *et al.* Respiratory Care, 56 (8) (2011), pp. 1151–1155

British Journal of Anaesthesia **107** (6): 998–1004 (2011)
Advance Access publication 9 September 2011 · doi:10.1093/bja/aer265

BJA

Oxygen delivery through high-flow nasal cannulae increase end-expiratory lung volume and reduce respiratory rate in post-cardiac surgical patients

A. Corley[1]*, L. R. Caruana[1], A. G. Barnett[2], O. Tronstad[1] and J. F. Fraser[1]



electrical impedance tomography（EIT, 電阻抗斷層造影）

A. Corley et al. Br. J. Anaesth. 2011;107:998-1004

HFNC vs low-flow oxygen

- increase in EELI (FRC) of 25.6%
- increased mean Paw by 3.0 cm H_2O
- Respiratory rate was lowered by 3.4 bpm
- Borg dyspnoea score by 0.8 points
- 10.5% increase of Vt
- PaO_2/FIO_2 ratio was improved by 30.6

A. Corley et al. Br. J. Anaesth. 2011;107:998-1004

Physiologic Effects of High-Flow Nasal Cannula in Acute Hypoxemic Respiratory Failure

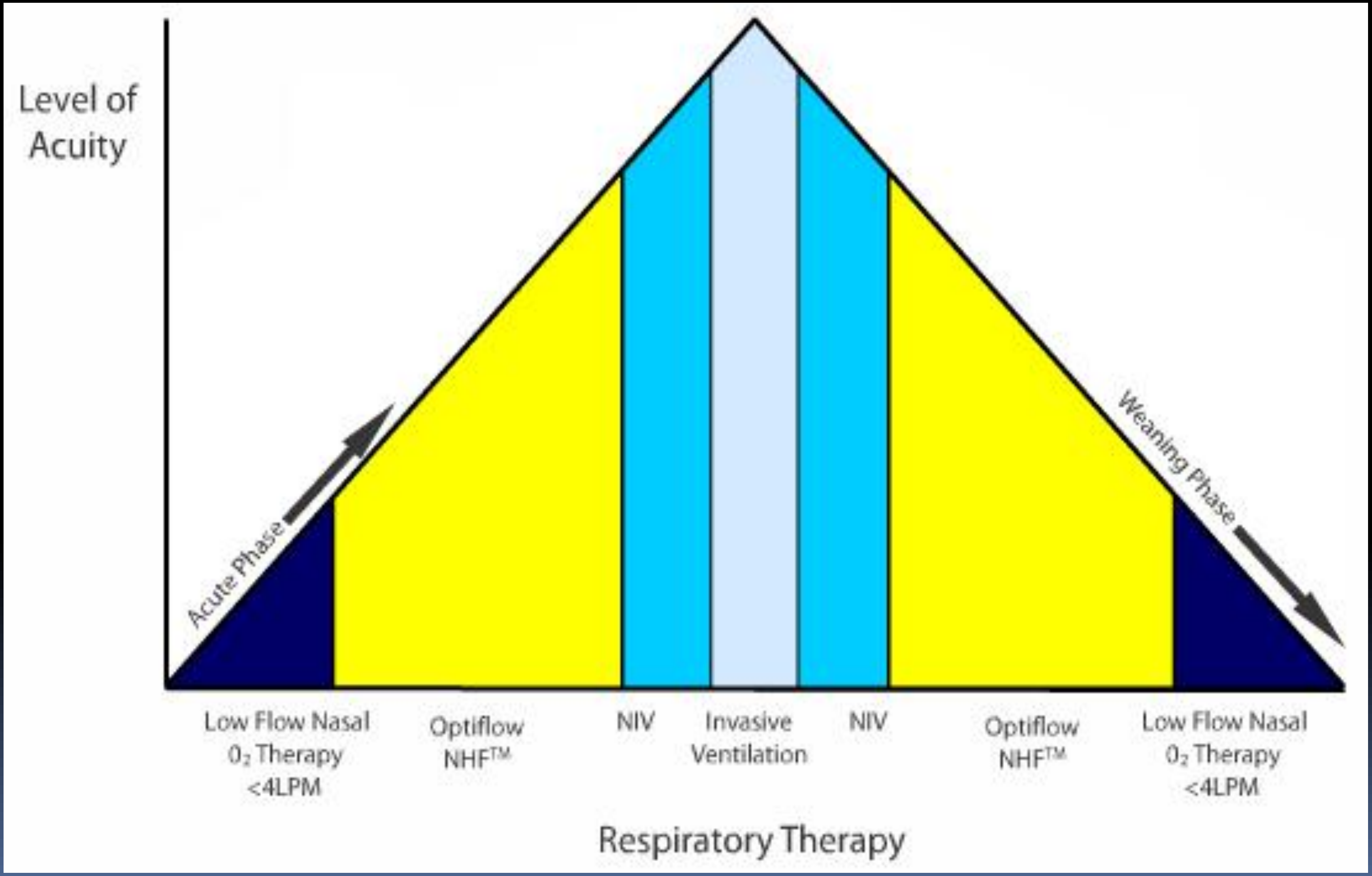
Tommaso Mauri[1,2], Cecilia Turrini[1,3], Nilde Eronia[4], Giacomo Grasselli[1], Carlo Alberto Volta[3], Giacomo Bellani[4,5], and Antonio Pesenti[1,2]

[1]Department of Anesthesia, Critical Care and Emergency, IRCCS (Institute for Treatment and Research) Ca' Granda Maggiore Policlinico Hospital Foundation, Milan, Italy; [2]Department of Pathophysiology and Transplantation, University of Milan, Milan, Italy; [3]Department of Morphology, Surgery and Experimental Medicine, Section of Anesthesia and Intensive Care, University of Ferrara, Ferrara, Italy; [4]Department of Emergency, San Gerardo Hospital, Monza, Italy; and [5]Department of Medicine and Surgery, University of Milan-Bicocca, Monza, Italy

- **Less ΔPes ($P < 0.01$),** and pressure time product ($P < 0.001$).
- **minute ventilation was reduced ($P < 0.001$)** at constant arterial CO_2 tension and pH
- **end-expiratory lung volume increased ($P < 0.001$)**
- the **ratio of tidal volume to ΔPes** (an estimate of **dynamic lung compliance**) increased ($P < 0.05$)
- ventilation was more **homogeneous** ($P < 0.01$)

Mauri T,et al. Am J Respir Crit Care Med . 2017, Vol 195, Iss 9, pp 1207–1215

Where Does Optiflow™ NHF™ Fit?

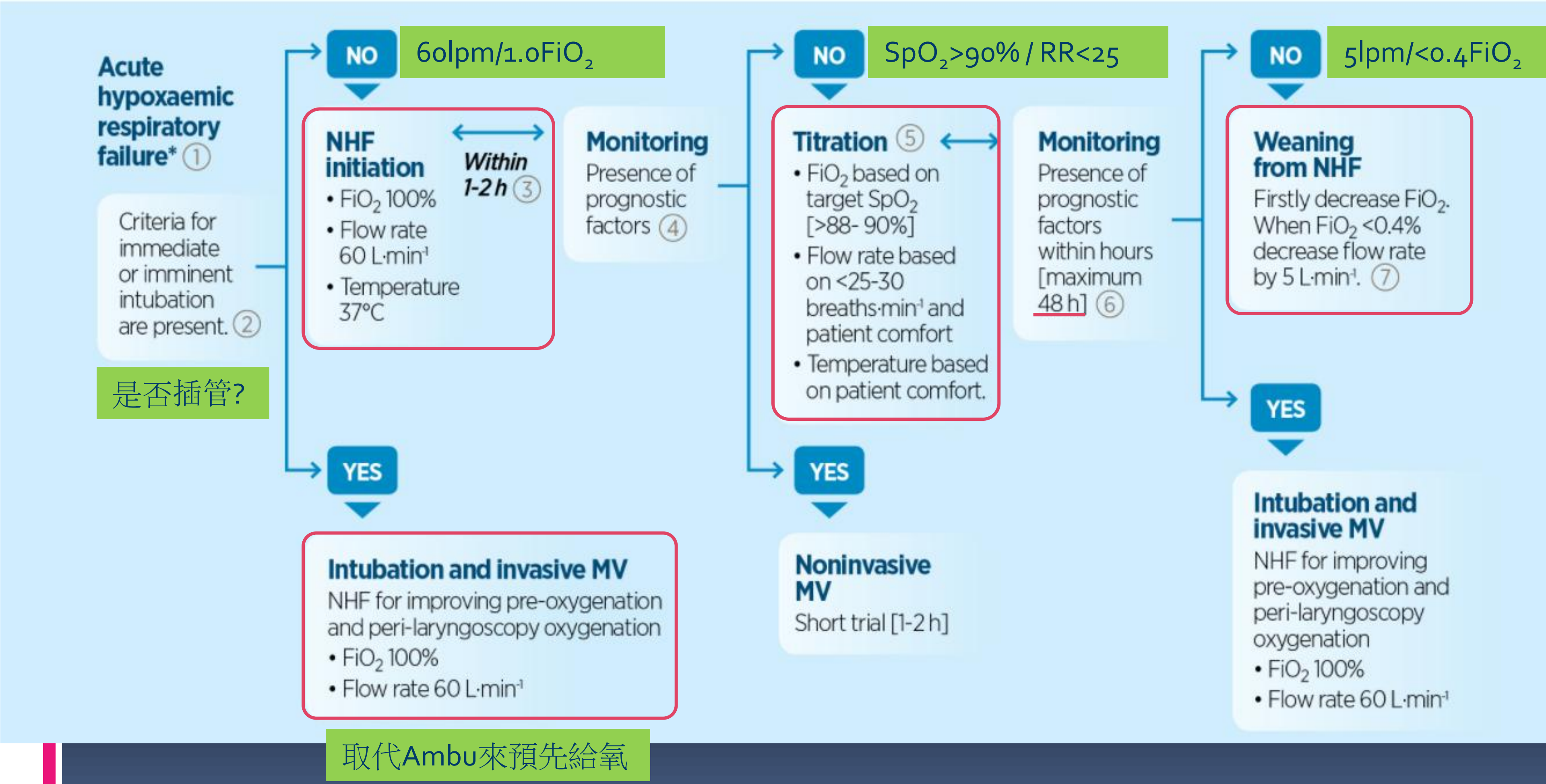


Clinical applications

- **Hypoxic respiratory failure**
- Immunocompromised patient
- Endotracheal intubation
- Emergent department
- Postextubation
- Postoperatively
- Cardiogenic pulmonary edema
- COPD
- Bronchoscope

Ischaki et al. 2017

Ischaki. Eur Respir Rev. 2017.



Take home message for NIV

- The right patient
- The right time
- The right equipment
- The right environment
- Ongoing audits and quality assurance should be done

Lancet Respir Med 2018; 6: 935–47

For HFNC

- Enhanced comfort
- Avoidance of desiccation and epithelial injury
- Facilitated secretion removal
- Reduced inspiratory entrainment of room air
- Washout of upper airway dead space
- Counterbalance auto-PEEP
- Decreased work of breathing
- **Hypoxic respiratory failure**
- **Postextubation**
- **Immunocompromised patient**

- Thanks for your attention