



기도가습과 **고유량산소요법**

- High Flow Nasal Cannula -

해운대백병원
호흡기내과 장항제

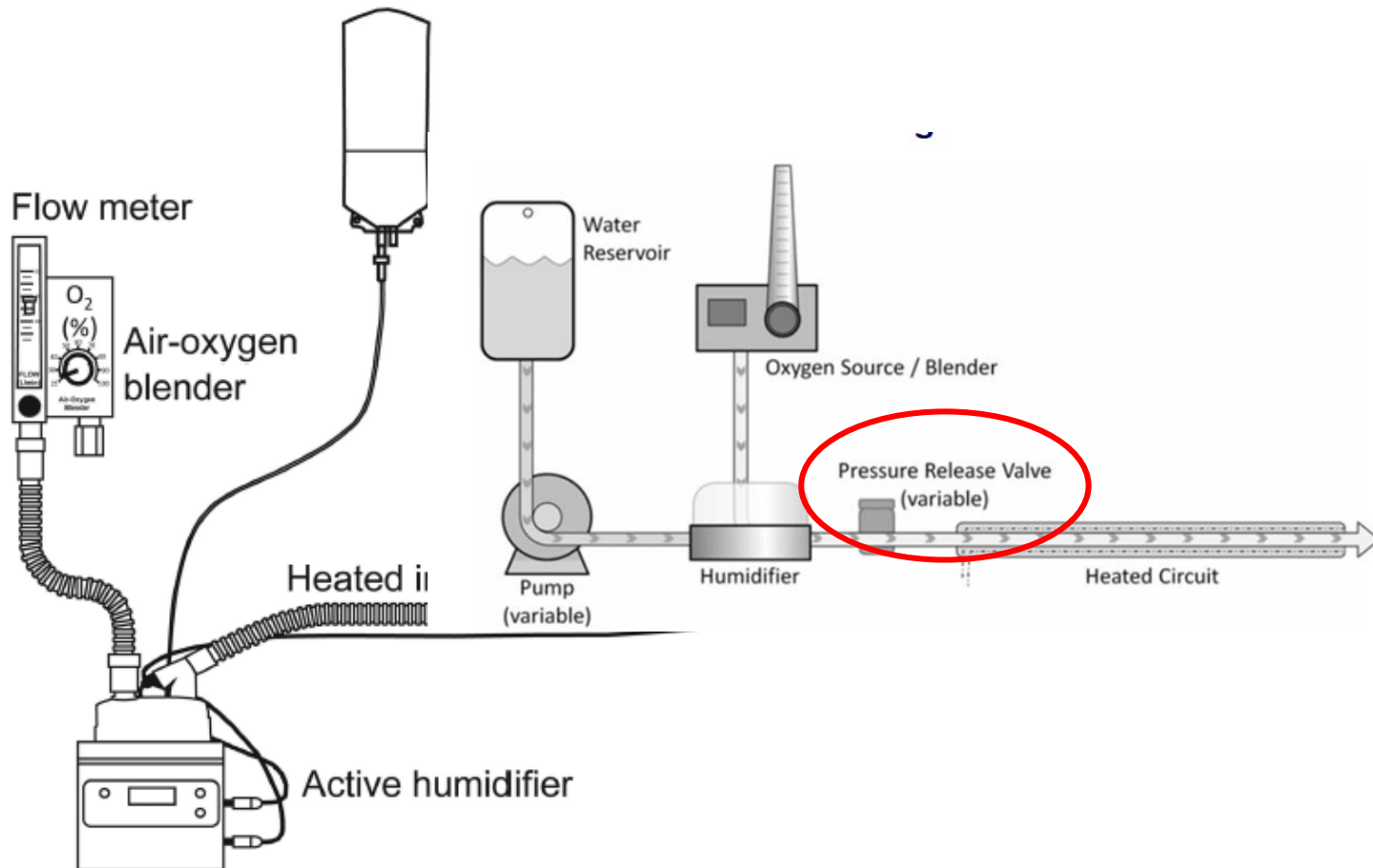
Contents

- ✓ HFNC 는 무엇인가?/ History
- ✓ 주요 관련 문헌 리뷰
- ✓ 원리 mechanism
- ✓ 임상 적용
- ✓ 주의할 점

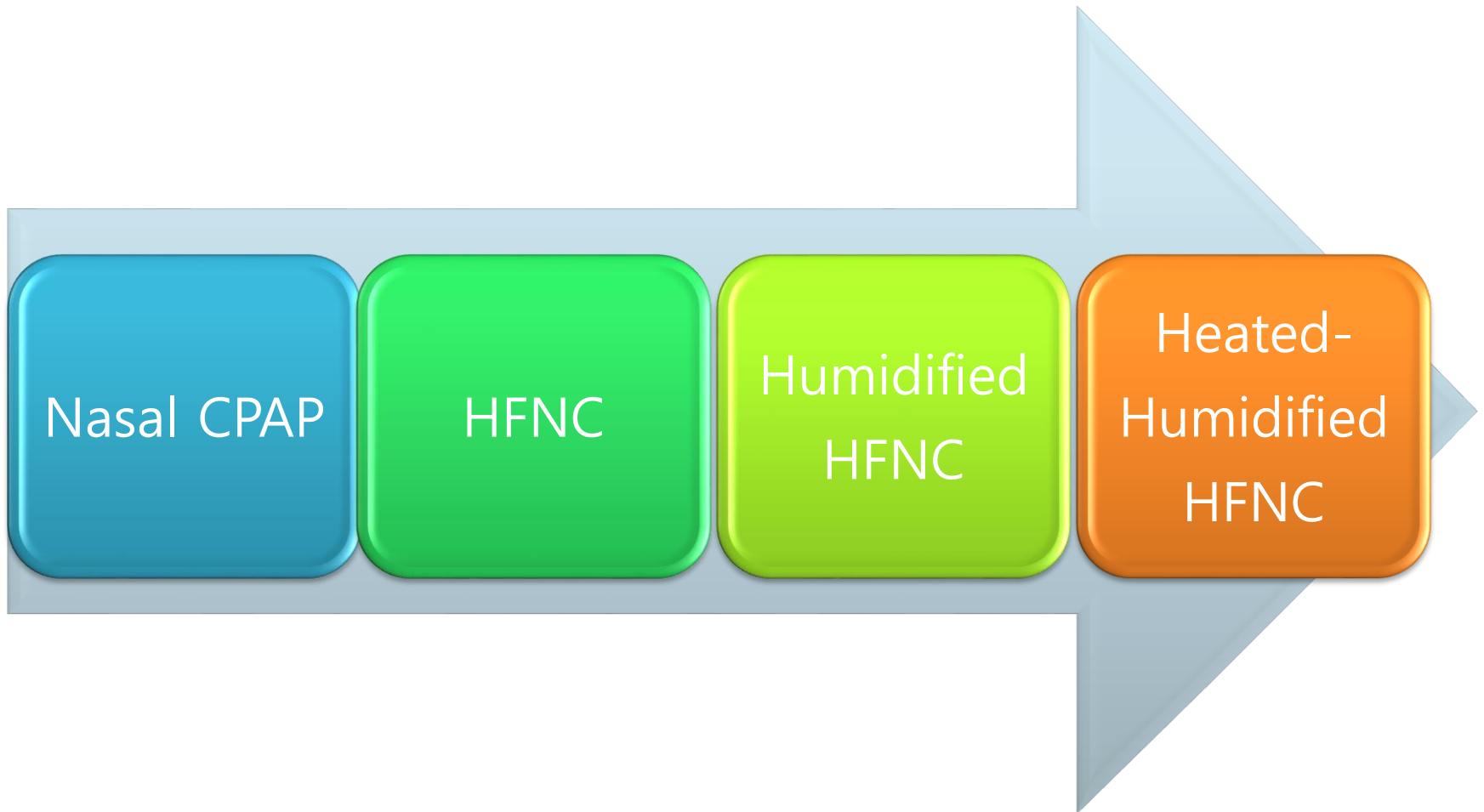
High flow oxygen therapy (HFOT)

High flow nasal cannula (HFNC)

Heated humidified high-flow therapy



High Flow Nasal Cannula



Devices of High flow nasal cannula



Precision Flow™, Vapotherm



Optiflow™, Fisher & Paykel Healthcare



HFT500, MEKICS, Korea



이용 분야의 확대

ICU

GW

ER

Home care
(만성폐질환)

transportation

bronchoscopy

Potential Mechanism - HFNC

TABLE 1] Potential Mechanisms of Clinical Benefit During HFNC Use

Mechanism	Clinical Benefit
Small, loose-fitting nasal prongs	Enhanced comfort ⁵⁻⁷
Heat and humidification	Enhanced comfort ⁵⁻⁷
Increased water content of mucus	Facilitated secretion removal Avoidance of desiccation and epithelial injury ^{8,9}
Decreased metabolic cost of breathing	Reduced work of breathing ^{10,11}
High nasal flow rate	Reduced inspiratory entrainment of room air if mouth closed; more reliable delivery of F_{IO_2} ¹²⁻¹⁴
Washout of upper airway dead space	Improved efficiency of ventilation ¹⁵⁻¹⁷ Enhanced oxygen delivery ¹⁸
PEEP ^{12,19-24}	Counterbalance auto-PEEP Decreased work of breathing

HFNC = high-flow nasal cannula; PEEP = positive end-expiratory pressure.

Giulia et al CHEST 2015; 148 (1): 253 - 261

Major literature review on HFNC

HFNC vs. NIV

High-Flow Nasal Oxygen vs Noninvasive Positive Airway Pressure in hypoxemic patients after cardiothoracic surgery: A Randomized Clinical Trial

Stéphan F, Barrucand B, Petit P, Rézaiguia-Delclaux S, Médard A, Delannoy B, Cosserant B, Flicoteaux G, Imbert A, Pilorge C, Bérard L; BiPOP Study Group.

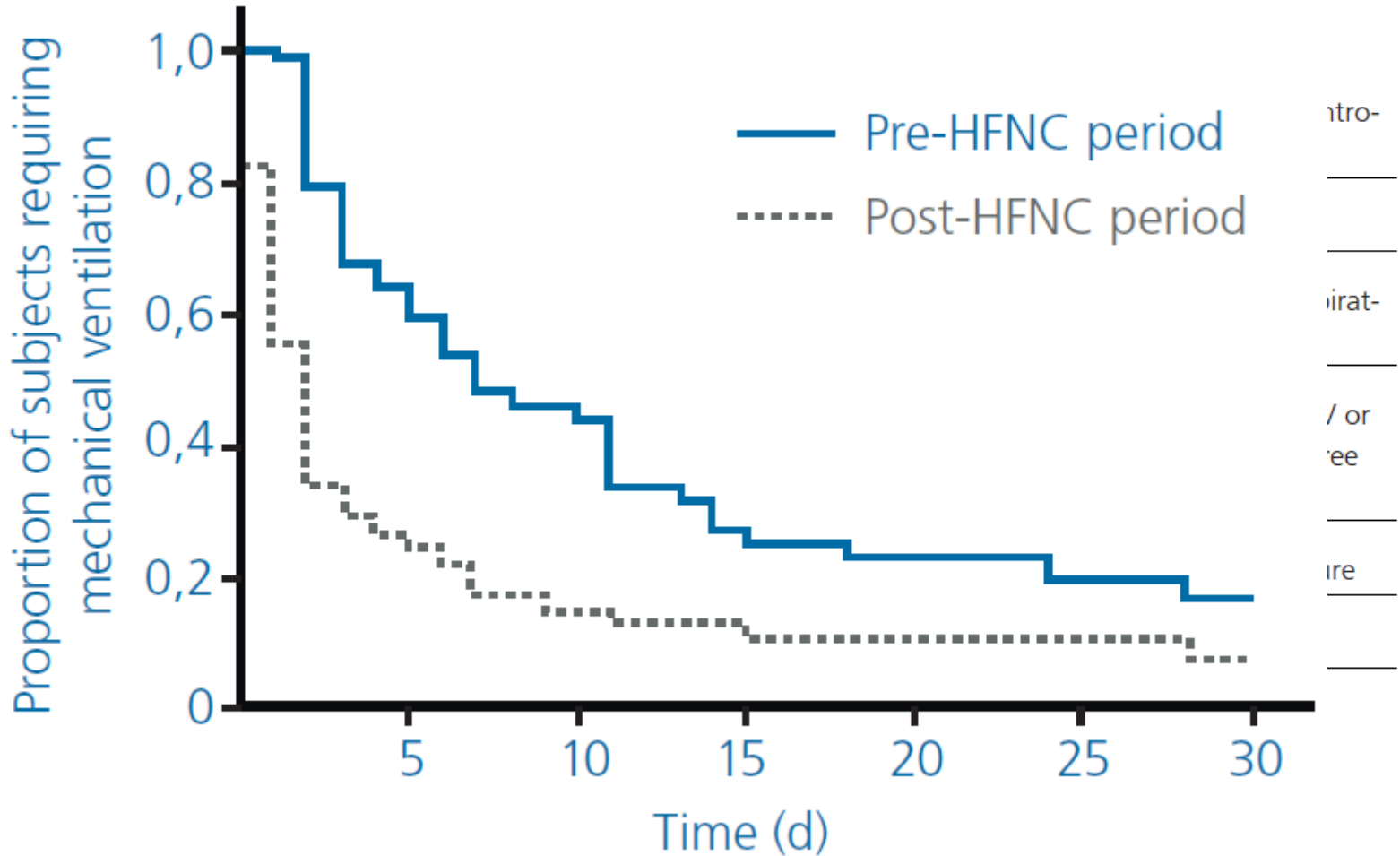
JAMA. 2015 Jun 16;313(23):2331-9.

PMID 25980660, <http://www.ncbi.nlm.nih.gov/pubmed/25980660>

Design	Multicenter, randomized, noninferiority trial comparing high-flow oxygen (flow = 50 l/min) and NIV (PS = 8 cmH ₂ O; PEEP = 4 cmH ₂ O)
Patients	830 patients after cardiothoracic surgery
Objectives	Compare the treatment failure, defined as reintubation, switch to the other study treatment, or premature treatment discontinuation between groups
Main Results	The treatment failed in 87 of 414 patients with high-flow oxygen (21.0%) and 91 of 416 patients with NIV (21.9%). No significant differences were found for intensive care unit mortality (23 patients with NIV [5.5%] and 28 with high-flow oxygen [6.8%]; p = 0.66). Skin breakdown was significantly more common with NIV.
Conclusion	High-flow oxygen was not inferior to NIV in cardiothoracic surgery patients
Comment	Noninferiority study

Efficacy of high-flow nasal cannula therapy in acute hypoxemic respiratory failure: decreased use of mechanical ventilation

Naqata K, Morimoto T, Fujimoto D, Otoshi T, Nakagawa A, Otsuka K, Seo R, Atsumi T, Tomii K.



The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812

JUNE 4, 2015

VOL. 372 NO. 23

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

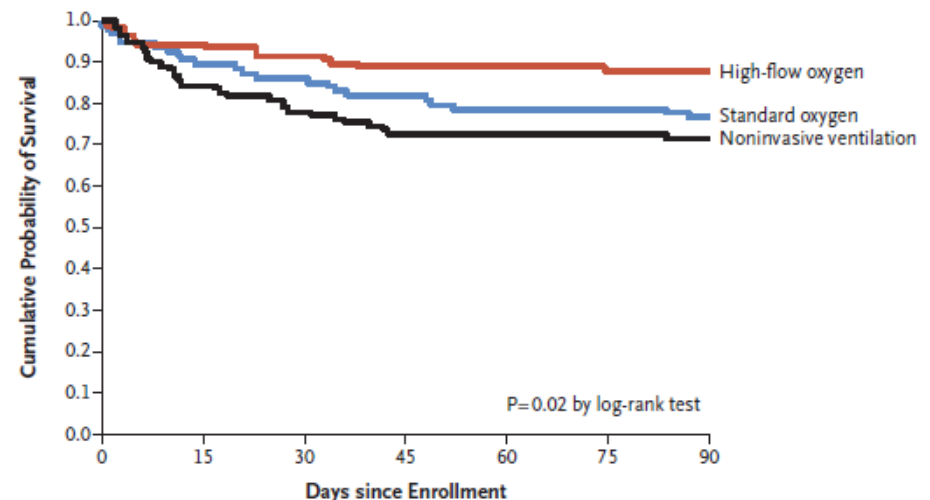
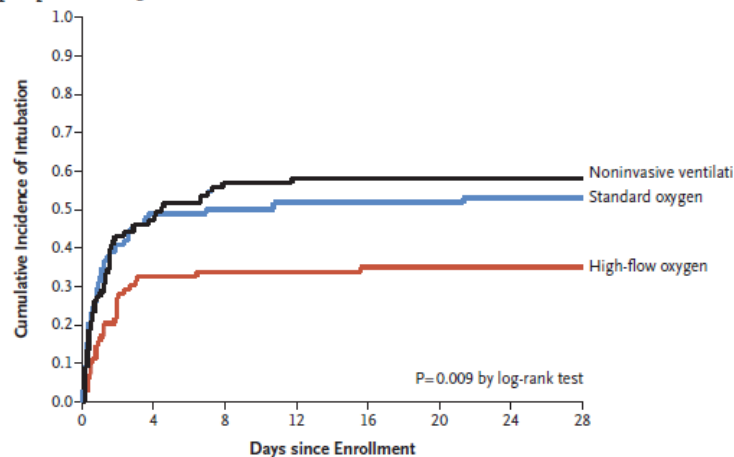
Conclusion

Treatment with high flow oxygen decreased intubation rates in the most severe patients. There was a significant difference in favor of high flow oxygen in 90-day mortality.

Comment

This study shows more intubation and mortality in the group treated by NIV. The hypothesis is that NIV could induce lung injuries by applying high tidal volumes.

B Patients with a $P_{aO_2}:F_{iO_2} \leq 200$ mm Hg



During Intubation

Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia

Miguel-Montanes R, Hajage D, Messika J, Bertrand F, Gaudry S, Rafat C, Labbé V, Dufour N, Jean-Baptiste S, Bedet A, Dreyfuss D, Ricard JD.

Crit Care Med. 2015 Mar;43(3):574-83.

PMID 25479117, <http://www.ncbi.nlm.nih.gov/pubmed/25479117>

Design	Prospective before/after study
Patients	101 ICU patients requiring tracheal intubation
Objectives	Compare pre- and per-procedure oxygenation with either a standard oxygen therapy or a high-flow nasal cannula oxygen (HFNC)
Main Results	Median lowest SpO ₂ during intubation were 94% (83-98.5) with the standard oxygen therapy versus 100% (95-100) with HFNC oxygen (p < 0.0001). SpO ₂ values at the end of preoxygenation were higher with HFNC oxygen. There were more episodes of severe hypoxemia in the standard oxygen therapy group (2% vs 14%, p = 0.03).
Conclusion	HFNC oxygen improved patient safety during intubation

Post-extubation period

Nasal high-flow versus Venturi mask oxygen therapy after extubation. Effects on oxygenation, comfort, and clinical outcome.

Maggiore SM, Idone FA, Vaschetto R, Festa R, Cataldo A, Antonicelli F, Montini L, De Gaetano A, Navalesi P, Antonelli M.

Am J Respir Crit Care Med. 2014 Aug 1;190(3):282-8.

PMID 25003980, <http://www.ncbi.nlm.nih.gov/pubmed/25003980>

Design	Randomized controlled trial: HFNC versus Venturi mask
Patients	105 hypoxemic patients
Objectives	Compare the effects of the Venturi mask and the NHFC on PaO ₂ /FiO ₂ after extubation
Main Results	PaO ₂ /FiO ₂ was higher with the HFNC (287 ±74 vs. 247 ±81 at 24 h; p = 0.03). Discomfort related both to the interface and to airway dryness was better with NHF (respectively, p = 0.006; and p = 0.002). Fewer patients had interface displacements, oxygen desaturations, required reintubation, or any form of ventilator support in the HFNC group.
Conclusion	HFNC resulted in better oxygenation, better comfort, fewer desaturations and interface displacements, and a lower reintubation rate
Comment	HFNC decreased the reintubation rate

Post-extubation period

Effect of postextubation high-flow nasal cannula vs. conventional oxygen therapy on reintubation in low-risk patients: a randomized clinical trial

Hernández G, Vaquero C, González P, Subira C, Frutos-Vivar F, Rialp G, Laborda C, Colinas L, Cuenca R, Fernández R

JAMA. 2016 Apr 5;315(13):1354-61

PMID 26975498, <http://www.ncbi.nlm.nih.gov/pubmed/26975498>

Design	Multicenter randomized clinical trial
Patients	527 patients at low risk for reintubation fulfilling extubation criteria
Objectives	Determine whether high-flow nasal cannula oxygen therapy is superior to conventional oxygen therapy for preventing reintubation
Main Results	Reintubation rate within 72 hours was lower in the high flow group compared with the conventional oxygen group (13 patients [4.9%] vs 32 [12.2%]; $p = 0.004$). Postextubation respiratory failure was lower in the high flow group compared with the conventional oxygen group (22/264 patients [8.3%] vs 38/263 [14.4%]; $p = 0.03$). Time to reintubation was not significantly different between the high flow group (19 h [12-28] vs 15 h [9-31] in the conventional oxygen group; $p = 0.66$).
Conclusion	The use of HFNC oxygen reduced the risk of reintubation in low risk of reintubation patients



가습 (humidification)의 중요성

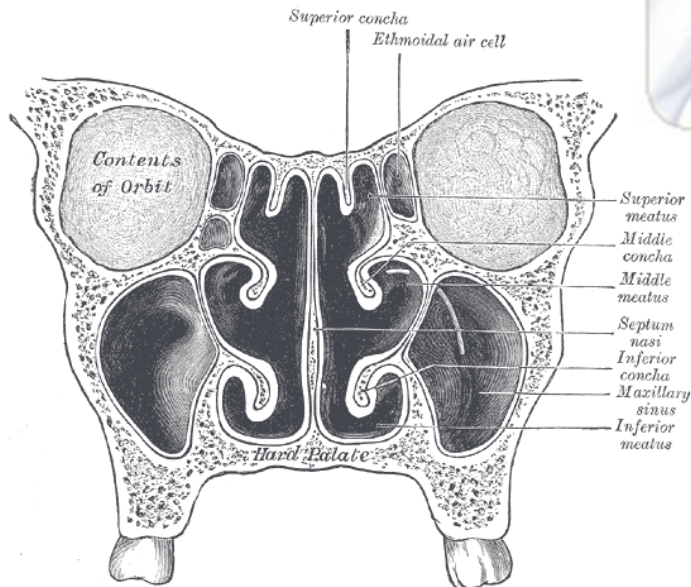
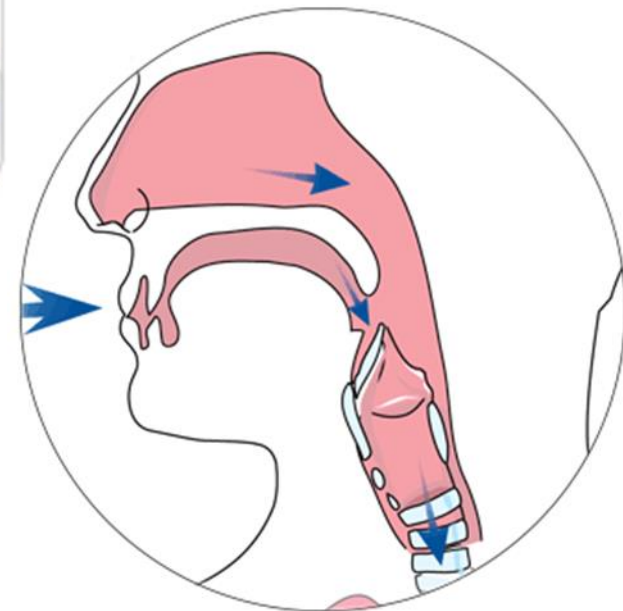
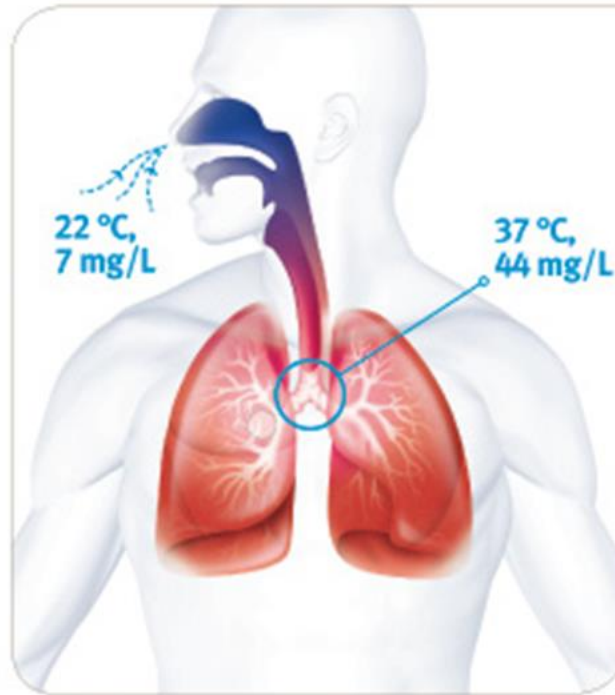
- Improve mucociliary function & secretion expectoration
- Avoid epithelial injury
- Airway resistance
- Decrease metabolic cost of breathing
- Less atelectasis

Normal airway Humidification

22°C 상대 습도 50%

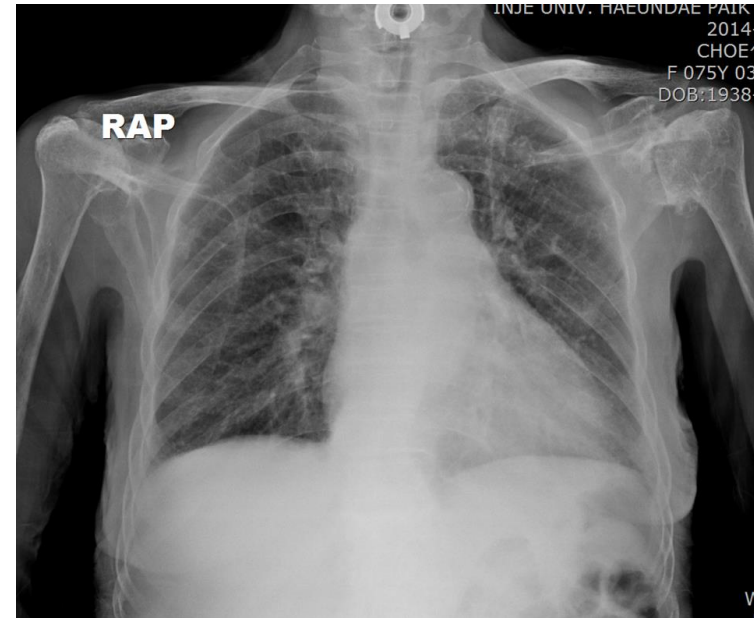
34°C 상대 습도 75%

37°C 상대 습도 100%



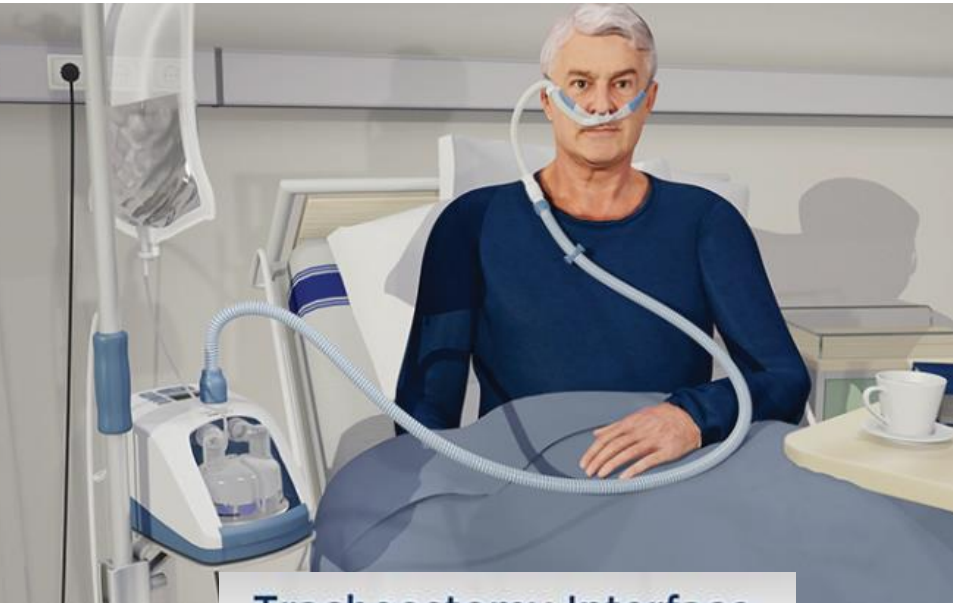
증례 1

- 75/F
- 폐렴으로 ICU care 후 요양병원에서 지냄
- Tracheostomy status
- 최근 간헐적 호흡곤란
- Tracheostomy suctioning 할 때 저항감 및 bloody mucus secretion 에 막히는 증세



기관지경 사진 – trachea mucosa

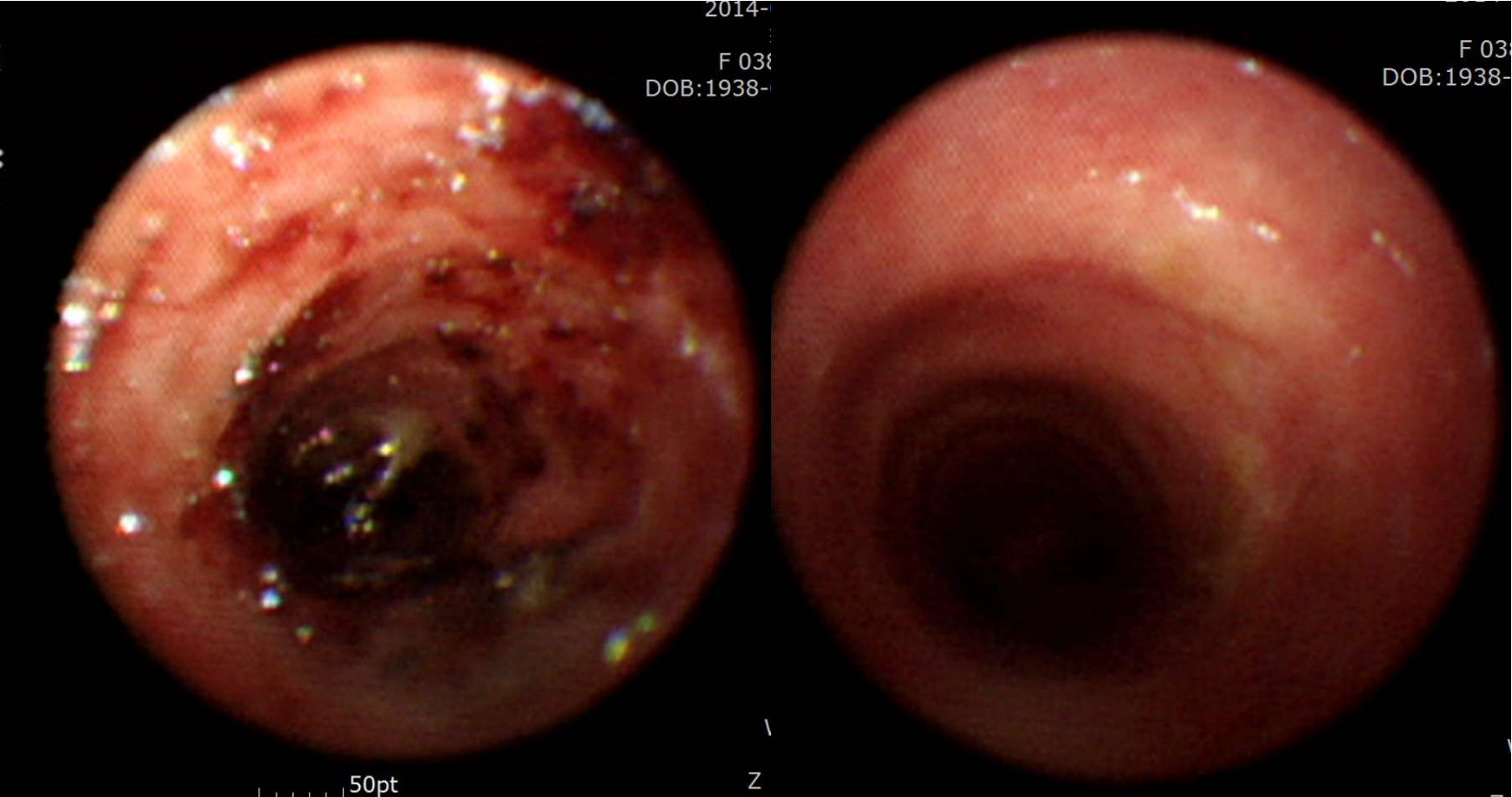




Tracheostomy Interface



4 days after



요양병원으로 전원



“Bubble” humidifier



Gerald Chanques
Jean-Michel Constantin
Magali Sauter
Boris Jung
Mustapha Sebbane
Daniel Verzilli
Jean-Yves Lefrant
Samir Jaber

Discomfort associated with underhumidified high-flow oxygen therapy in critically ill patients

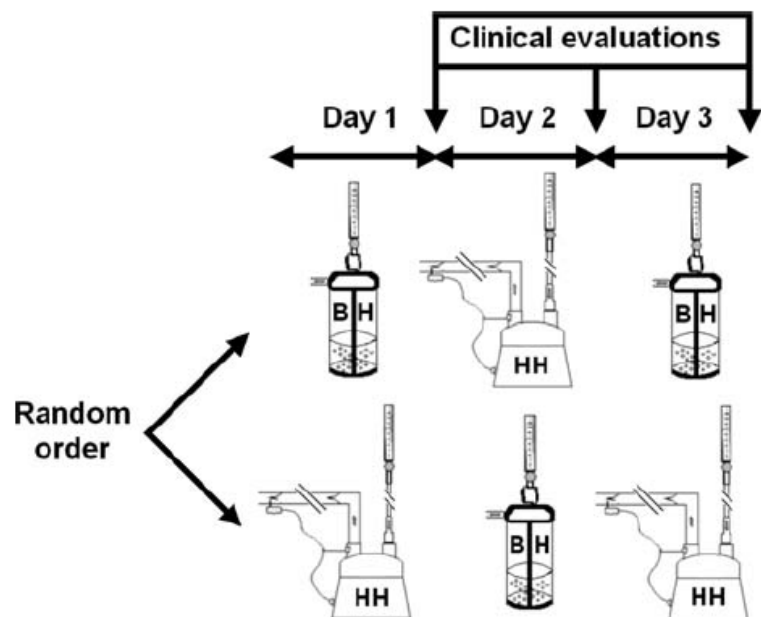
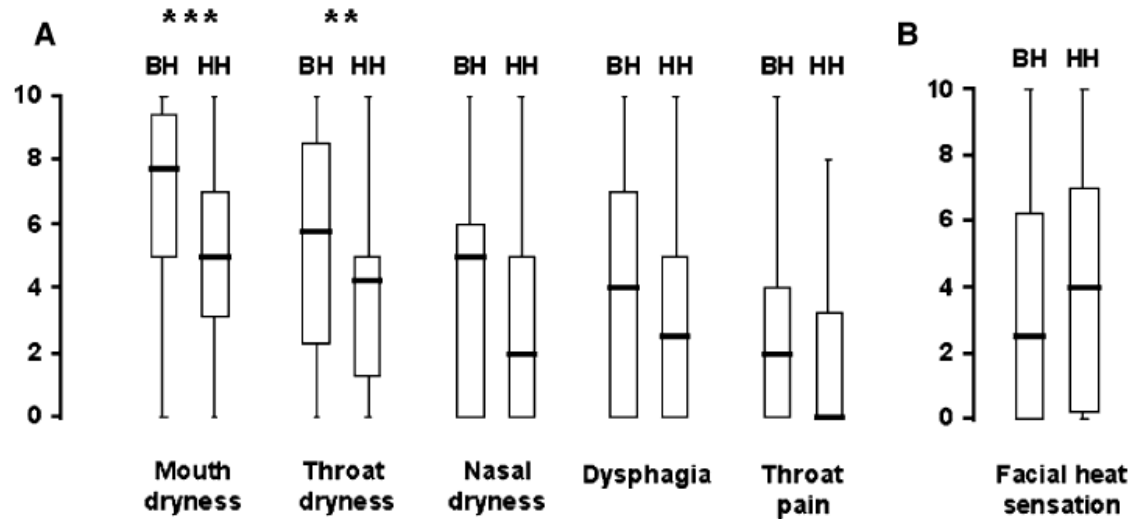
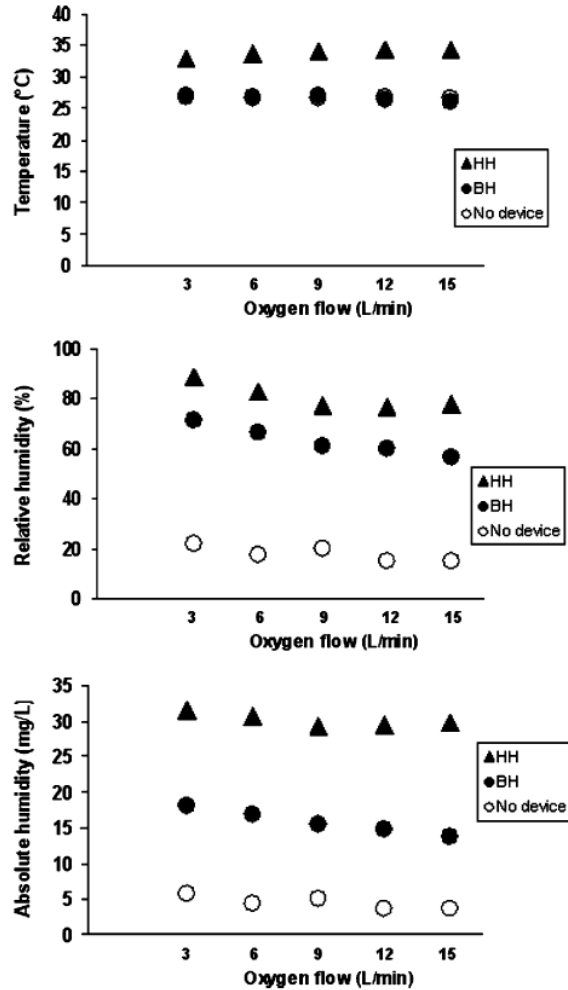


Fig. 2 Design of the clinical study *BH* bubble humidifier; *HH* heated humidifier

Discomfort symptom evaluation

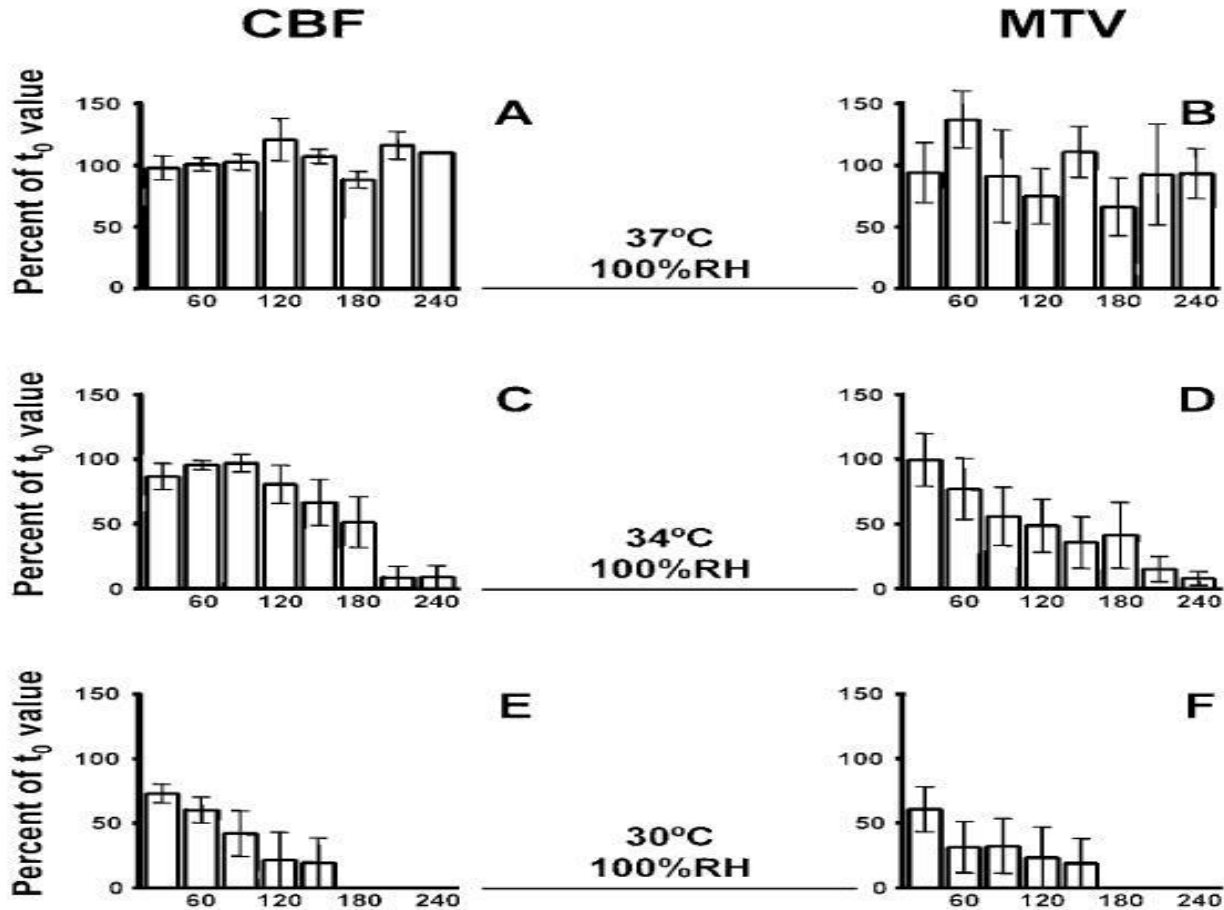
Bubble H vs. heated H



Humidified & Heated HFNC

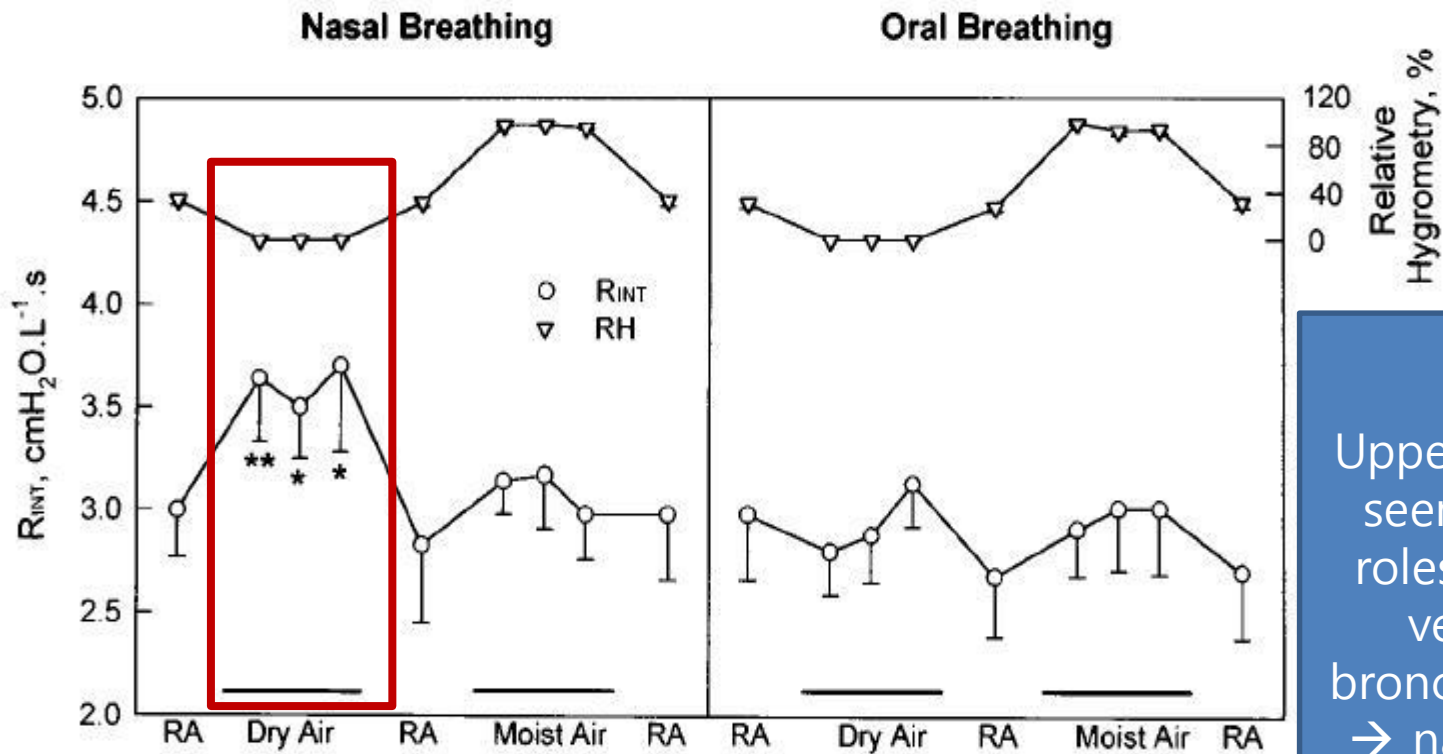
Ciliary beat frequency

Mucus transport velocity



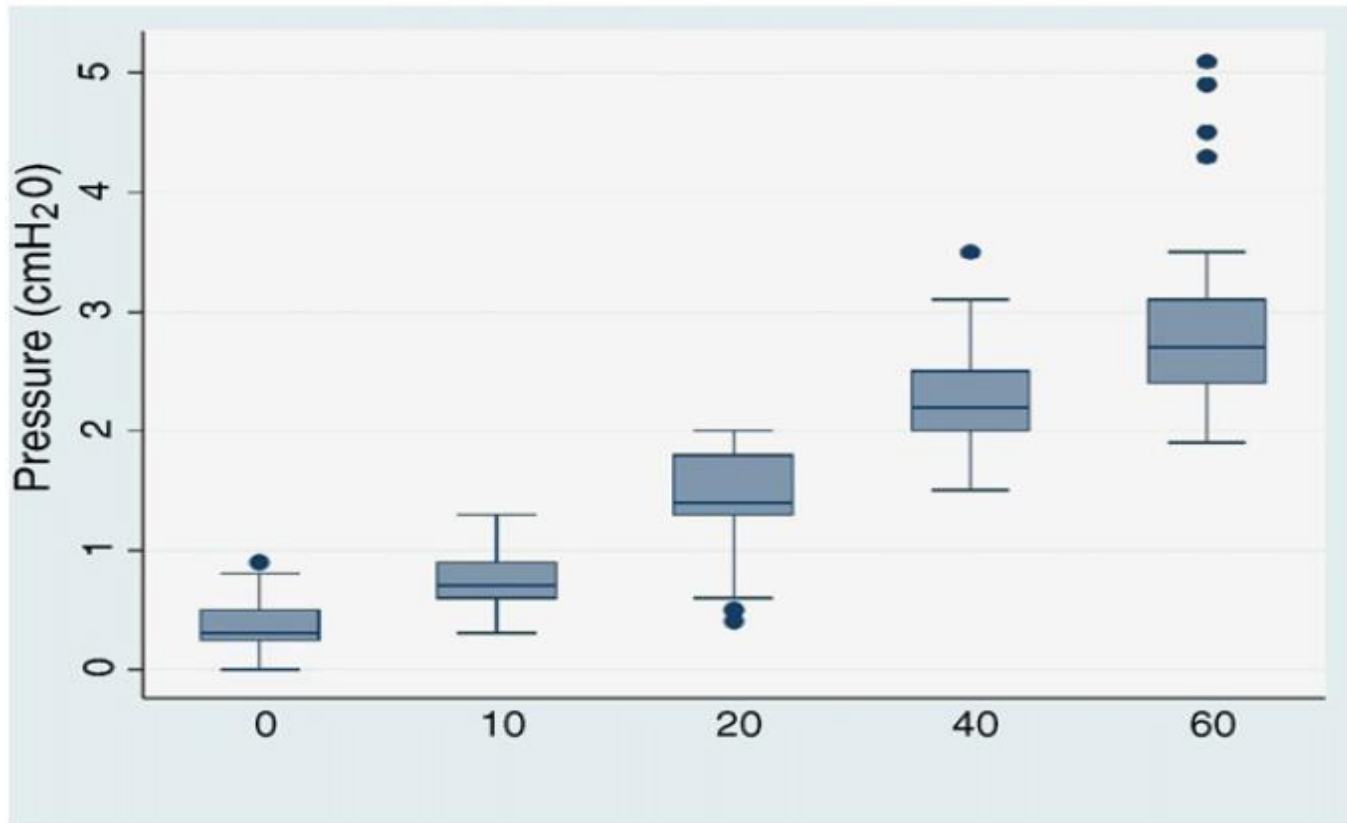
Delivery of inspired gas at 30 °C or 34 ° C, with 100% RH may not be sufficient to prevent epithelial damage

Humidified & Heated HFNC



Upper airway(Nose) seem to play key roles in control of ventilation & bronchomotor tone.
 → nasopulmonary reflex

Nasal continuous positive airway pressure



PAP 는 flow 에
비례해서
발생하고,
closed
mouth에서
증가한다

Figure 1 Expiratory Pharyngeal Pressure- Mouth Open.

Nasal continuous positive airway pressure



Effect of Very-High-Flow Nasal Therapy on Airway Pressure and End-Expiratory Lung Impedance in Healthy Volunteers

Parke RL, Bloch A, McGuinness SP.

Respir Care. 2015 Oct;60(10):1397-403

PMID 26329355, <http://www.ncbi.nlm.nih.gov/pubmed/26329355>

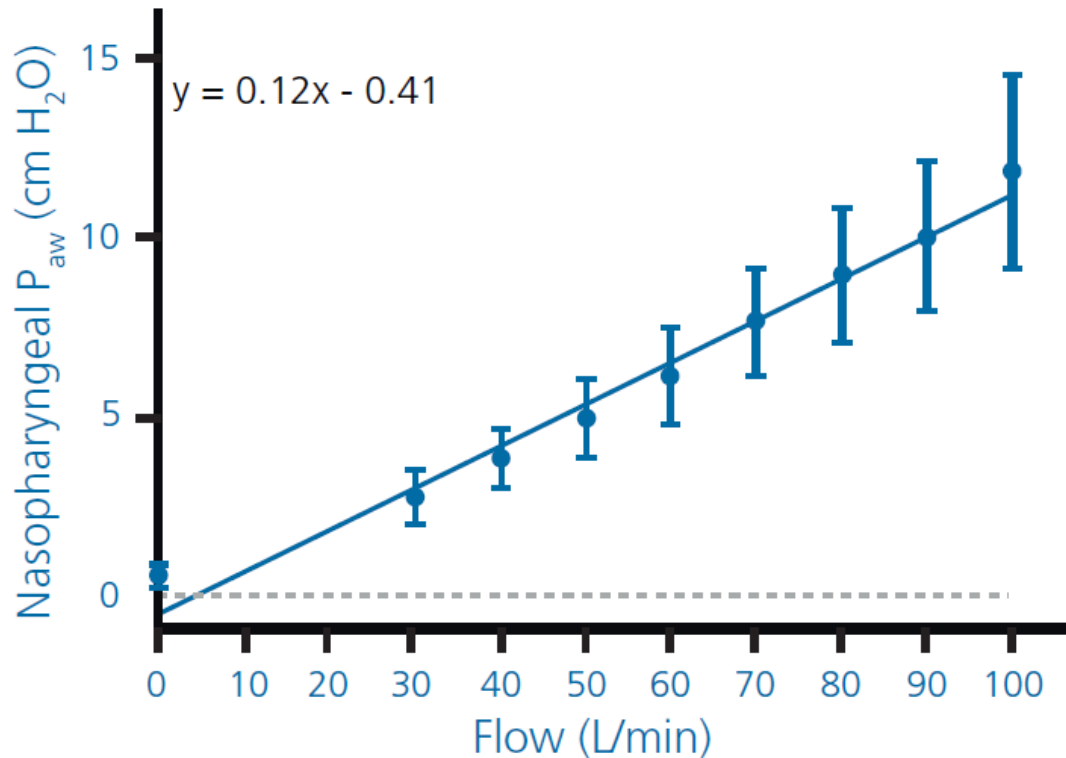
Design Physiological study using EIT

Patients 15 h

Objectives Asses

Main Results Flow
11.9
obse

Conclusion Very

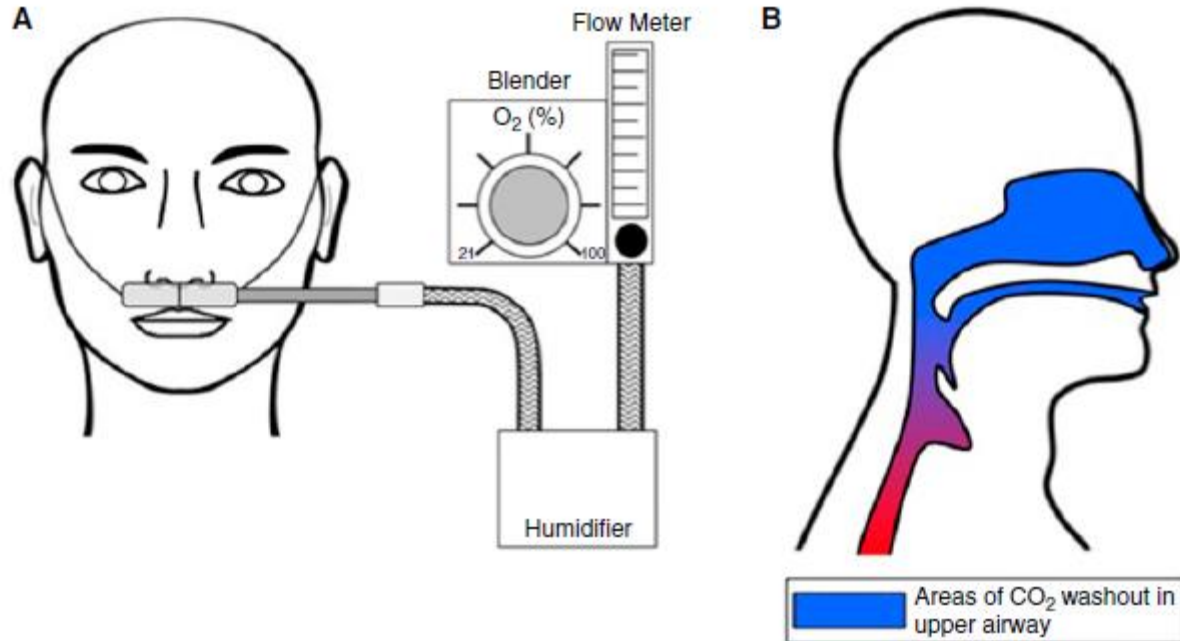


physiology

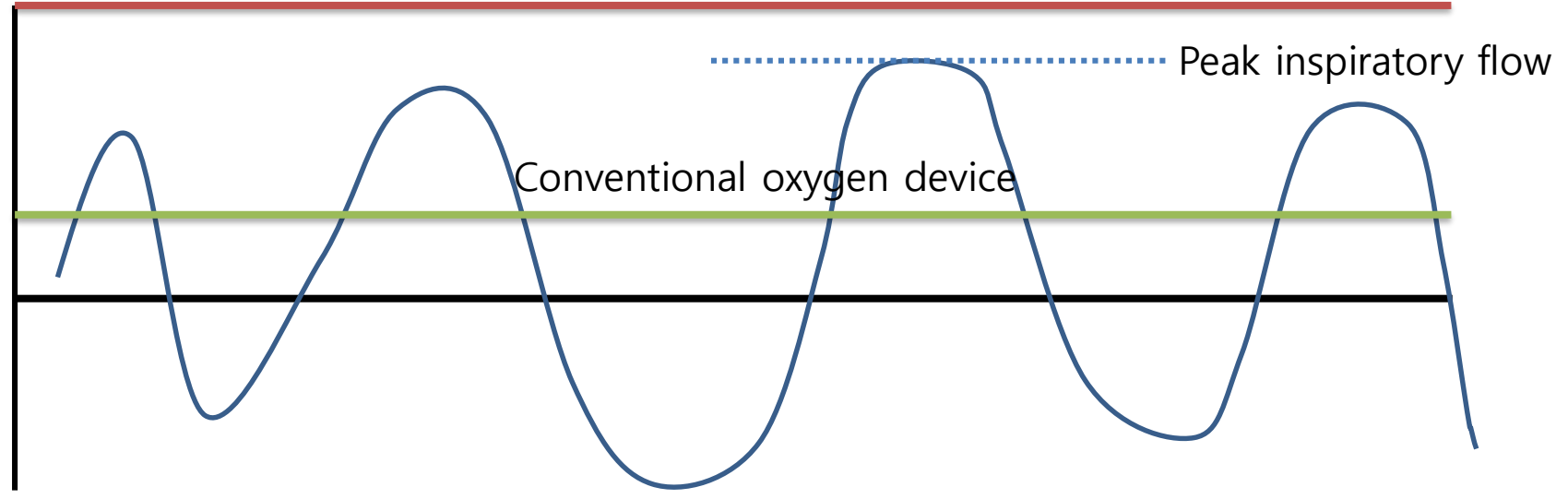
impedance was

Stable FiO₂

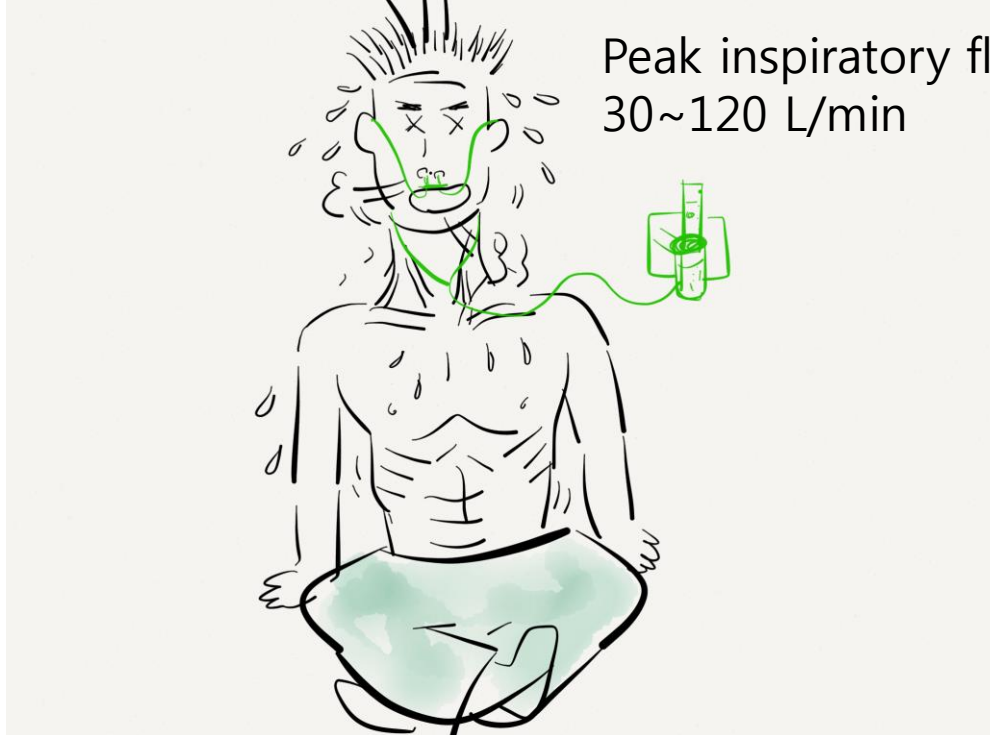
Prevent CO₂ re-breathing



HFNC



Flow



Mechanism of HFNC

Humidification

- Improve mucociliary function & secretion expectoration
- Avoid epithelial injury
- Decrease metabolic cost of breathing

High Flow rate

- Wash out dead space of upper airway
- Generate low-level positive airway pressure
- Reduce Work of Breathing

FiO₂

- More reliable delivery of FiO₂
- Allow to speak, cough and oral intake

Setting of HFNC

Humidification

- 34 ~ 37 도에 맞추어 고정 (환자의 **compliance** 에 따라)

High Flow rate

- Flow rate 는 환자의 demand 에 따라(Inspiratory flow rate = $(TV * RR) / F_{ti}$ (예 - TV 450ml, RR 14, F_{ti} 0.3) = 21L/min)
- 실제적으로는 20L/min ~ 60L/min (RR 과 FIO₂ 의 변화를 고려)

FiO₂

- SaO₂ 를 target 으로 조정(AIM for RR < 25 , SaO₂ > 90%)
- 가능하면 FiO₂ < 0.6

Heated Humidified High-Flow Nasal Oxygen in Adults

Mechanisms of Action and Clinical Implications

Application	Benefits
Procedures	Enhanced oxygenation during endoscopy ⁴⁴
Hypoxemic respiratory failure	
ARDS	Mild and early ⁴⁵
Pneumonia	Enhanced oxygenation ^{5,16}
Idiopathic pulmonary fibrosis	Lower respiratory rate ²⁴
Cardiogenic pulmonary edema	Enhanced oxygenation Reduced dyspnea ⁴⁵
Postoperatively	
Cardiothoracic and vascular	Improved thoracoabdominal synchrony ⁴⁶
Cardiac surgery	Increased end-expiratory lung volume ³⁶ Less escalation of therapy ²⁶
Postextubation	Improved oxygenation and ventilation ⁴⁷ Enhanced comfort ^{6,7} Less displacement of interface ⁴⁷ Less escalation of therapy to noninvasive ventilation or intubation ⁴⁷
Do-not-intubate patients	Improved oxygenation and respiratory mechanics ⁴⁸

HFNC (New insights)

천식악화에 써야 할까요?

COPD 환자에 도움이 되나요?

언제까지 사용해야 하나요?



Asthma

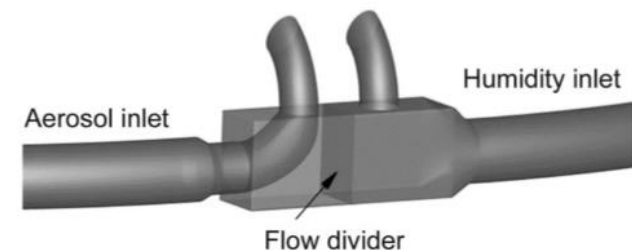
장점 vs. 단점

1) 호흡부전에 대한 효과

2) Aerosol drug delivery

- The available in vitro evidence is not sufficient to make a recommendation for or against aerosol delivery during HFNC
- Few clinical studies
- At high flows, the amount of aerosol delivery is likely to be very low.

“Washout effect of bronchodilator”



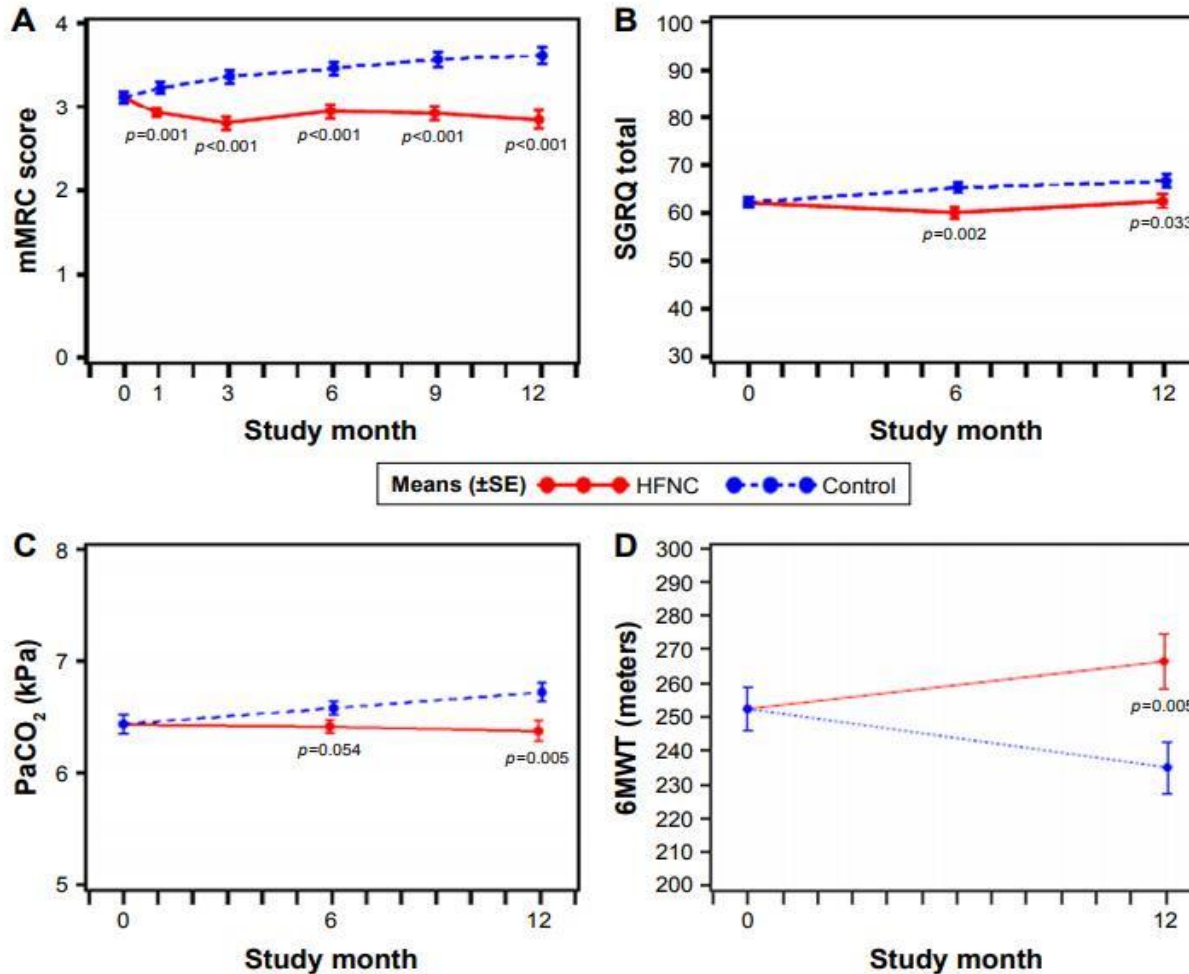
ORIGINAL ARTICLE

Physiological effects of titrated oxygen via nasal high-flow cannulae in COPD exacerbations: A randomized controlled cross-over trial

Intervention status	Time (min)	NHF Mean (SD)	SNP Mean (SD)	NHF minus SNP adjusted for time zero (95% CI)	<i>P</i>
Intervention	0	49.0 (10.3)	48.9 (10.4)	N/A	N/A
	5	48.0 (10.1)	48.8 (10.3)	-0.8 (-1.3 to -0.4)	<0.001
	10	47.3 (10.0)	48.7 (10.1)	-1.5 (-2.1 to -0.8)	<0.001
	15	47.4 (10.0)	48.8 (10.1)	-1.5 (-2.2 to -0.7)	<0.001
	20	47.7 (10.3)	48.3 (10.1) [†]	-0.9 (-1.8 to 0.0) [†]	0.052
	25	47.8 (10.1)	48.0 (10.0) [†]	-0.6 (-1.5 to 0.3) [†]	0.19
	30	47.4 (10.1)	48.5 (10.1) [†]	-1.4 (-2.2 to -0.6) [†]	0.001
Washout	35	47.2 (10.0) [‡]	48.3 (10.0) [†]	-0.9 (-1.9 to 0.04) [‡]	0.059
	40	46.5 (9.4) [§]	48.8 (10.1) [‡]	-1.0 (-1.9 to -0.01) [¶]	0.047
	45	47.2 (9.4) [‡]	48.4 (9.9) [‡]	0.3 (-1.3 to 0.7) [§]	0.49

Reduction in PtCO₂ – small, unlikely clinically significant
 Reduction of respiratory rate -> decrement of work of breathing
 (Increased alveolar volume, tidal volume, reduction of dead space)

COPD (Hypercapnic respiratory failure)



LTOT 를 필요로 하는 COPD 환자군에서 HFNC 의 적용은 급성 악화 및 입원을 줄여주고, 삶의 질 및 PaCO₂ 감소 효과를 보여주었다

Predictor of HFNC therapy failure ?

Intensive Care Med (2015) 41:623–632
DOI 10.1007/s00134-015-3693-5

ORIGINAL

Byung Ju Kang
Younsuck Koh
Chae-Man Lim
Jin Won Huh
Seunghee Baek
Myongja Han
Hyun-Suk Seo
Hee Jung Suh
Ga Jin Seo
Eun Young Kim
Sang-Bum Hong

Failure of high-flow nasal cannula therapy may delay intubation and increase mortality

Failure of HFNC might cause delayed intubation(after 48hrs) and worse clinical outcomes in patients with respiratory failure. But no contributing factor...

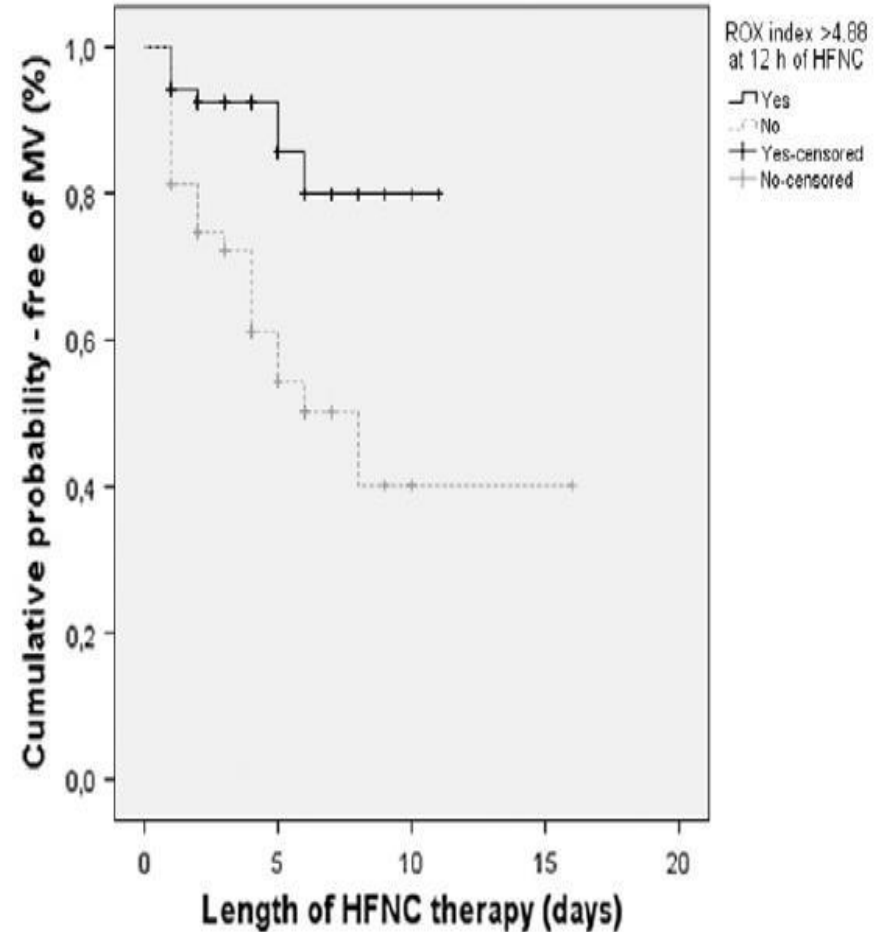
After apply of HFNC, closed observation of Respiratory rate !

ROX INDEX

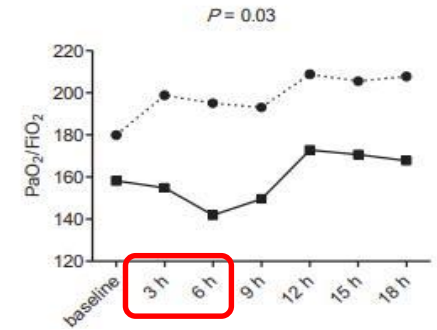
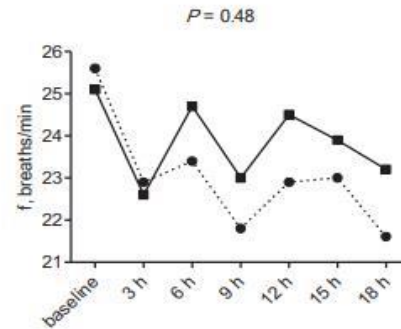
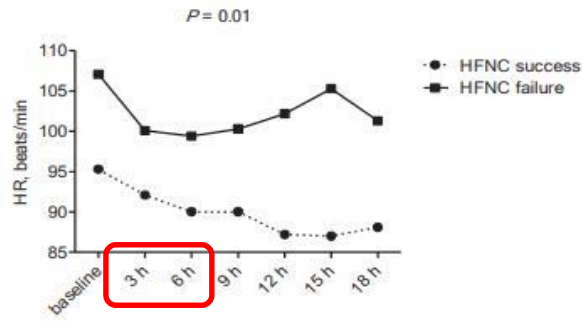
PaO₂/FiO₂ to RR < 4.88 이하면 실패의 가능성이 높다
(Oxygenation 과 호흡양상이 호전 안되면 실패한다)
HFNC 실패하면 사망률이 증가한다

Respiratory variables during HFNC treatment

Variable	Time	HFNC success	HFNC failure	P
SpO ₂ /FiO ₂	2 h	100 (98-125)	99 (95-124)	.291
	6 h	121 (99-160)	100 (96-140)	.202
	12 h	129 (115-162)	100 (96-126)	.007
	18 h	158 (115-165)	100 (95-133)	.030
	24 h	162 (125-205)	104 (95-124)	.001
RR (beats per minute)	2 h	25 (20-28)	26 (22-28)	.223
	6 h	24 (20-27)	24 (21-29)	.480
	12 h	22 (18-26)	26 (22-28)	.059
	18 h	22 (19-25)	28 (24-33)	.001
	24 h	21 (18-24)	25 (22-30)	.121
Paco ₂ (mm Hg)	2 h	36.00 (32.75-40.18)	37.75 (31.78-45.53)	.849
	6 h	36.80 (34.00-43.23)	36.20 (32.28-43.50)	.932
	12 h	38.25 (33.75-42.53)	40.70 (35.00-49.40)	.312
	18 h	39.00 (34.75-43.60)	40.00 (31.80-51.50)	1.000
	24 h	37.75 (33.75-42.40)	39.50 (30.00-46.10)	.710
Flow (L/min)	2 h	40 (40-60)	55 (40-60)	.470
	6 h	40 (40-60)	50 (40-60)	.695
	12 h	40 (40-60)	55 (40-60)	.226
	18 h	40 (40-60)	55 (40-60)	.329
	24 h	40 (40-60)	40 (40-60)	.769
ROX index	2 h	4.40 (3.53-5.62)	3.65 (3.17-5.41)	.216
	6 h	4.95 (4.13-7.34)	4.60 (3.73-5.71)	.426
	12 h	5.89 (4.58-7.85)	4.36 (3.55-5.31)	.001
	18 h	6.09 (5.05-8.17)	4.18 (3.14-5.41)	.003
	24 h	7.69 (5.33-10.00)	4.19 (3.61-5.22)	<.001

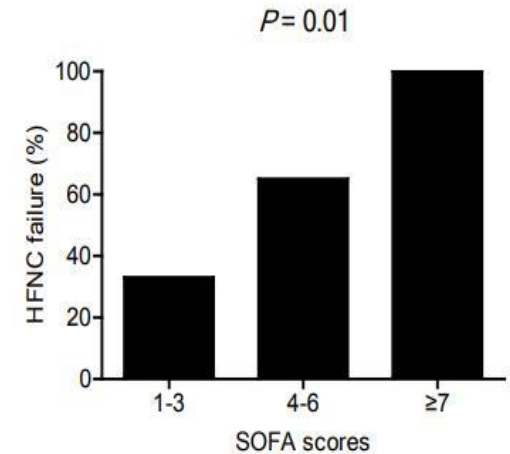
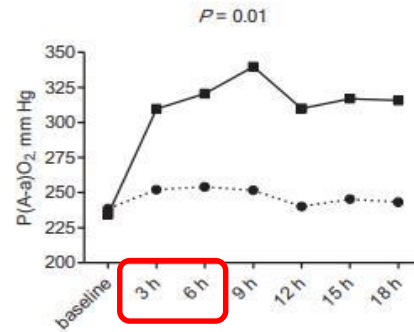
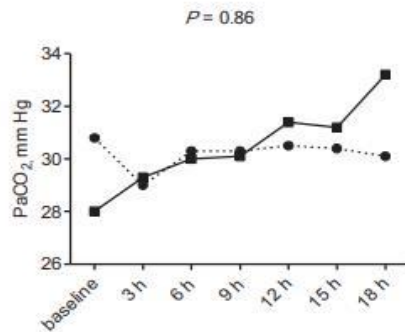


Predictors of high flow nasal cannula failure in immunocompromised patients with acute respiratory failure due to non-HIV pneumocystis pneumonia



No. on HFNC

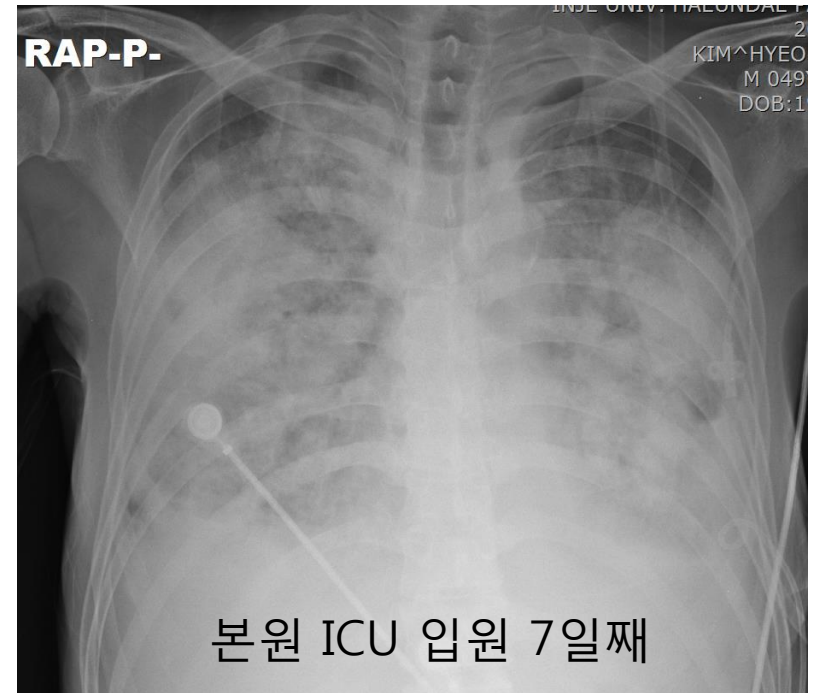
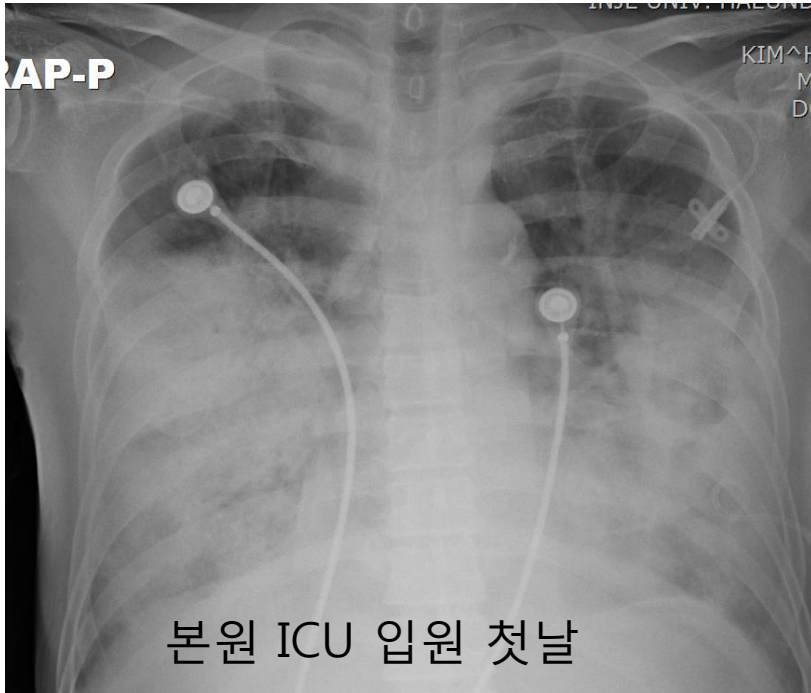
HFNC success	23	23	23	23	23	23	23
HFNC failure	29	29	26	22	20	17	16



Organ dysfunction
Failure of early oxygenation improvement

49/M, pneumonia, lung abscess

타 병원에서 1주일 입원 치료 중 호전 없어 전원



PH	7.44
PCO ₂	38
PO ₂	73
Ca ²⁺ (Ionized)	0.87
Base Excess-ECF	1.6
Base Excess-Blood	1.6
Standard bicarbonate	26.1
Actual bicarbonate	25.8
Total CO ₂	27.0
O ₂ Saturation	95

7.37
63
63
0.95
11.1
9.2
32.0
36.4
38.3
91

입원 7일째 ,,,,

- **HFNC Fio2 100% flow 60 L/min**
- spO2 92~94%
- Respiration rate **35/min**
- Intubation 성공
- SPO2 81% → 인공호흡기 적용 high PEEP 적용에도 감소 추세
- Cardiac arrest → CPR
- ROSC ; inhaled nitric oxide 적용
- No response → 다시 cardiac arrest on CPR

- Emergent Veno-arterial ECMO 적용
- 며칠 후 veno-veno ECMO 로 전환



Predictor of HFNC therapy failure ?

“Decision to intubate”

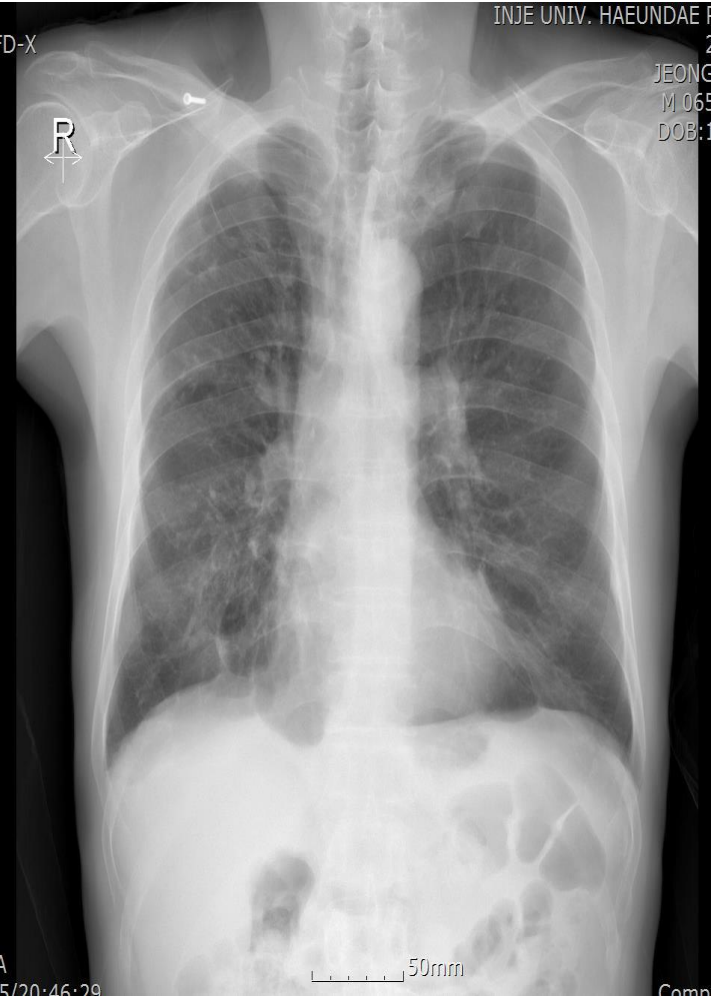
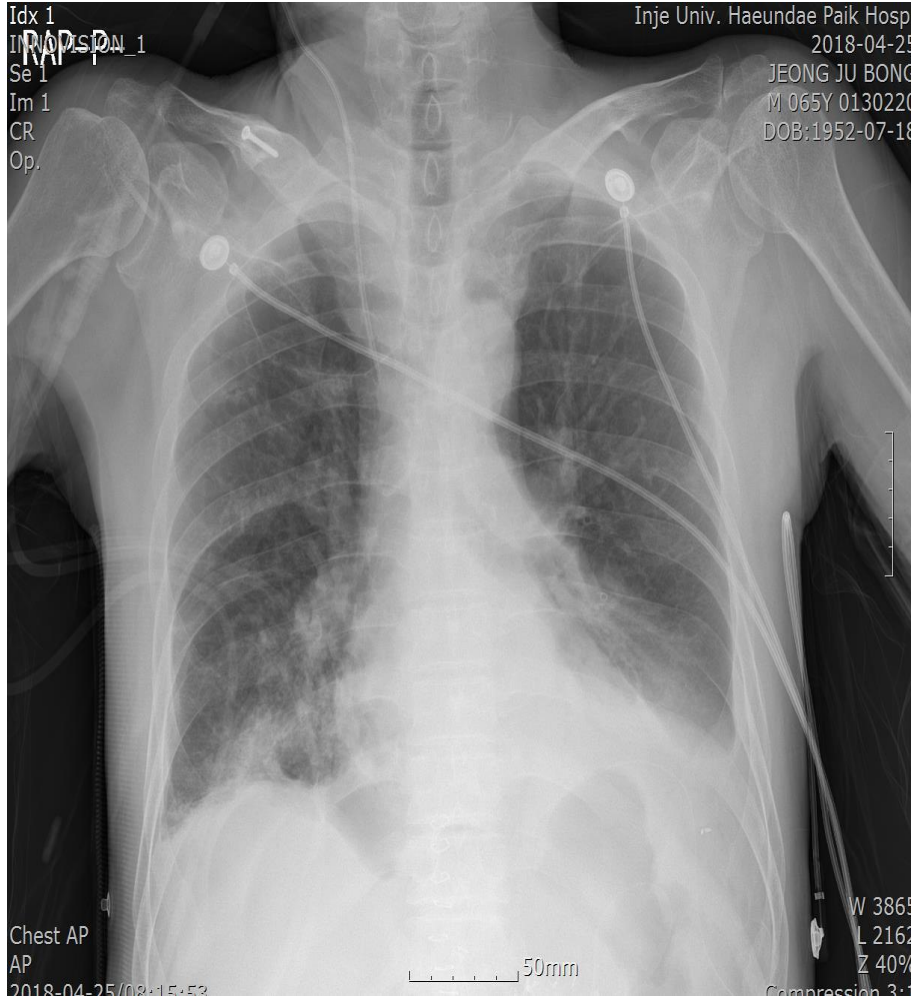
- 1) HFNC 로 버티는 severe hypoxemic respiratory failure 환자는 spO₂, pO₂ 만 보고 판단하지 말고 환자의
 - Status of ventilatory fatigue, failure (caution for mild hypercapnia)
 - Hemodynamic status (septic shock , cardiac function)
 - Metabolic status (sepsis, metabolic acidosis)을 close observation 하면서 결정
- 2) Intubation 과정이 매우 위험할 수 있음을 예상하고 대비
 - Volume status, vasomotor collapse after intubation
 - Preparation for resuscitation, call for help, back up system
- 2) Mechanical ventilation and high PEEP 을 적용한 후에도 상황이 어려울 수 있음을 대비하자 (rescue therapy for ARDS!)

Case

- M/65
- Ex-smoker
- Distal pancreatectomy 수술 시행
- PFT – ratio 39%, FVC 90%, FEV1 – 48%, DLco – 74%

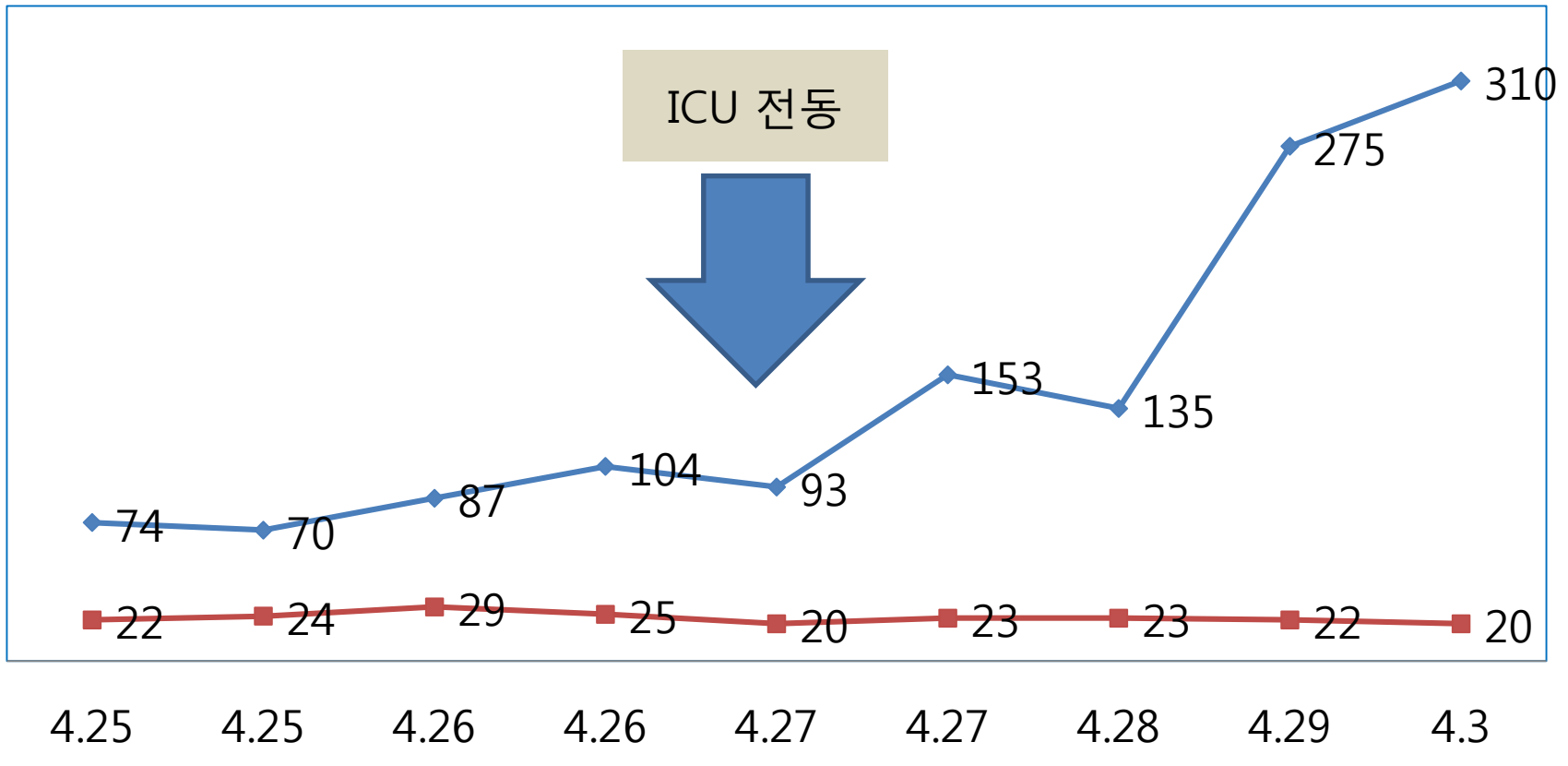
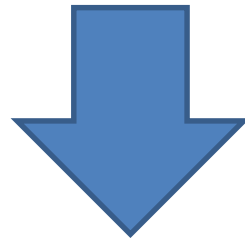
s/p O&C, pancreatic head cancer # old TB # COPD 안녕하십니까 교수님 상환자분 일전에 보셨던 분으로 POD#2인 분입니다. 환자분 금일 새벽부터 dyspnea 호소하시고 saturation, PO2 감소로 pain control하는 중이나 여전히 호흡곤란 남아있는 상태입니다. 귀과적인 고견여쭙고자 합니다. 고진선처 바라겠습니다

PFT – severe obstructive pattern c moderate decreased DLco clear B.S
p) COPD 의 급성 악화 보다는 수술 이후 OP wound 에 따른 deep breathing 장애, 객담 배출 장애에 따른 atelectasis 에 의한 소견으로 생각됩니다 HFNC (Flow 60L/min, 37도, FiO2 0.5) 로 시작하시면, 호흡일도 감소하고, humidification 에 도움이 되어 객담배출에도 용이합니다. (HFNC 가 꼭 필요한 경우로 이후 천명음발생 또는 CO2 retention 될 경우 재협진 부탁드립니다

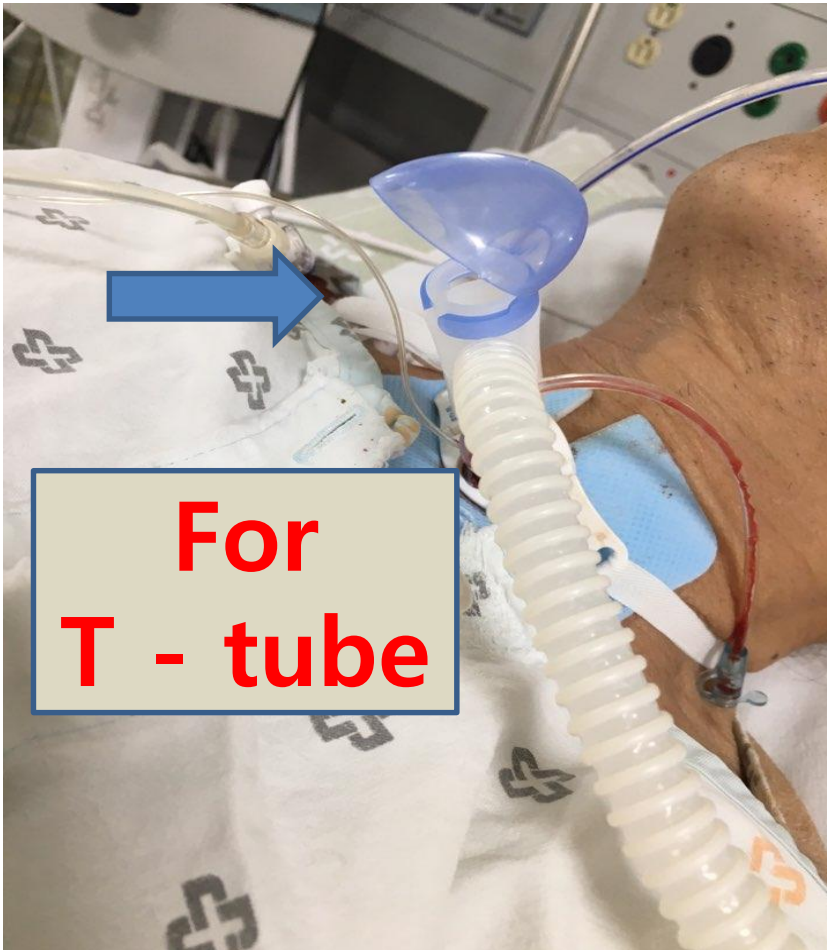


◆ PF ratio ■ RR

ICU 전동



Additional Use

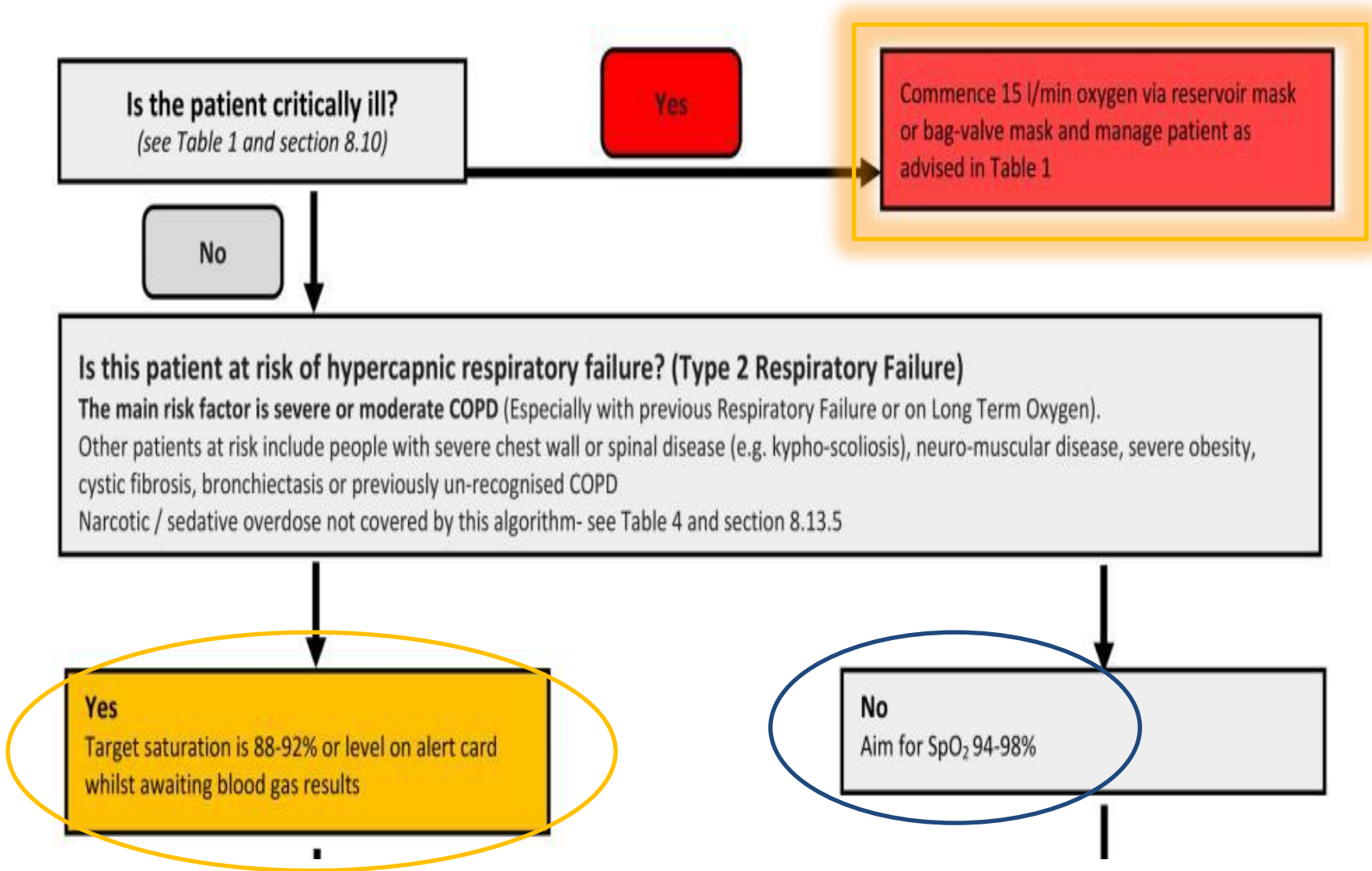


Summary

- HFNC 는 Heating – Humidification – High flow 의 장점이 있다
- HFNC는 Invasive ventilator 이전, 이후 단계에서 매우 유용한 수단이다
 - 기관 삽관 전
 - 기관 삽관 할 때
 - 탈관 후 재 삽관 예방
 - 상기도 유지
- HFNC failure 의 예측이 환자의 예후에 중요하다
- **Criteria for starting and stopping it, indications for treatment escalation**

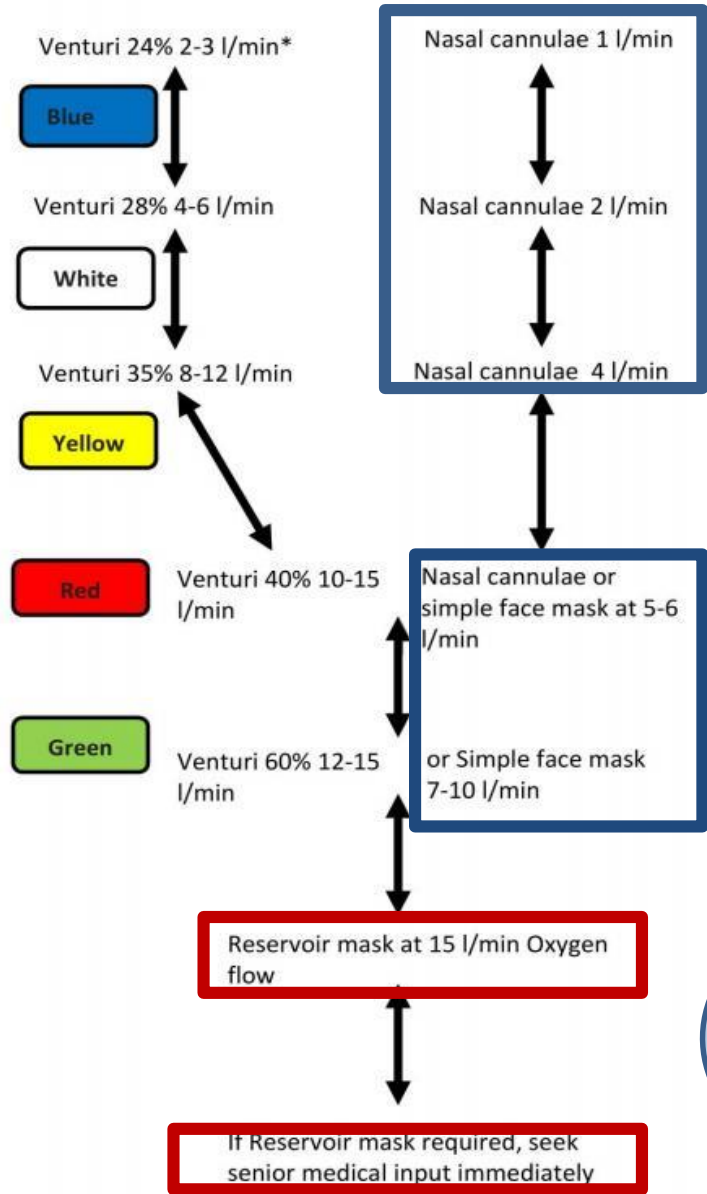
감사합니다





Seek medical advice if patient appears to need increasing oxygen therapy or if there is a rising NEWS or Track and Trigger score.

All Patients **must** have ABG or Earlobe Blood Gases (ELBG) within **1** hour of requiring increased oxygen dose.



Signs of Respiratory Deterioration

- ↑ Resp Rate (especially if >30)
- ↓ SpO₂
- ↑ oxygen dose needed to keep SpO₂ in target range
- ↑ EWS/Trigger score

CO₂ Retention

- Drowsiness
- Headache
- Flushed face
- Flapping Tremor

Seek Medical Advice

HFNC