Home Mechanical Ventilation in ICU

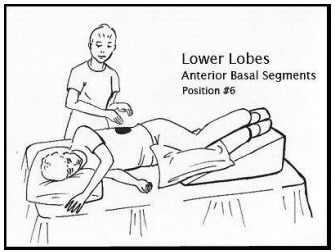
Sunghoon Park
Department of Pulmonary, Allergy and Critical Care Medicine
Director of ICUs
Hallym University Sacred Heart Hospital

Pulmonary rehabilitation

Excercise for respiratory muscle function + Management of airway secretion

Postural drainage

https://rtmagazine.com/department-management/clinical/physiotherapy-icu/



Percussion

https://www.verywellhealth.com/postural-drainage-4020317

Incentive spirometry

High-frequency oscillation

Oscillatory (flutter valve) device

Cycle ergometer

Upper body exercise

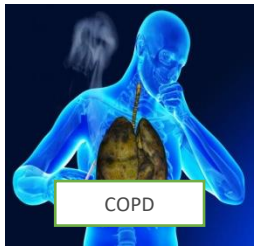
Upper body exercise

Jang et al . Acute Crit Care 2019;34:1-13

HMV > rehabiliataion

Who can get benefits from HMV?

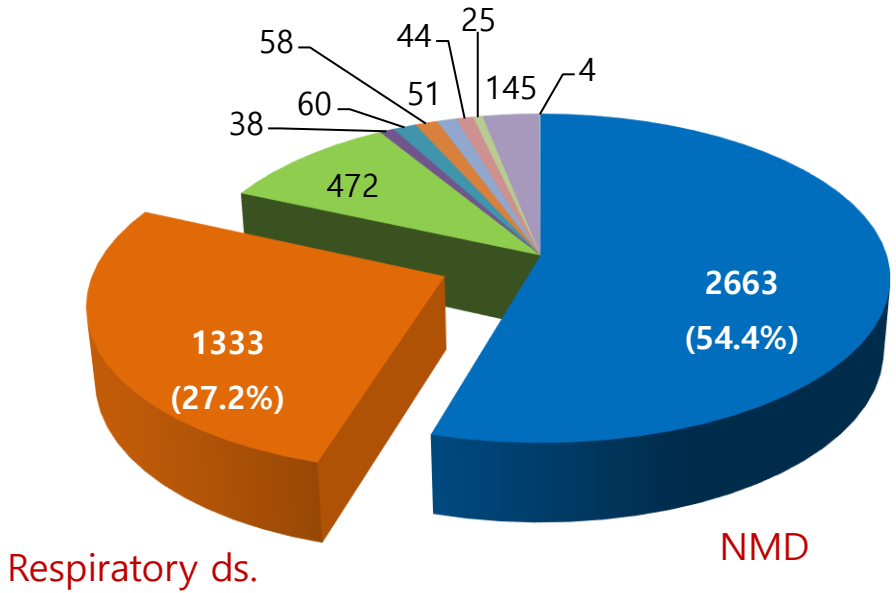
- Chronic obstructive pulmonary disease (COPD)
- Neuromuscular disorder (NMD)
- Chest wall disorder (CWD)
- Obesity hypoventilation syndrome (OHS)



Contents

- Considerations for specific diseases
- Interfaces (mask)
- Ventilator machine and circuits
- Ventilator mode and settings
- Humidification and ancillary devices
- Safety issue

Primary diagnoses for HMV in Korea



- NMD
- Respiratory Ds. (COPD, BE, ILD, TB)
- Cerebrovascular Ds.
- Congenital Ds.
- Central sleep apnea
- Chest wall disorder
- Brain tumors
- Neonatal respiratory failure
- Metabolic Ds.
- C-spine injury
- Prion Ds.

Kim et al. Respir Care. 2019;64:528-535

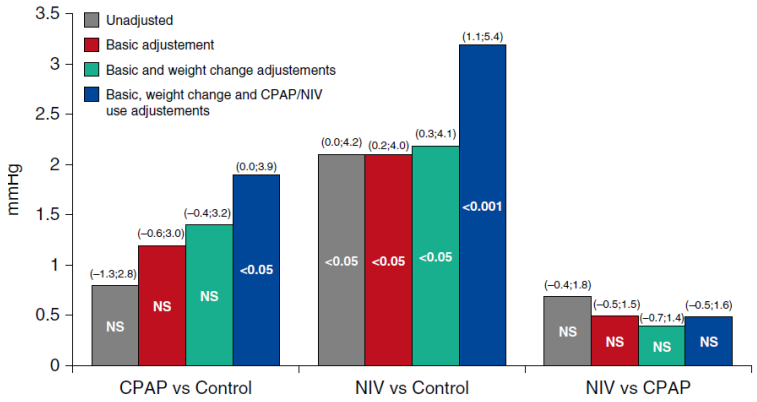
OHS

ORIGINAL ARTICLE

Efficacy of Different Treatment Alternatives for Obesity Hypoventilation Syndrome

Pickwick Study

Juan F. Masa[1,2], Jaime Corral[1,2], Maria L. Alonso[2,3], Estrella Ordax[2,3], Maria F. Troncoso[2,4], Monica Gonzalez[5], Soledad Lopez-Martínez[6], Jose M. Marin[2,7], Sergi Martí[2,8], Trinidad Díaz-Cambriles[2,9], Eusebi Chiner[10], Felipe Aizpuru[11,12], and Carlos Egea[2,13]; on behalf of the Spanish Sleep Network*



Change of PCO_2

	Intragroup Differences [*Mean (SD)*]		
	NIV	**CPAP**	**Control**
ESS	−4.8 (5)*	−4.3 (4.7)*	−1.0 (4.4)
FOSQ	4.3 (17)§	5.1 (16)‖	−1.7 (16)
SF-36, physical	1.8 (8.7)	1.2 (8.9)	0.2 (6.8)
SF-36, mental	1.7 (14)	4.6 (12)‖	1.2 (8.8)
VAWS	11 (25)*	8.1 (21)‖	2.1 (17)
Weight, kg	−2.4 (6.6)‖	−1.1 (5.6)	−1.6 (5.0)‖

VAWS = visual analogical well-being scale
ESS = Epworth sleepiness scale

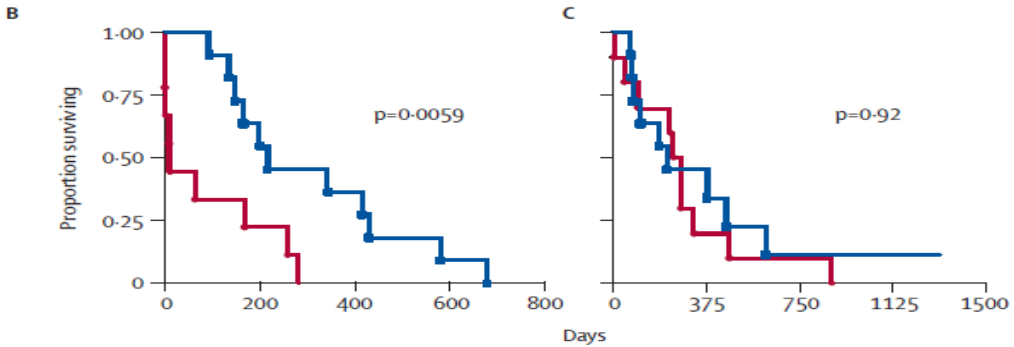
Am J Respir Crit Care Med 2015;192:86–95

NIV use for ALS

Effects of non-invasive ventilation on survival and quality of life in patients with amyotrophic lateral sclerosis: a randomised controlled trial

Stephen C Bourke, Mark Tomlinson, Tim L Williams, Robert E Bullock, Pamela J Shaw, G John Gibson

In patients with ALS without severe bulbar dysfunction, NIV improves survival with maintenance of, and improvement in, quality of life.



Bulbar function (+) Bulbar function (-)

Bourke et al. Lancet Neurol 2006;5:140-147

NMD

- NIV can be effective to treat ARF caused by myasthenia gravis (i.e., crisis).
- NIV can avert intubation and may improve survival in patients with ALS or Duchenne muscular dystrophy.
- NIV should not be used in patients with Guillain–Barre syndrome with rapidly progressive weakness

Alejandro A. Rabinstein Curr Opin Crit Care 2016, 22:94–99

CWD

- Nickol et al. Thorax 2005 (restrictive thoracic ds.)
  - Nocturnal NIV reverses ventilatory failure by increasing the ventilatory response to CO_2.
- Buyse et al. ERJ 2003 (kyphoscoliosis)
  - Nocturnal nasal NIV resulted in more favorable survival and changes in blood gas than long-term O2 (LTOT) alone.
- Jagor et al. Chest 2008 (TB-destroyed lung)
  - Better survival with home NIV than with LTOT alone

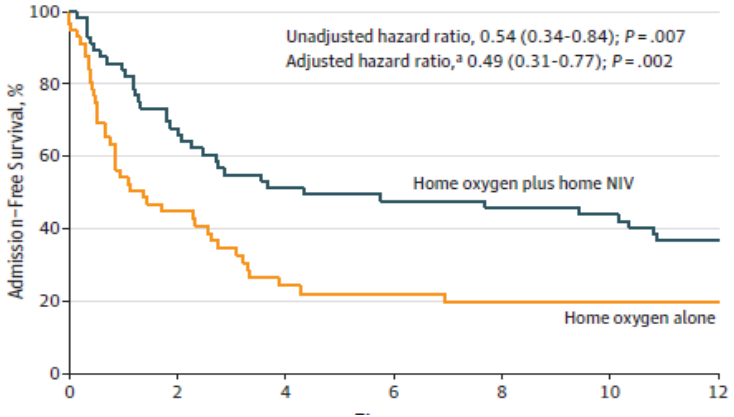
HOT-HMV trial for COPD

JAMA | Original Investigation

Effect of Home Noninvasive Ventilation With Oxygen Therapy vs Oxygen Therapy Alone on Hospital Readmission or Death After an Acute COPD Exacerbation

A Randomized Clinical Trial

Among patients with persistent hypercapnia following an AE of COPD, NIV and LTOT prolonged the time to readmission or death.

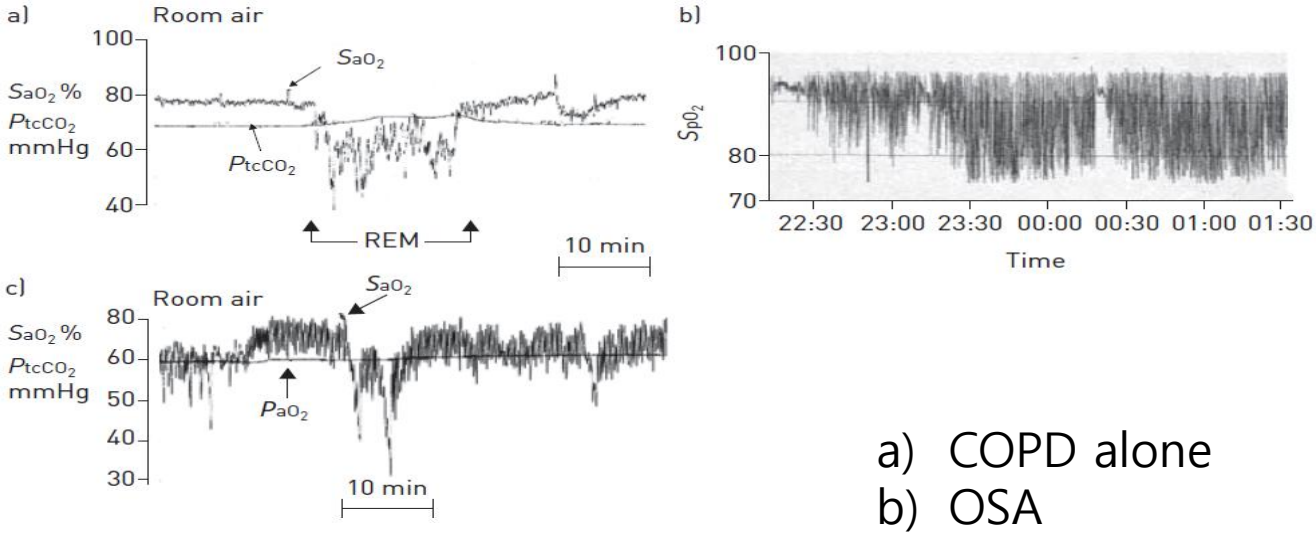


Baseline FEV1 0.6 L
High levels of pressure support
IPAP/EPAP 24/4 (RR 14)

↓ daytime P_aCO_2 with NIV+LTOT

Murphy et al. JAMA 2017;317:2177-86

Overlap syndrome

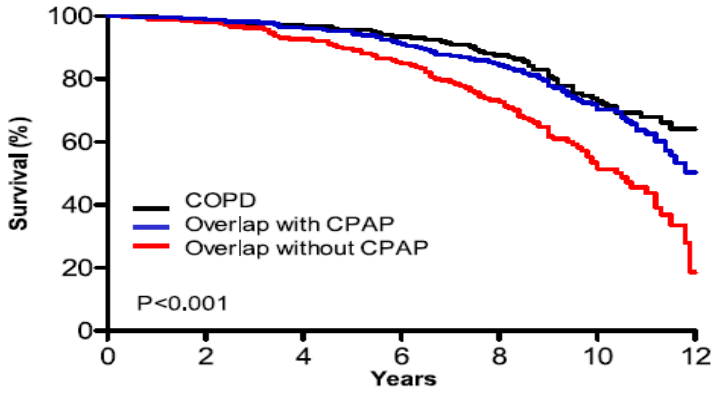


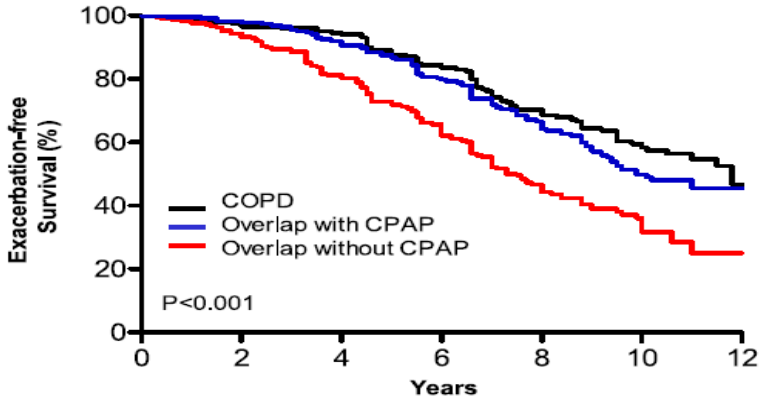
a) COPD alone
b) OSA
c) COPD plus OSA

McNicholas et al. Eur Respir Rev 2019;28: 190064

PAP for overlap syndrome

- The overlap syndrome is associated with an increased risk of death and hospitalization because of COPD exacerbation.
- CPAP treatment was associated with improved survival and decreased hospitalizations in patients with overlap syndrome.



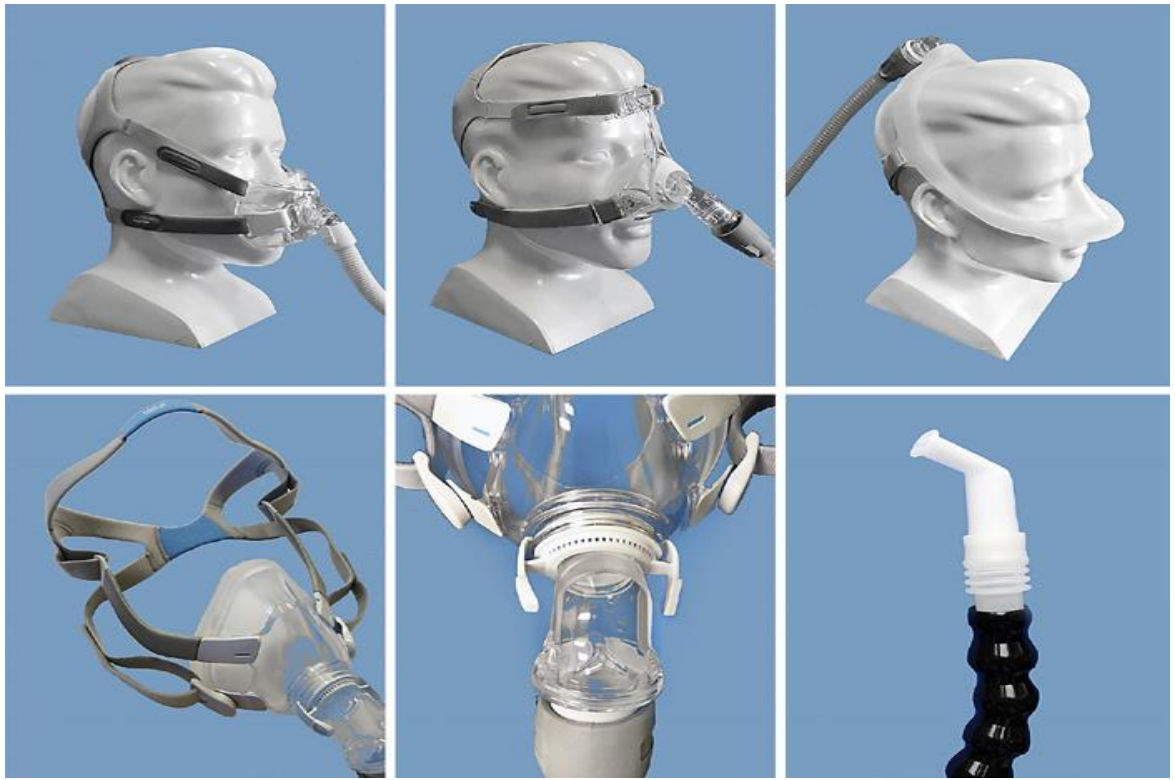


Marin et al. Am J Respir Crit Care Med 2010;182:325–331

Contents

- Considerations for specific diseases
- Interfaces (mask)
- Ventilator machine and circuits
- Ventilator mode and settings
- Humidification and ancillary devices
- Safety issues

Masks for NIV



Schwarz et al. Respiration 2019;98:1–15

Mouthpiece ventilation (MPV)

"Kissing trigger"

Masks for NIV

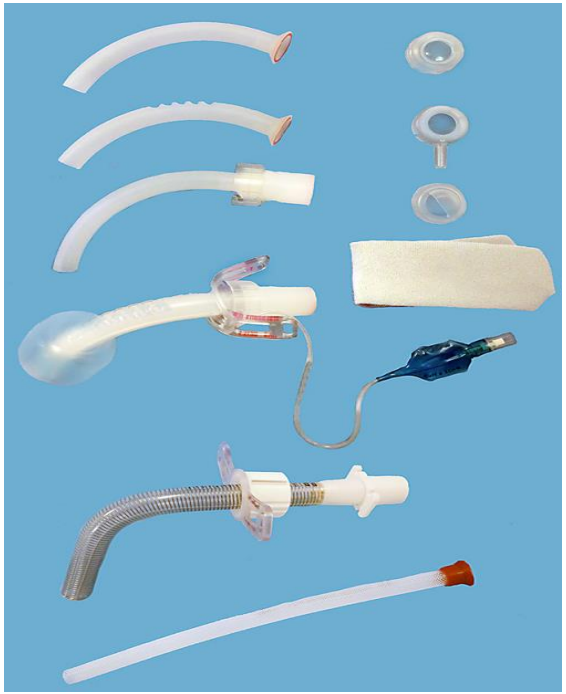
Nasal mask

- Less risk of aspiration
- Easier secretion clearance
- Easier speech
- May allow patient to eat
- Mouth leak
- Nasal irritation and rhinorrhea
- Mouth dryness

Facial mask

- Better control of mouth leak
- More dead space
- Claustrophobia
- More risk of aspiration
- More difficulty in speaking and eating
- Good for night sleep

Tracheostomy



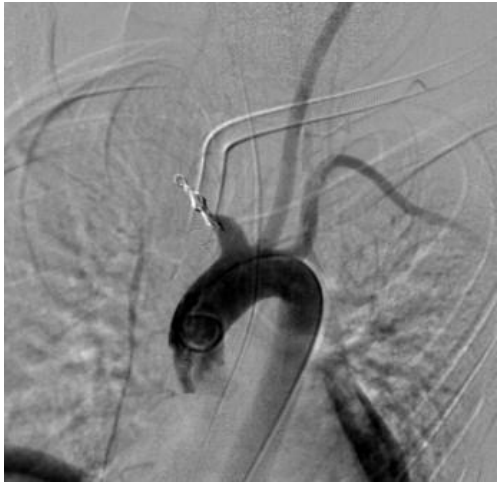
Who and When?

- Large amount of secretion
- Dependent patients (24h)

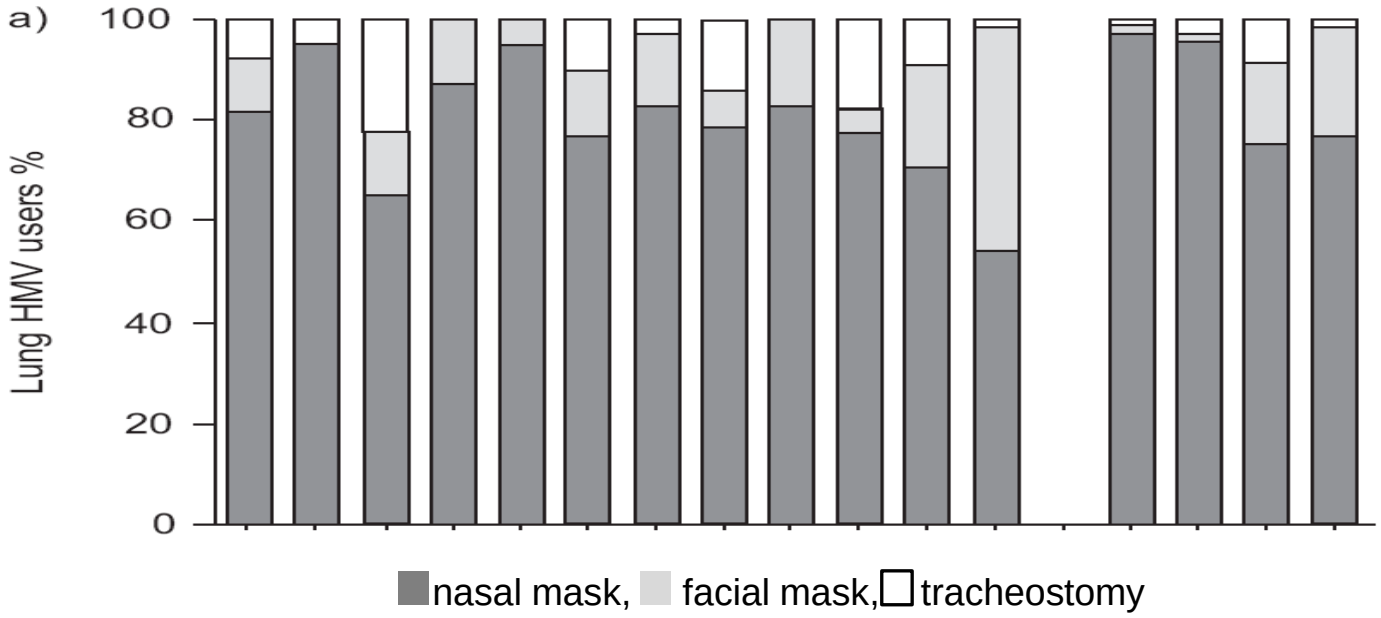
Problems

- Bleeding
- Cuff-induced ulcer or stenosis
- Airway obstruction by secretion


Yushin
7.5
OD 10.6

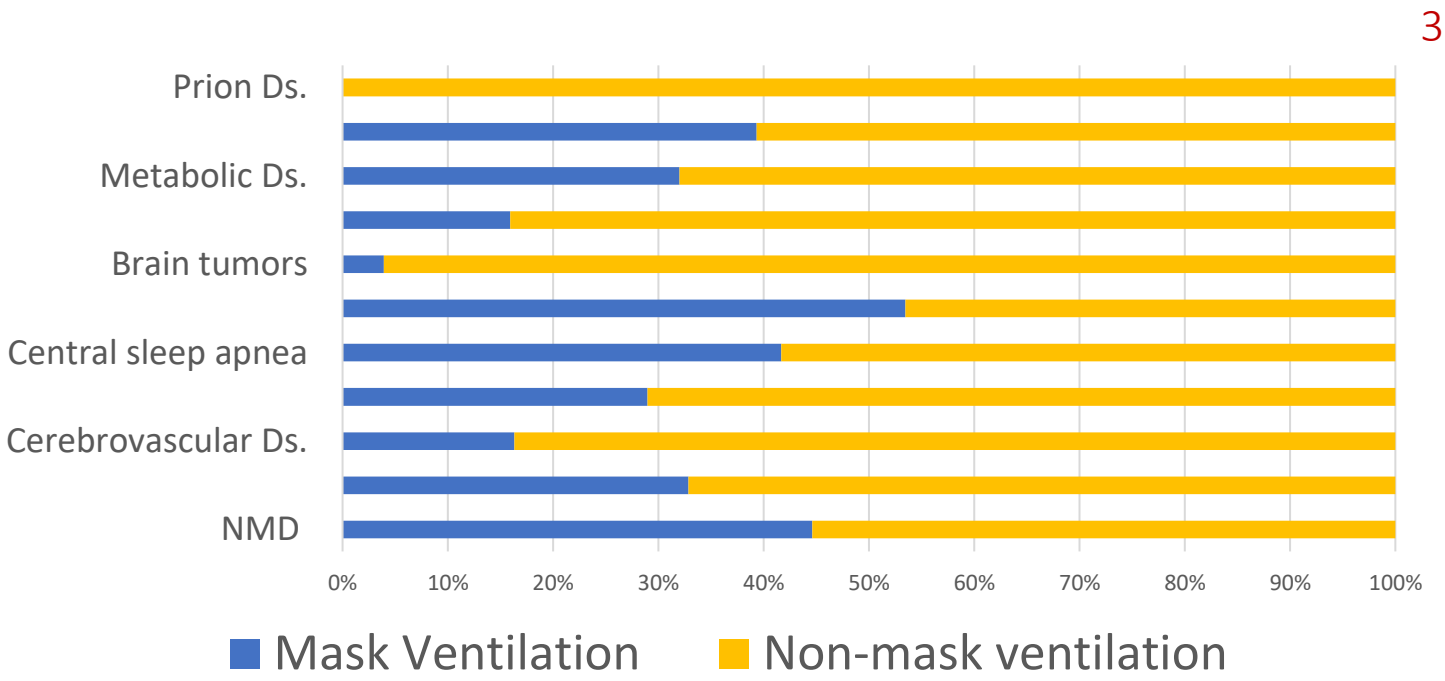


Mask ventilation in Europe



Eur Respir J 2005; 25: 1025–1031

Proportion of mask ventilation



Kim et al. Respir Care. 2019;64:528-535

Contents

- Considerations for specific diseases
- Interfaces (mask)
- Ventilator machine and circuits
- Ventilator mode and settings
- Humidification and ancillary devices
- Safety issue

Non-life-support ventilator

A40

Stella

For intermittent use,
With a single limb (vented) circuit
Usually in patients with mask HMV

Life-support ventilator

Trilogy

Astral

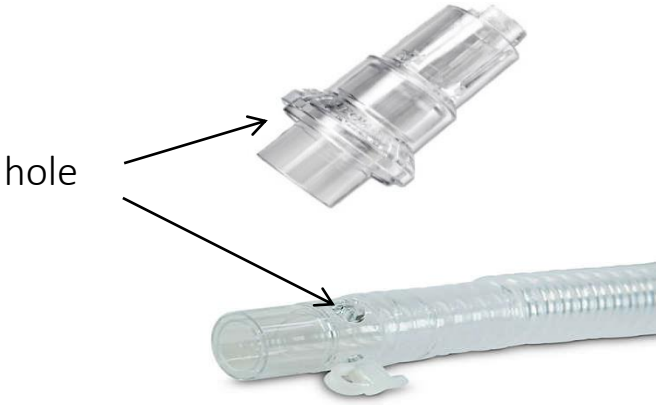
For 24h use,
With a single limb (vented) or non-vented circuit
Usually in patients with tracheostomy

Life-support ventilator vs. non-life-support ventilator

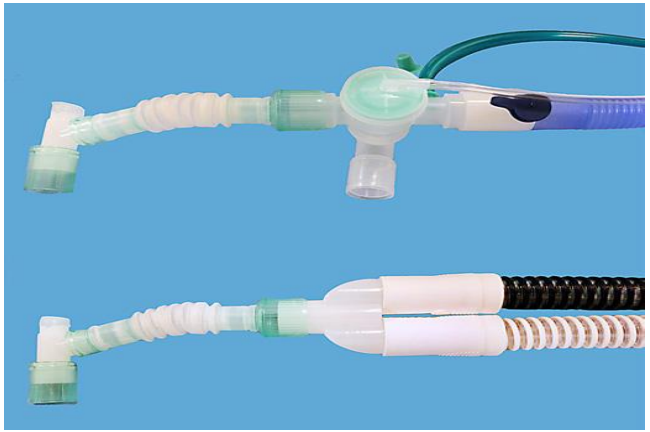
Variable (item)	Life-support ventilator	Life-sustaining ventilator
Interface	Tracheostomy or mask	Mask
Hours of use per day	>16 hours	<16 hours or nocturnal use
Primary diagnosis	Advanced chronic respiratory failure	Chronic stable COPD, OHS, ALS, early DMD
Circuit configuration	Double-limb circuit, single-limb circuit with an exhalation valve sometimes, single-limb with a leak port (i.e., vented circuit)	Single-limb circuit with a leak port (i.e., any vented circuit)
Mode	Various modes including assisted and controlled modes	S, S/T, PSV, PCV, CPAP, or volume-assured pressure support
Monitoring	Full range	Basic range
Internal battery	3–9 hours	Irrelevant

Sunghoon Park and Eui-Sik Suh. Acute Crit Care 2020;35:131-141

Vented vs. non-vented circuits



Passive exhalation valve



Active exhalation valve

Vented vs. non-vented circuits

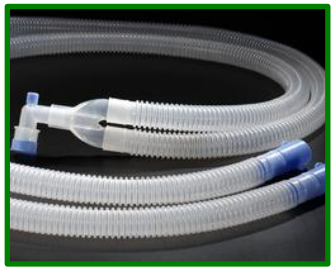
Single limb with leak port (or vented circuit)

CO_2 re-breathing (+)
Intentional leak (+)

vs.

Single limb with active exhalation valve (non-vented circuit)

Double limb as in ICU vent



CO_2 re-breathing (-)
Intentional leak (-)

Vented vs. non-vented circuits

Vented circuit (single limb)

- Either in mask or trache pts.
- Usually intermittent use for mask pts.
- Rebreathing is affected by orifice size and EPAP.
- TV is estimated value.
- Occasionally, not tolerable to chronic patients with decreased chest wall compliance

Non-vented circuit (exhal. Vale)

- Only in tracheostomy pts
- Connected to life-support ventilator
- TV is measured.
- Patients with decreased chest wall compliance

Contents

- Considerations for specific diseases
- Interfaces (mask)
- Ventilator circuits
- Ventilator mode and settings
- Humidification and ancillary devices
- Safety issue

Ventilator modes

Abbreviation	Mode	Settings*
CPAP	Continuous positive airway pressure	CPAP, maintained through all phases of the breathing cycle
PSV-S	Pressure support ventilation, spontaneous mode	IPAP, EPAP, TImin, TImax, inspiratory and expiratory (cycle) trigger sensitivity, inspiratory rise time
PSV-ST	Pressure support ventilation, spontaneous/timed mode	IPAP, EPAP, respiratory frequency, TImin, TImax, inspiratory and expiratory (cycle) trigger sensitivity, inspiratory rise time, expiratory pressure decrease speed (cycle-off)
PSV-T	Pressure support ventilation, timed mode	IPAP, EPAP, respiratory frequency, TI, inspiratory rise time, expiratory pressure decrease speed, cycle-off
(a)PCV	(assisted) Pressure control ventilation	IPAP, EPAP, respiratory frequency, TI (TI:TE), inspiratory trigger sensitivity, inspiratory rise time, expiratory pressure decrease speed
VAPS/AVAPS and tri-level PAP	(average) Volume-assured pressure support ventilation and variable inspiratory/expiratory positive pressure ventilation	EPAP fixed or variable (autoEPAP), variable pressure support with PS min, PS max, target volume, TImin, TImax, inspiratory and expiratory (cycle) trigger sensitivity, inspiratory rise time, expiratory pressure decrease speed, cycle-off

Schwarz et al. Respiration 2019;98:1–15

Considerations for ventilator settings

- Independent vs. dependent patients?
- Noctural ventilation vs. 24-h use?
- NIV vs. tracheostomy ?
- Intact spontaneous breating?
- C spine injury?

PSV (ST) vs. PCV I:E ratio Rising time IPAP EPAP

Schwarz et al. Respiration 2019;98:1–15

Suggested MV setting

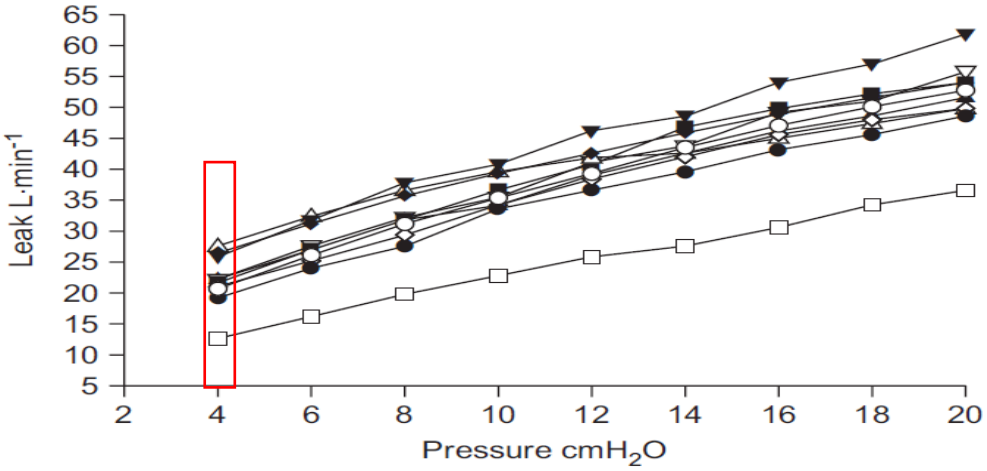
Setting	Normal	COPD	Restrictive/neuromuscular
Ti	0.3–2.0 s	0.3–1.0 s	0.8–1.5 s
Rise time	300 ms	150 ms	300 ms
Trigger	Medium	Medium	High
Cycle	Medium	High	Low

Abbreviations: COPD, chronic obstructive pulmonary disease; PAP, positive airway pressure; Ti, inspiration time; s, second.

Johoson et al . Medical Devices: Evidence and Research 2015

Minimal leaks for CO_2 elimination

Exhalation flow (V_T/t_E)
NMD in sleep, 14.5L/min
NMD awake, 20.0L/min
ARF with intubation, 22.0L/min



This is why we need EPAP!

Louis et al. Eur Respir J 2010;35:627-636

Solutions for air leaks

- Leak can decrease NIV efficacy and patient compliance.
  - auto-trigger, delayed cycling, underestimation of VT, $\downarrow FiO_2$, $\downarrow PO_2$, $\uparrow PCO_2$.
- For NIV with vented circuit, a minimum of intentional leak is required (> 22L/min) for CO_2 washout.
- Mean intentional leak is 30-45 L/min (at IPAP 14cmH_2O).
- Many NIVs can compensate leaks (~60L/min).
- In case of a large leak, chin strap, IPAP adjustment, and mask change should be considered.
- Right mask and circuit should be used.

A patient with brain injury

HR 102/min
RR 20/min

leak

Different points of veiw

- Patients on invasive MV
  - Lung injury (ARDS or pneumonia)
  - Low tidal volume

- Subjects on HMV
  - Relatively normal lung tissue
  - Problem airway collapse due to secretion
  - Deceased chest wall compliance
  - Problem of increased $PaCO_2$
  - Relatively high tidal volume

Contents

- Considerations for specific diseases
- Interfaces (mask)
- Ventilator machine and circuits
- Ventilator mode and settings
- Humidification and ancillary devices
- Safety issue

Humidification

- Essential for facial mask and tracheostomy
- Not recommended when moving in wheelchair

Ancillary devices

- Cough assistant
- Suction device
- AMBU bag
- VEST
- Pulse oxymeter
- Transcutaneous PCO_2

AMBU is important

- In case of ventilator failure at home
- Caregiver training

Contents

- Considerations for specific diseases
- Interfaces (mask)
- Ventilator circuits
- Ventilator mode and settings
- Humidification and ancillary devices
- Safety issue

When distressed with HMV

- Deterioration of clinical condition or pneumonia
- Large leaks?
- Humidification?
- Secretion?
- Adjust MV setting
  - TV
  - I:E ratio (a long insp. time in pts with NMD)
  - Rising time
  - Mode (PSV vs. PCV)
- Think of changing circuit (vented -> non-vented)?
- Think of changing vent machine (non-life-support -> life-support ventilator)?

Emergency visits over a 6-month period

Reason	Home Visits, No.
Ventilator not working	52
Technical issue (alarming, not reaching pressure, noisy)	43
Equipment required (tubing, filters, mask spares)	39
No fault	25
Circuit fitted incorrectly	9
Hospital requested exchange	9
Patient changed settings by mistake	8
Patient did not like replacement ventilator	2
Set up of ventilator at home	1
Total visits	188

Respir Care 2012;57:921-930

Causes of Death in Pediatric Patients with HMV

Cause of Death	No. (%)
Progression of reason for chronic respiratory failure or other underlying condition	16 (34)
Cardiac	10 (21)
Acute respiratory failure	4 (8.5)
Brain death	4 (8.5)
Infectious/sepsis/multiple organ dysfunction syndrome	4 (8.5)
Tracheal bleeding	4 (8.5)
Tracheal obstruction	4 (8.5)
Tracheostomy accident	1 (2)
Total	47 (100)

J Pediatr 2010;157;(6):955-959.e2.

Tuberculosis and Respiratory Diseases
□원 저□
결핵 및 호흡기질환, Vol. 49, No. 5, Nov, 2000

가정용 인공호흡기를 사용하는 서울 및 경기 지역 환자의 실태

울산대학교 의과대학 울산대학교 병원[1] 및 서울중앙병원 호흡기내과

안종준[1], 이기만[1], 심태선, 임채만, 이상도
김우성, 김동순, 김원동, 고윤석

간호 관리: 배우자 14명/29명 (48.3%)

관리에 소요되는 시간: 24시간(24명/29명)

분비물 흡인교육: 2명은 사전 교육을 전혀 받지 않음

인공호흡기교육: 20명이 회사직원, 4명 의사

2명 간호사, 3명 전혀 배우지 못함

경관식 교육 : 3명 전혀 배우지 못함

Use of ancillary devices

from a cross-sectional survey

	Adults (n = 38)	Children (n = 26)	P -value
Oxygen saturation monitoring device	16 (42.1%)	21 (80.8%)	0.008
CO_2 monitoring device	0 (0.0%)	0 (0.0%)	1.000
Cough assist (in-exsufflator)	1 (2.6%)	1 (3.8%)	1.000
Chest wall oscillation	2 (5.3%)	0 (0.0%)	0.510
Suction device	14 (36.8%)	20 (76.9%)	0.002
AMBU-bag	11 (28.9%)	18 (69.2%)	0.001
Oxygen generator	20 (52.6%)	11 (42.3%)	0.417

AMBU, artificial manual breathing unit

Data submitted

Use of medical care service

from a cross-sectional survey

	Adults (n = 38)	Children (n = 26)	P -value
Who cares for the patient at home			
Family members	25 (65.8%)	23 (88.5%)	
Privately hired caregivers	7 (18.2%)	3 (11.5%)	0.131
Self-care	2 (5.3%)	0 (0.0%)	
Others	4 (10.5%)	0 (0.0%)	
Regular visit by a nurse, per month	0.0 (0.0 – 1.0)	0.0 (0.0 – 0.0)	0.025
Regular visit by a provider, per month	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)	0.808
During the last year (yes)			
Occurrence of emergencies at home	15 (39.5%)	13 (50.0%)	0.404
Visiting to outpatient clinics	29 (76.3%)	24 (92.3%)	0.176
Visiting to emergency departments	5 (13.2%)	9 (34.6%)	0.041
During the total period of HMV use			
Admission to hospitals	11 (28.9%)	21 (80.8%)	<0.001
Admission to intensive care units	5 (13.2%)	5 (19.2%)	0.728

Data submitted

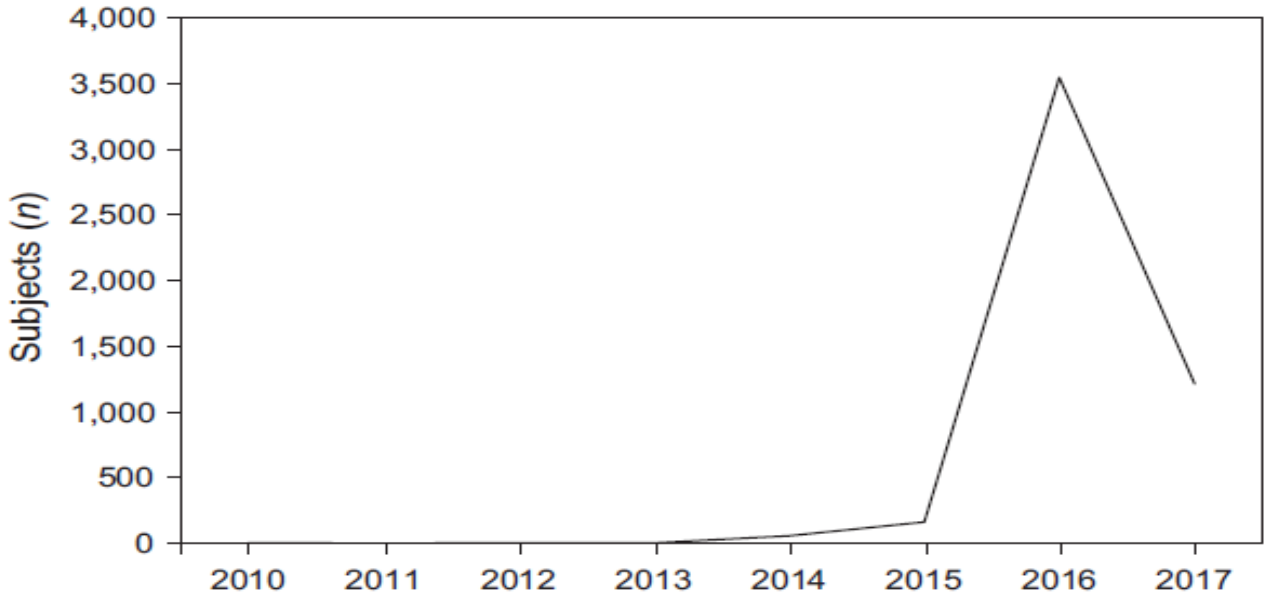
Key factors for HMV

- Experienced team
- Selection of right patients
- Timely initiation of HMV
- Selection of an appropriate interface
- Effective monitoring

+ collaborations with community service

Thank you.

South Korea (2010 to 2017)



Kim et al. Respir Care. 2019;64:528-535

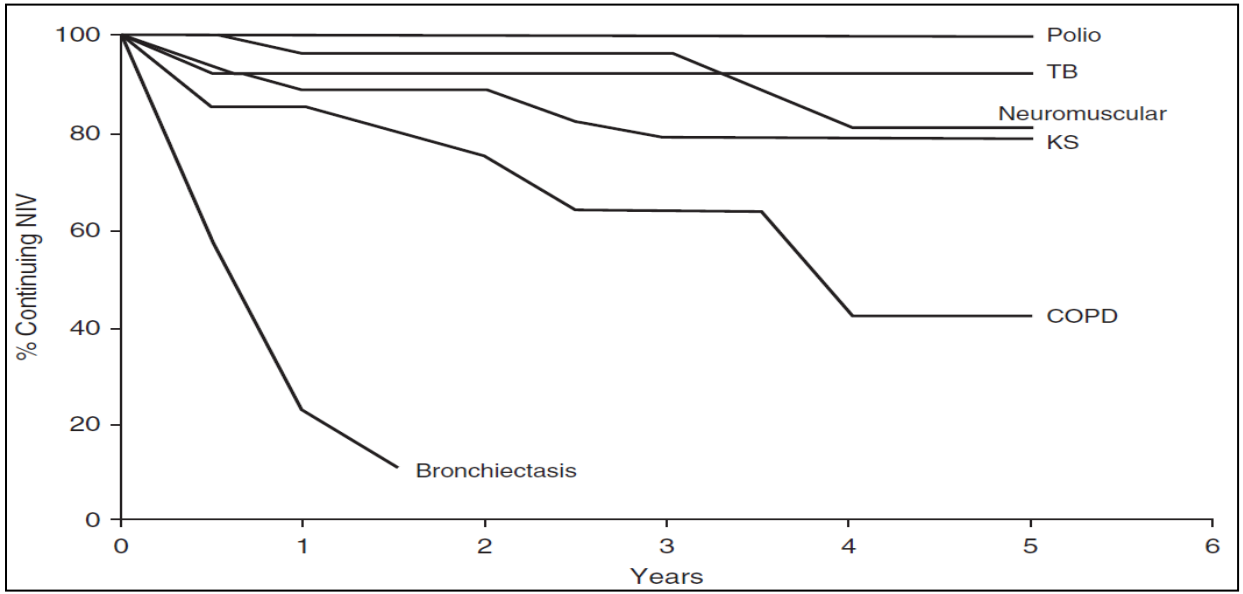
South Korea (2010 to 2017)

Countries	Study years	Estimated prevalence of HMV use (per 100,000)	Mask ventilation (%)
European countries[1]	2001-2002	6.6 (0.1 – 17.0)	87%
Canada[2]	2012-2013	12.9	73%
Massachusetts[3,4]	2006	3.4*	22%
ANZ [5]	2011	9.8 and 12.0	96%
Hong Kong (adults)[6]	2002	2.9	94.8%
South Korea	08/2015-07/2017	9.3‡	37.2%

Kim et al. Respir Care. 2019;64:528-535

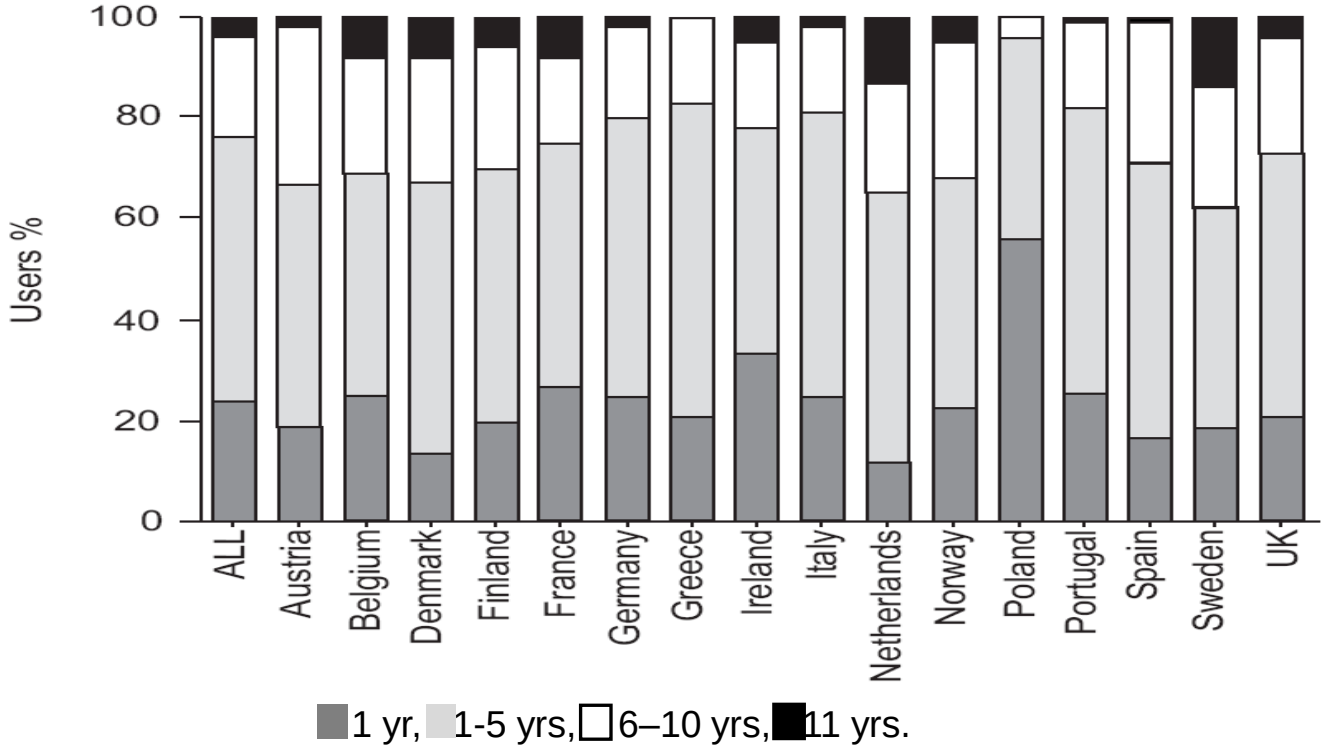
Long-term survival

Probability of continuing NIV



Hind et al. Am J Respir Crit Care Med 2017;195:1140-1149

Duration of HMV in Europe



Eur Respir J 2005; 25: 1025–1031