Domiciliary ventilation

Dr. K T Prasad

Make BJ et al. Chest. 1998 May;113(5 Suppl):289S-344S

Cost per patient:
718.80 $ **vs.**
235.13 $ per day

Bach JR et al. Chest. 1992 Jan;101(1):26-30

HMV: Patients' perspective

- Care by unrelated staff
- Noisy
- Lighted most of the time
- Limited outside view
- Cramped
- Restricted visitors
- Alien surrounding
- Little control over things

Hospital

- Family care
- Quiet
- Day/night cycles
- Good view
- Roomy
- Supportive visitors encouraged
- Personal objects
- More independence

Home

King AC. Respir Care. 2012 Jun;57(6):921-30

Current status

EuroVent Study

- Designed to assess patterns of HMV use
- Across 16 countries in Europe
- Questionnaire based survey
- July 2001 to June 2002

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

EuroVent study

- The study was designed to assess the patterns of use of home mechanical ventilation (HMV) for patients with chronic respiratory failure across Europe.
- A detailed questionnaire of centre details, HMV user characteristics and equipment choices was sent to carefully identified HMV centres in 16 European countries.
- Surveys were sent out by the National Representatives to all centres from July 2001 onwards with a covering letter of explanation. The deadline for receipt of the completed surveys was June 1, 2002.

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

EuroVent: HMV definition

- Noninvasive ventilation or ventilation via a tracheostomy for ≥3 months on a daily basis carried out mostly in the user's home or other long-term care facility (not a hospital)
- **Excluded patients with obstructive sleep apnoea alone, or patients with a tracheostomy not requiring mechanical ventilation**
- Included negative pressure ventilation, phrenic nerve stimulation and the use of ventilatory adjuncts, such as rocking beds

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

EuroVent: HMV prevalence

	Estimated		
	Centres	Users	Prevalence[¶]
Austria	8	300	3.8
Belgium	23	500	5
Denmark	2	500	9.6
Finland	20	450	8.7
France[§]	50	10000	17
Germany	54	5000	6.5
Greece	12	70	0.6
Ireland	15	155	3.4
Italy	70	2200	3.9
Netherlands	4	900	5.6
Norway	38	350	7.8
Poland	8	40	0.1
Portugal	39	933	9.3
Spain	35	2500	6.3
Sweden	65	900	10
UK	40	2320	4.1
All countries	483	27118	6.6

Per 100,000 population

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

EuroVent: Results

- **A total of 483 centres treating 27,118 HMV users were identified.**
- Of these, 329 centres completed surveys between July 2001 and June 2002, representing up to 21,526 HMV users and a response rate of between 62% and 79%.
- **The estimated prevalence of HMV in Europe was 6.6 per 100,000 people.**
- The variation in prevalence between countries was only partially related to the median year of starting HMV services. In addition, there were marked differences between countries in the relative proportions of lung and neuromuscular patients using HMV, and the use of tracheostomies in lung and neuromuscular HMV users. Lung users were linked to a HMV duration of <1 yr, thoracic cage users with 6–10 yrs of ventilation and neuromuscular users with a duration of ≥6 yrs.

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

Asia-Pacific region: Hong Kong

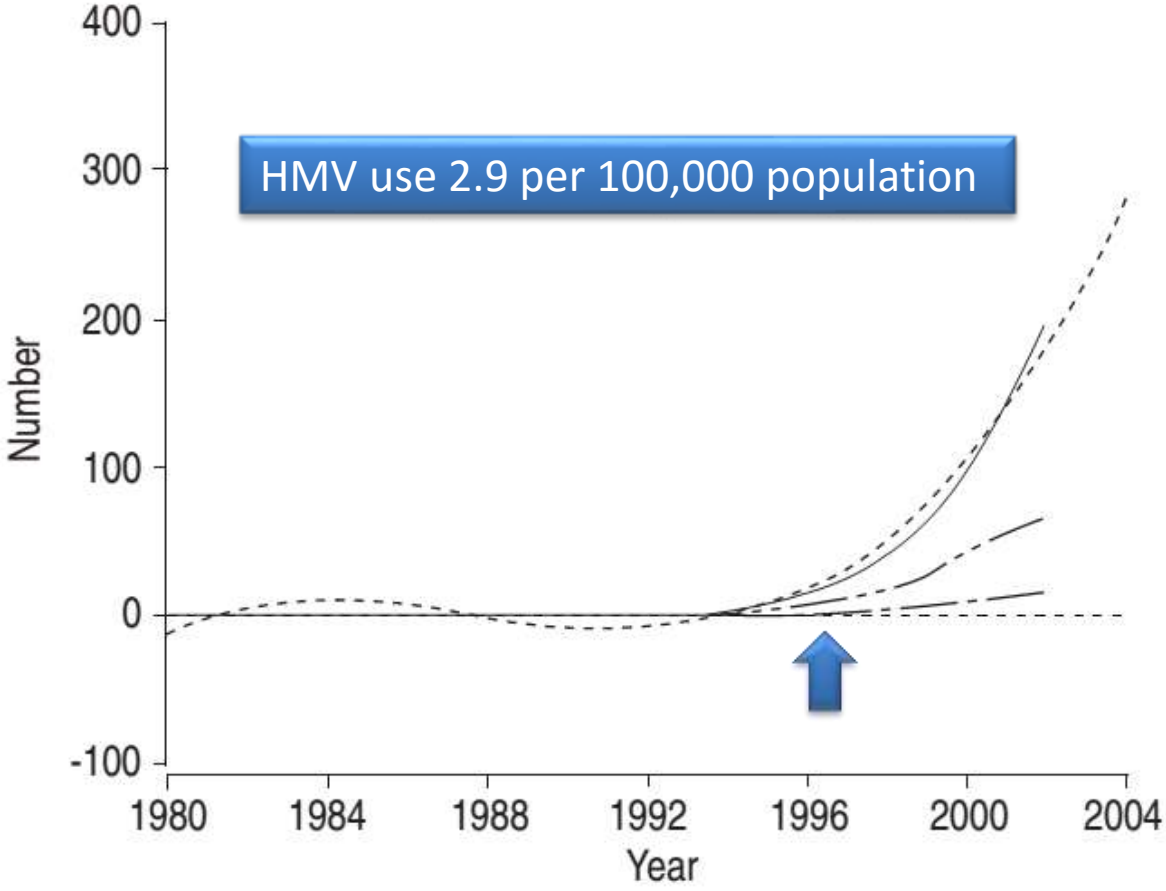


Fig. 1.–New cases (— - - —), withdrawn cases (— - —) and cumulative number of home ventilation (observed (——) and predicted (- - -)).

Chu CM et al. Eur Respir J. 2004 Jan;23(1):136-41

Indian data

First report on HMV in 1992…

Indian J Chest Dis Allied Sci. 1992 Jul-Sep;34(3):149-52.

Domiciliary mechanical ventilation in a patient with severe chronic obstructive lung disease and respiratory failure.

Guleria R, Batra YK, Sharma BK, Jindal SK.

Department of Pulmonary Medicine, Postgraduate Institute of Medical Education and Research, Chandigarh.

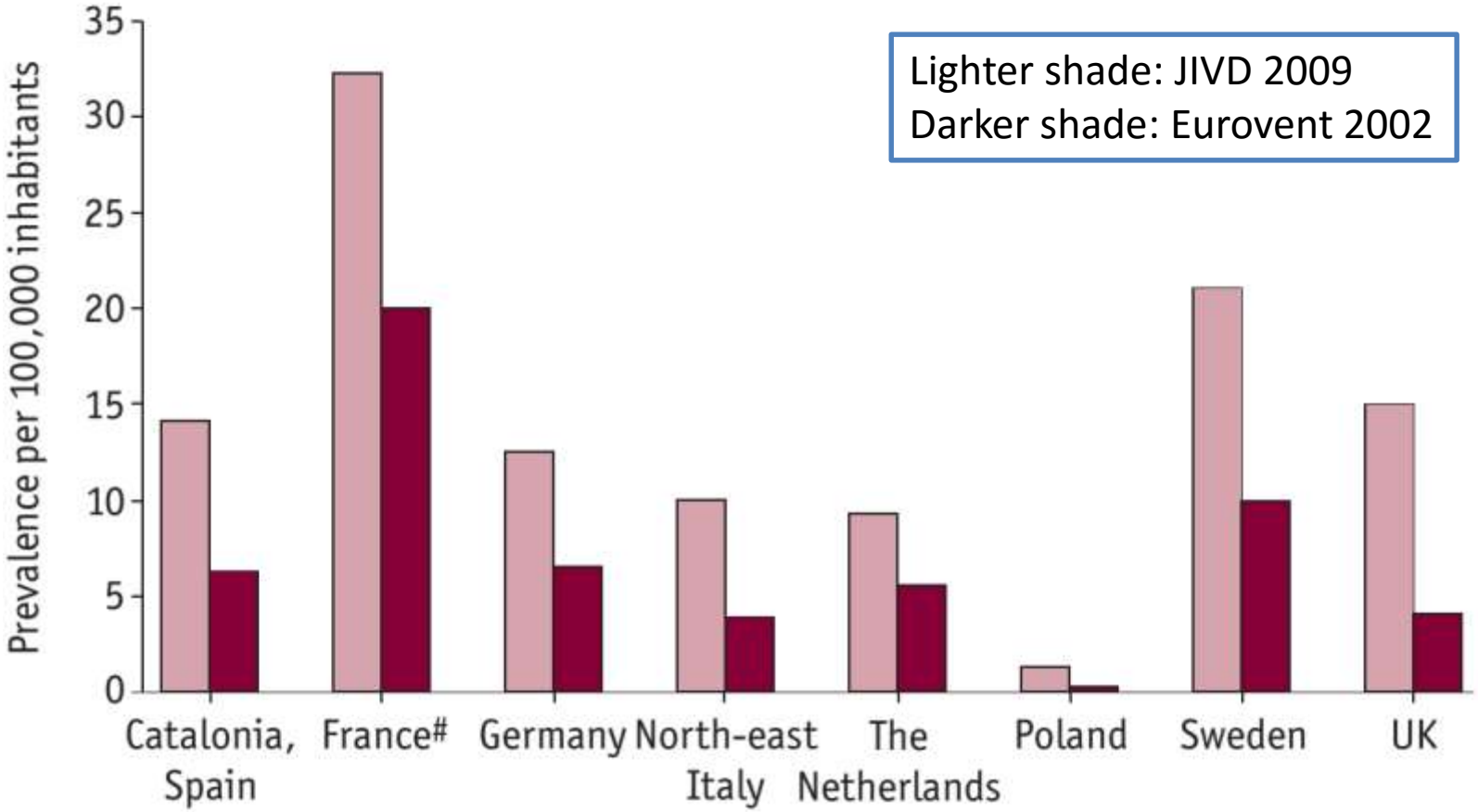
Abstract

A patient of chronic obstructive pulmonary disease (COPD) with cor-pulmonale and chronic respiratory failure, who was given intermittent positive pressure ventilation at home, is reported. The patient did remarkably well on home mechanical ventilatory support. We believe this to be the first case report of domiciliary mechanical ventilation in a patient of COPD from India.

PMID: 1302224 [PubMed - indexed for MEDLINE]

No data since then…

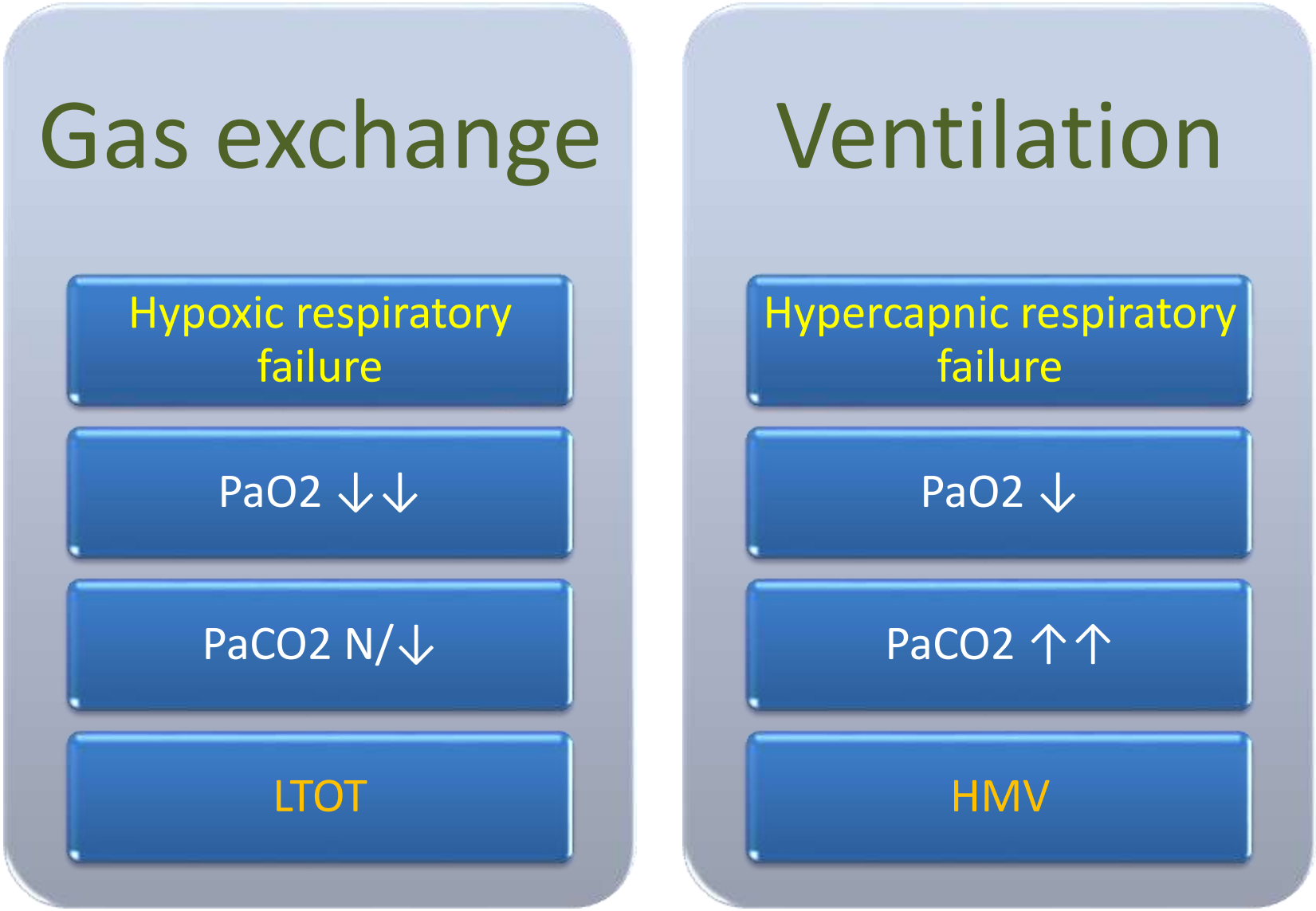
International Conference on HMV (JIVD 2009)



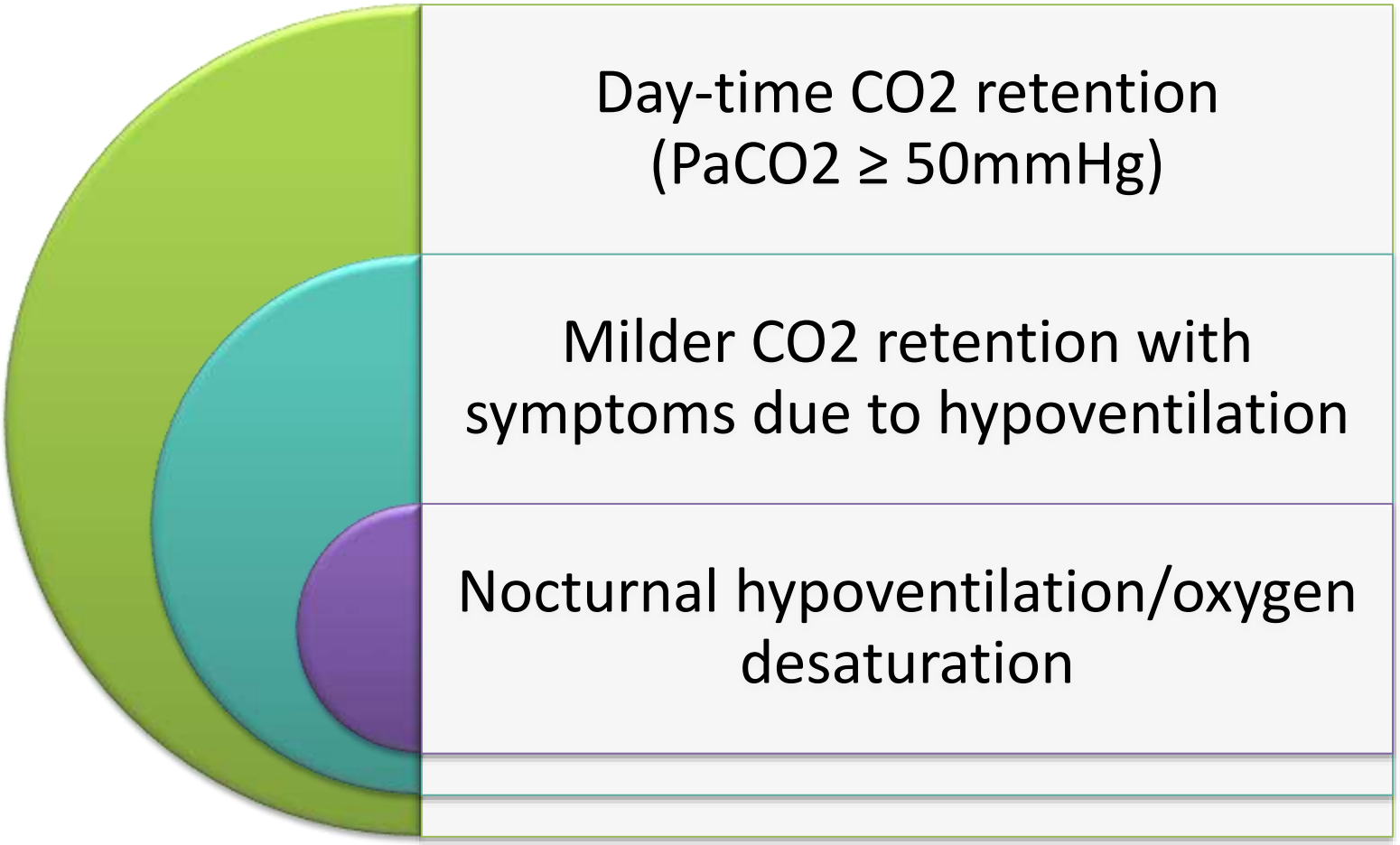
HMV use had almost doubled in 7 years!

Escarrabill J. Breathe 2009; 6: 36-44

Indications


Gas exchange
Hypoxic respiratory failure
PaO2 ↓↓
PaCO2 N/↓
LTOT
Ventilation
Hypercapnic respiratory failure
PaO2 ↓
PaCO2 ↑↑
HMV

Indications for HMV



King AC. Respir Care. 2012 Jun;57(6):921-30

Table 1—*Indications for Mechanical Ventilation Beyond the ICU*

Indications for NIV

- Patient has chronic stable or slowly progressive respiratory failure:
  - Significant daytime CO_2 retention (≥ 50 mm Hg) with appropriately compensated pH or
  - Mild daytime or nocturnal CO_2 retention (45 to 50 mm Hg) with symptoms attributable to hypoventilation (*eg*, morning headaches, restless sleep, nightmares, enuresis, daytime hypersomnolence, etc)
  - Significant nocturnal hypoventilation or oxygen desaturation
- The following conditions have been met:
  - Patient has had optimal medical therapy for underlying respiratory disorders
  - Patient is able to protect airway and clear secretions adequately
  - Patient's reversible contributing factors have been treated (*eg*, obstructive sleep apnea, hypothyroidism, congestive heart failure, severe electrolyte disturbance).
- The diagnosis is appropriate (see Table 2) and may include the following:
  - Neuromuscular disorders
  - Chest wall deformity
  - Central hypoventilation syndrome or obesity hypoventilation
  - Obstructive sleep apnea, and a failure to improve with nasal CPAP
  - COPD, with severe hypercapnia or nocturnal desaturation (tentative indication)*

Indications for invasive ventilation

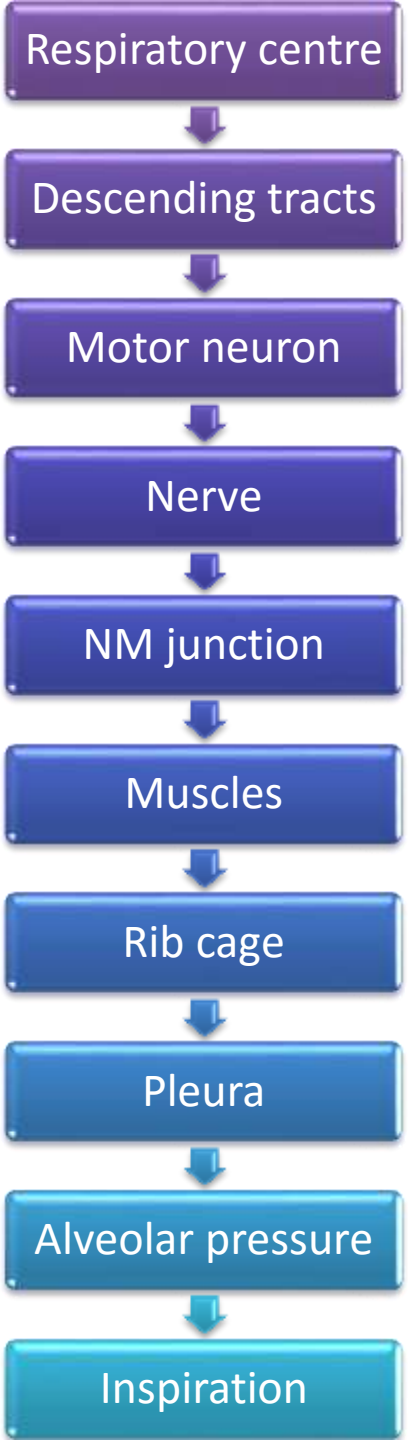
- Patient meets indications for NIV and has the following:
  - Uncontrollable airway secretions despite use of noninvasive expiratory aids; or
  - Impaired swallowing leading to chronic aspiration and repeated pneumonias
- Patient has persistent symptomatic respiratory insufficiency and fails to tolerate or improve with NIV
- Patient needs round-the-clock (> 20 h) ventilatory support because of severely weakened or paralyzed respiratory muscles (*eg*, quadriplegia due to high spinal cord lesions or end-stage neuromuscular disease) and patient or provider prefers invasive ventilation.

* However, some conferees strongly prefer NIV, even when the patient has a need for continuous ventilatory support, as long as upper airway function is intact.

Make BJ et al. Chest. 1998 May;113(5 Suppl):289S-344S. PMID: 9599593

Diseases requiring HMV

- Restrictive disorders: Neuromuscular and chest wall disorders
- Obstructive airway disorders: COPD
- Sleep-related breathing disorders: Central/obstructive sleep apnea syndromes, hypoventilation syndromes
- Other: TB sequelae, cystic fibrosis



Neuromuscular diseases:

Central apnea syndromes

Cervical cord injury

Motor neuron disease

Neuropathies

Myasthenia gravis

Muscular dystrophies & myopathies

Thoracic cage diseases:

Chest wall deformities

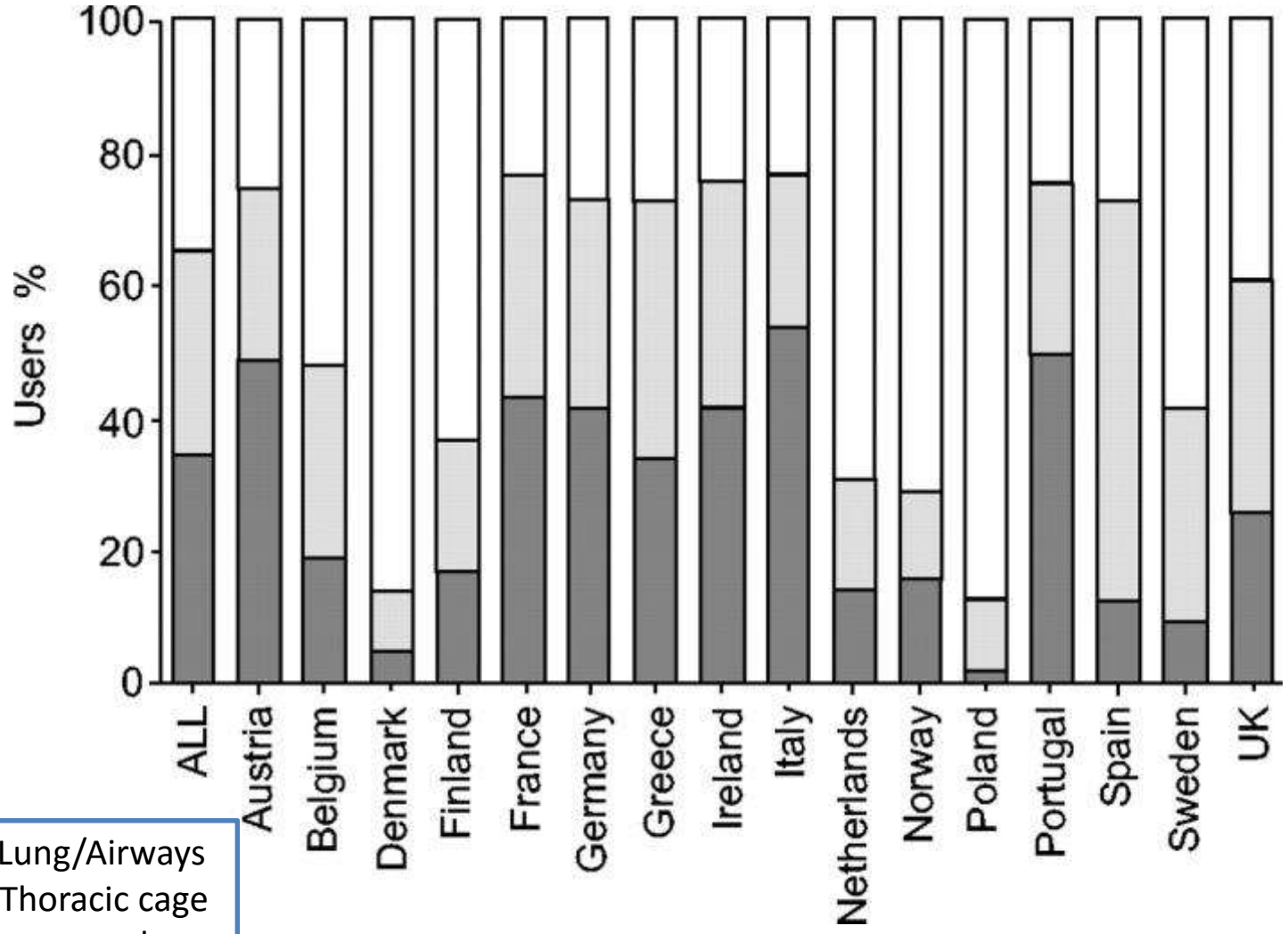
Pleural fibrosis

Lung & airway diseases:

Parenchymal fibrosis

Airway obstruction: COPD, OSA

Disease treated by HMV: EuroVent 2002



Dark grey: Lung/Airways
Light grey: Thoracic cage
White: Neuromuscular

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

EuroVent: Disease categories

- **Lung and airway diseases:** chronic obstructive pulmonary disease (COPD), cystic fibrosis, bronchiectasis, pulmonary fibrosis and paediatric diseases, including bronchopulmonary dysplasia
- **Thoracic cage abnormalities:** early-onset kyphoscoliosis, tuberculosis sequelae such as thoracoplasty, obesity hypoventilation syndrome and sequelae of lung resection
- **Neuromuscular diseases:** muscular dystrophy, motor neurone disease (including amyotrophic lateral sclerosis), post-polio kyphoscoliosis, central hypoventilation, spinal cord damage and phrenic nerve paralysis.

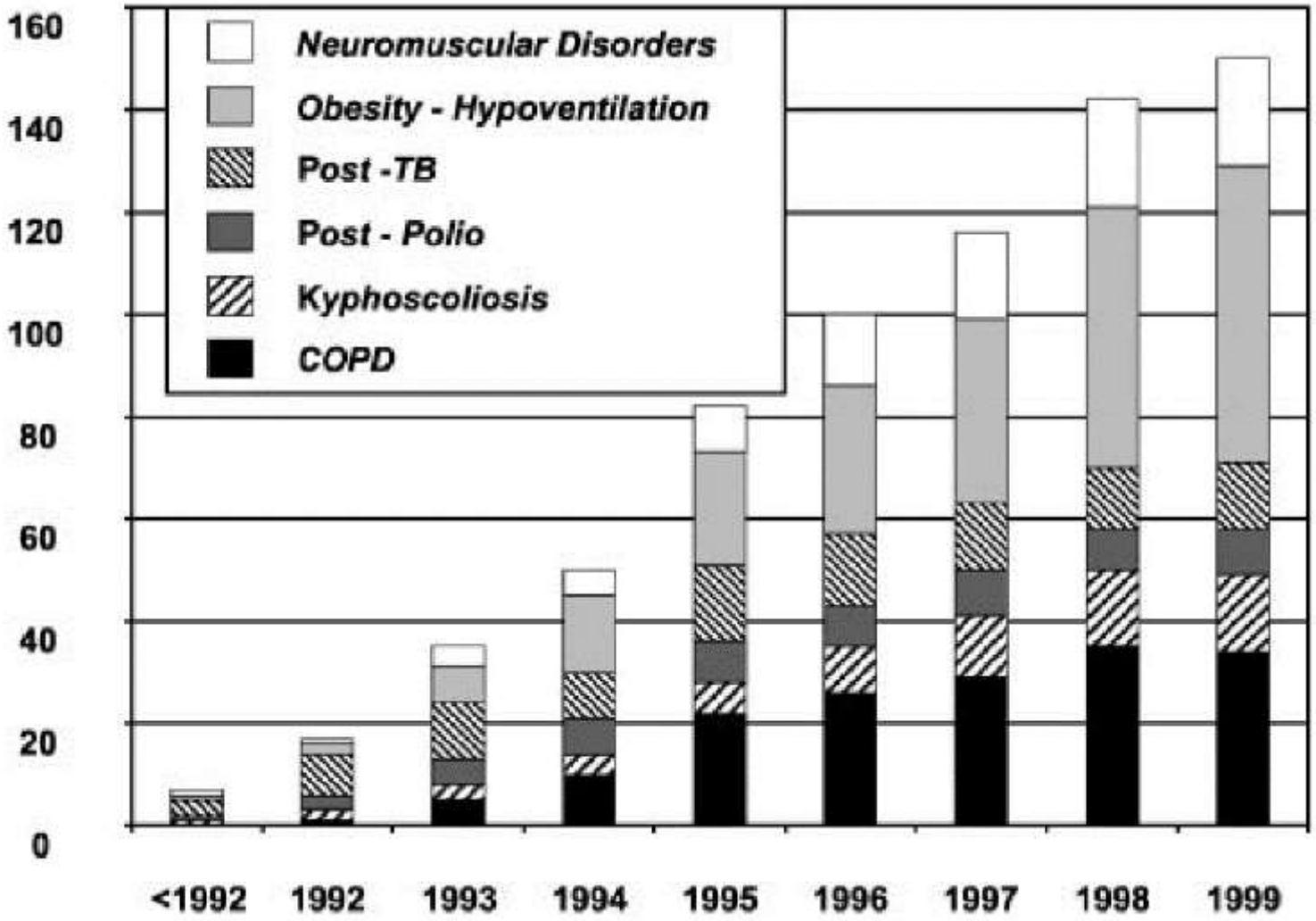
Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

Diseases treated by HMV: Hong Kong

Diagnosis	N (%)
Restrictive thoracic disorders	
Thoracic cage disorders	38 (15.3)
Post-tuberculous fibrothorax	9 (3.6)
Neuromuscular disorder	30 (12.0)
Mixed pathologies and miscellaneous	8 (3.2)
Complicated OSA/OHS	
OHS	11 (4.4)
COPD: OSA overlap syndrome	22 (8.8)
Severe OSA, intolerant to CPAP	10 (4.0)
COPD	121 (48.6)

Chu CM et al. Eur Respir J. 2004 Jan;23(1):136-41

Changing trends…



Janssens JP et al. Chest. 2003 Jan;123(1):67-79

Outcomes

Goals of HMV

- To improve blood gases
- To correct hypoventilation and associated symptoms
- To improve quality of sleep
- To improve QoL
- To improve survival

HMV & HRQoL

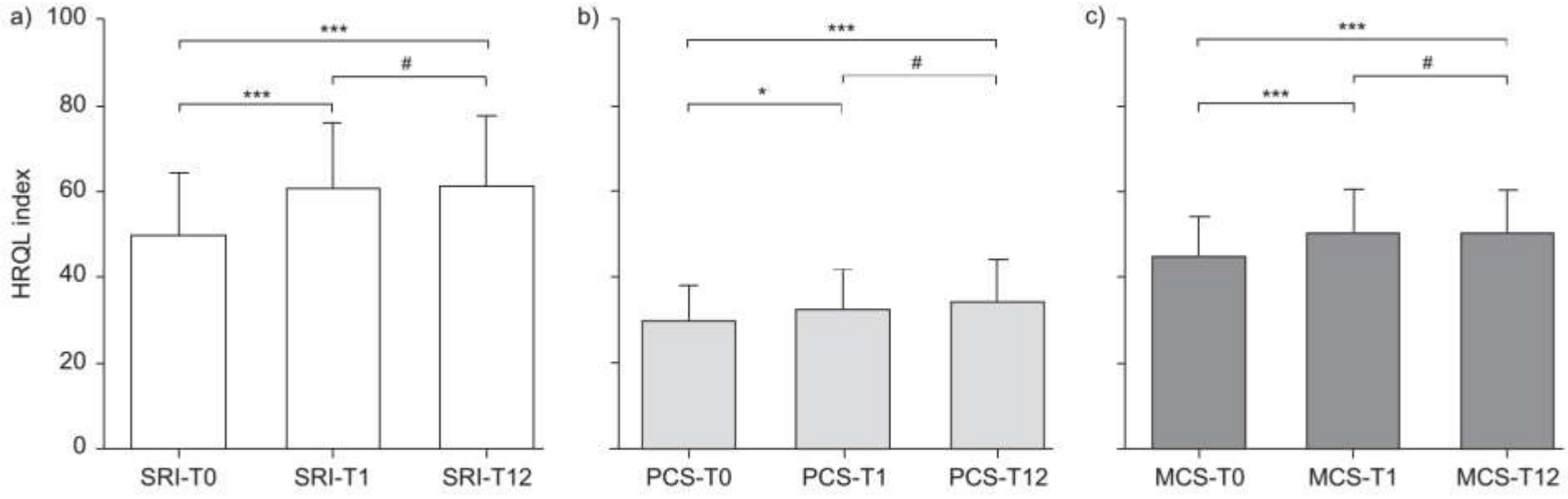
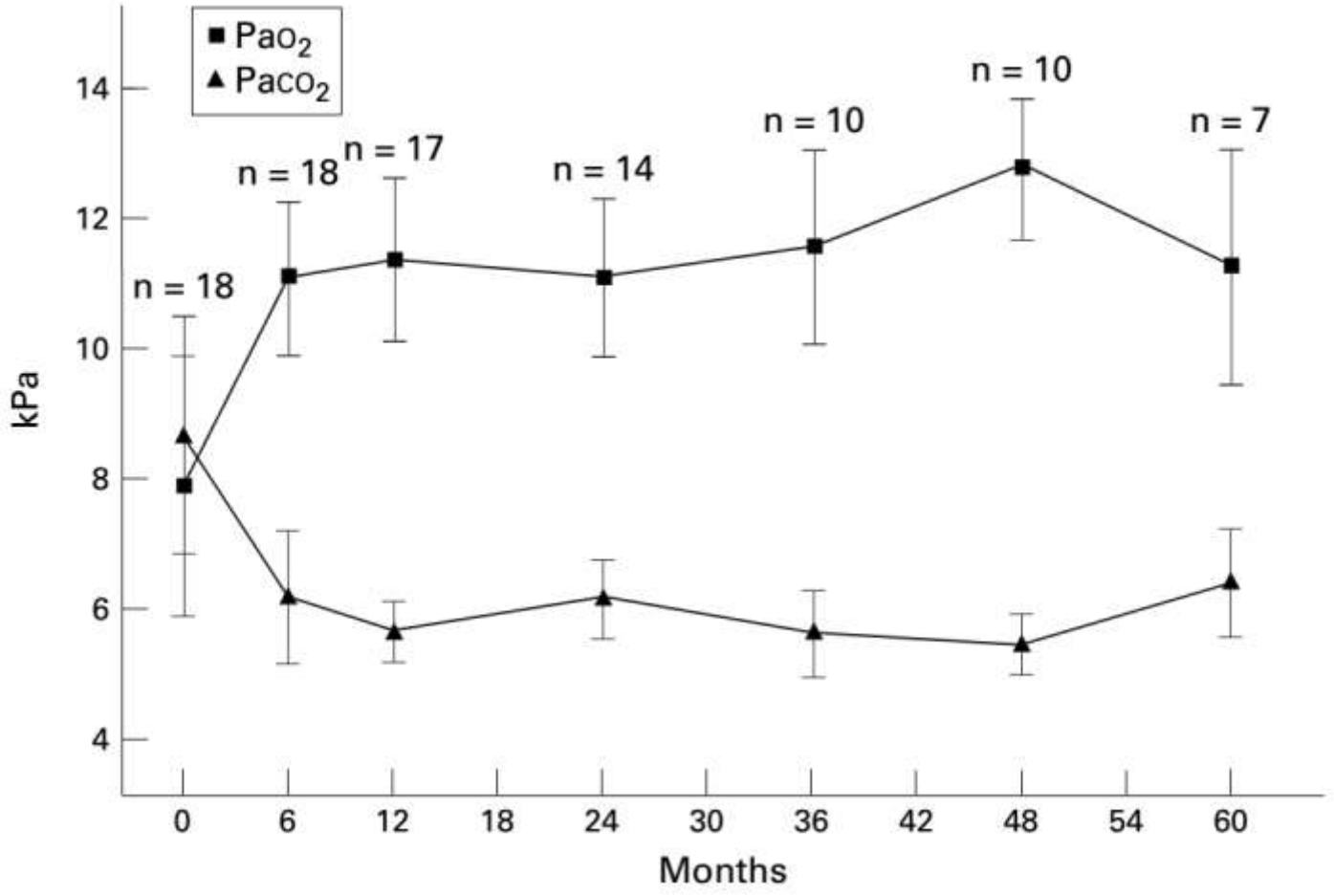


FIGURE 2. a) Summary score of Severe Respiratory Insufficiency (SRI) Questionnaire, b) physical component summary (PCS) of the Medical Outcome Survey 36-Item Short-form Health Survey (SF-36), and c) mental component summary (MCS) of the SF-36 in patients with chronic hypercapnic respiratory failure prior (T0) to home mechanical ventilation (HMV), and 1 month (T1) and 12 months (T12) following the institution of HMV (n=85). Higher values indicate better health-related quality of life (HRQL). #: nonsignificant; *: $p<0.05$; ***: $p<0.001$.

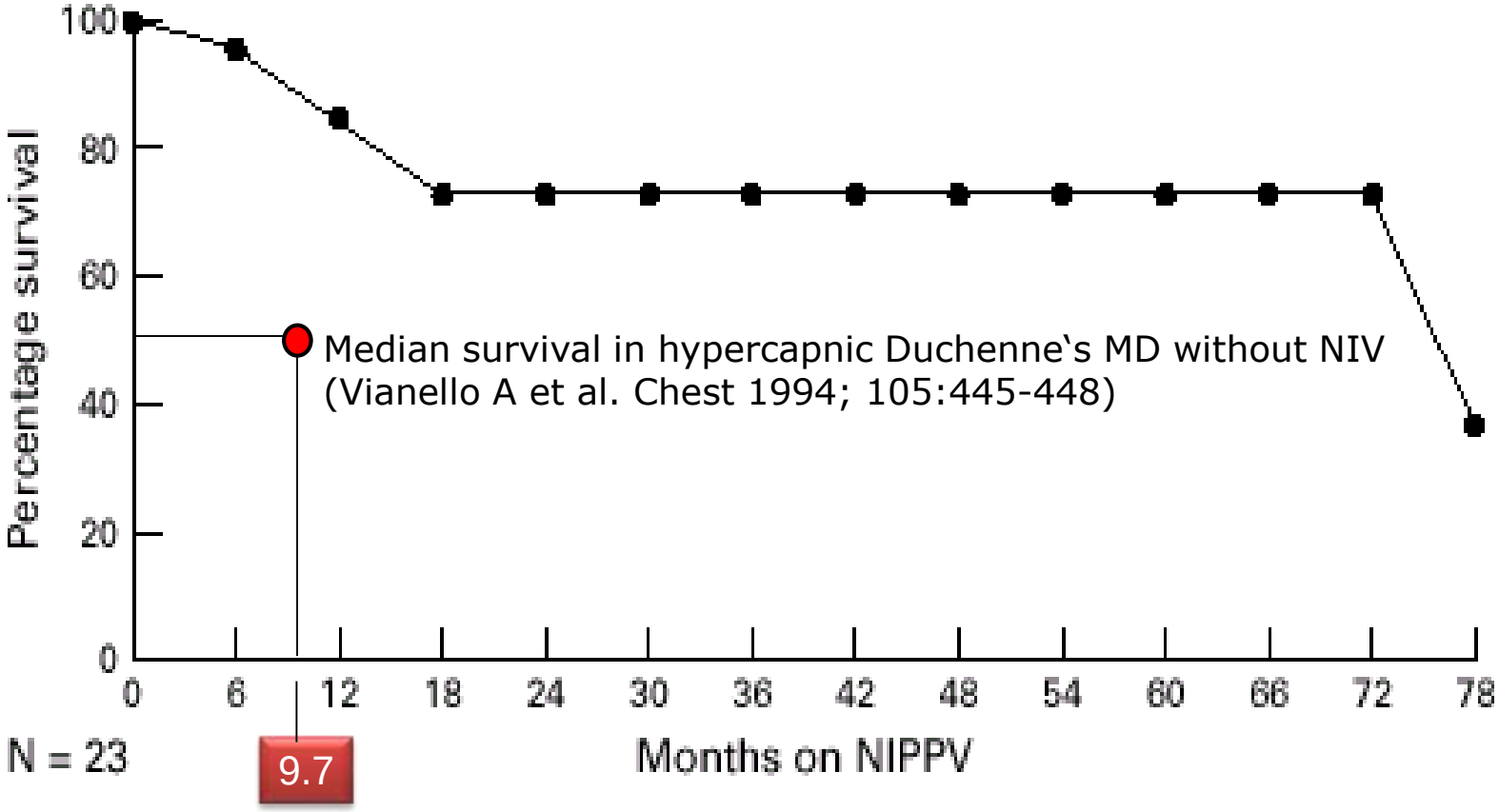
Windisch W. Eur Respir J. 2008 Nov;32(5):1328-36

Duchenne's MD: Impact of NIV on ABG



Simonds AK. et al. *Thorax* 1998; 53:949-952

Duchenne's MD: Impact of NIV on survival

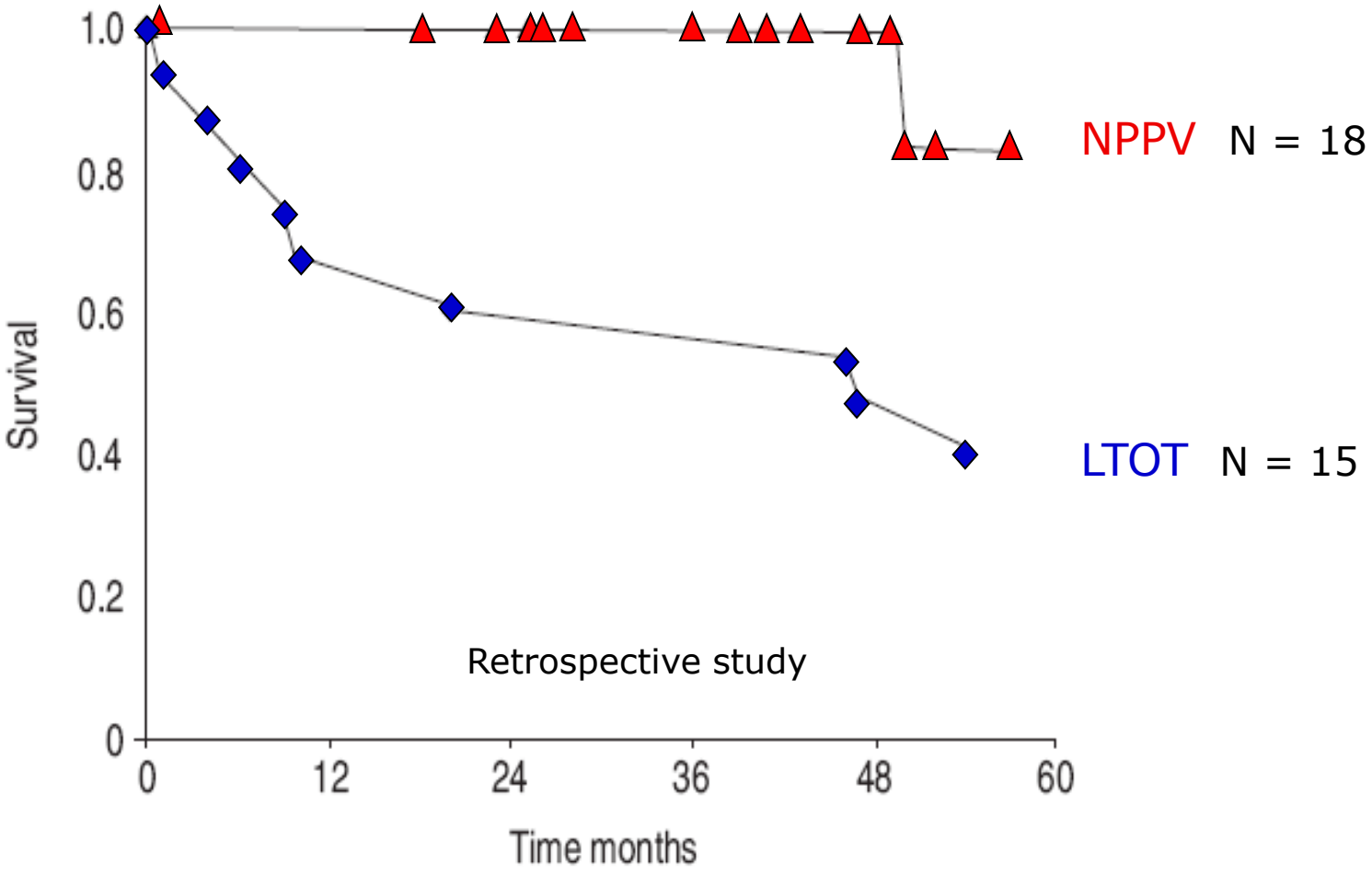


Simonds AK. et al. *Thorax* 1998; 53:949-952

Can patients with chronic hypoventilation be managed with oxygen alone?

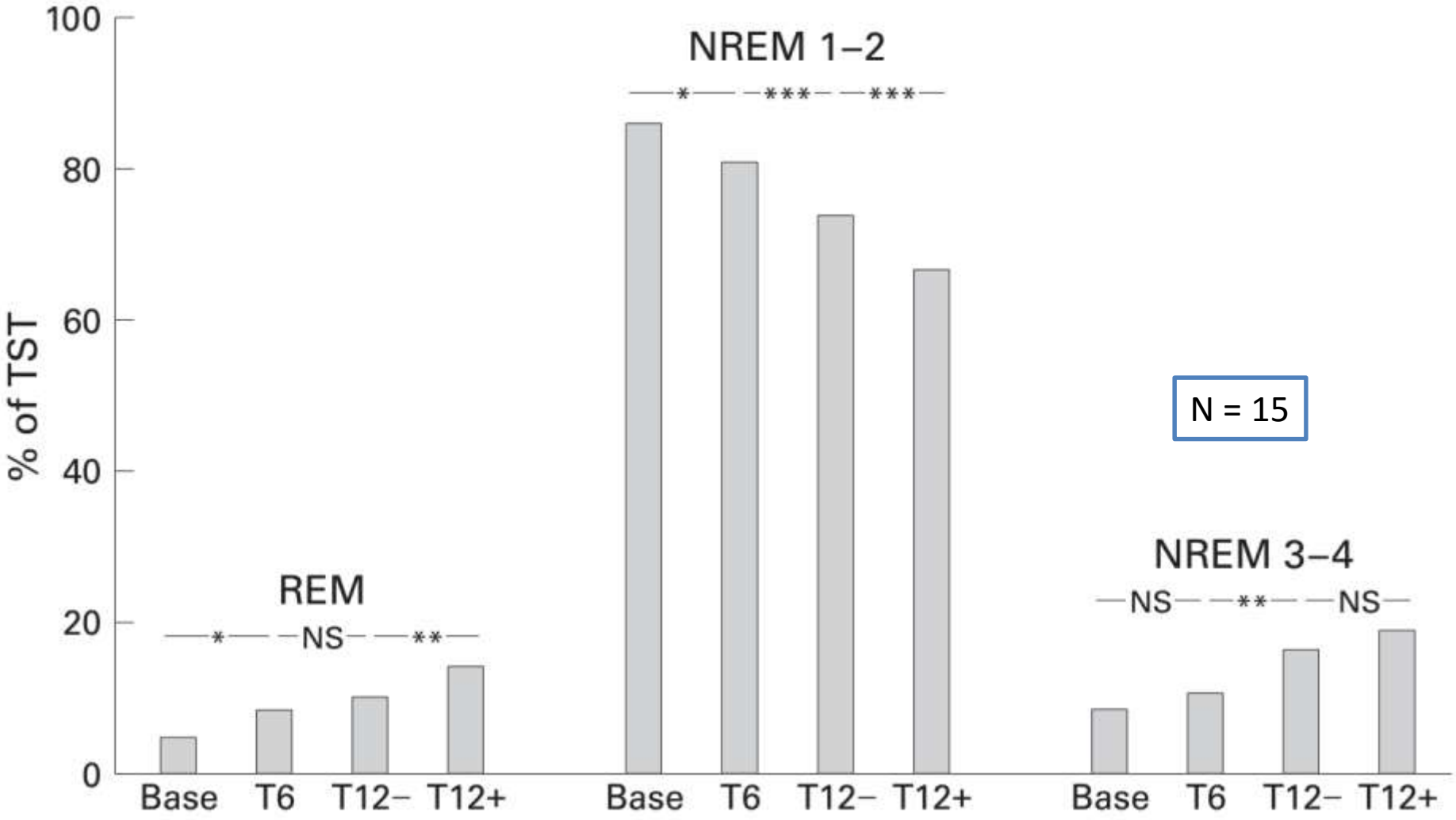
Do they really require HMV?

Kyphoscoliosis: Oxygen vs. ventilation



Buyse B, Meersseman W, Demedts M. Eur Respir J. 2003 Sep;22(3):525-8

Thoracic restriction: HMV & Sleep quality



Schönhofer B, Köhler D. Thorax. 2000 Apr;55(4):308-13

Sleep: Schonhofer 2000

- Fifteen consecutive patients (13 women) of mean (SD) age 57.9 (12.0) years with **CRF due to thoracic restriction** were included in the study.
- During the one year observation period four polysomnographic studies were performed: three during spontaneous breathing without NMV-
  - before initiation of NMV (T0) and
  - after withdrawing NMV for one night
    - at six months (T6) and
    - 12 months (T12-)-and
  - the fourth during NMV after 12 months (T12+).

Schönhofer B, Köhler D. Thorax. 2000 Apr;55(4):308-13

Indications for NIV in restrictive diseases

Clinical Criteria	Physiologic Criteria
Severe, irreversible disease	Vital capacity <25% predicted
Symptoms of nocturnal hypoventilation	Pimax > -50 cmH2O (COPD), or > -25 cmH2O (restrictive disorder)
Dyspnea at rest or sleep	PaCO2 >45 mmHg
Refractory cor pulmonale	Nocturnal SaO2 <88% despite supplemental O2

*Patients must satisfy at least two clinical criteria and two physiologic criteria

Criner GJ et al. Chest. 1999 Sep;116(3):667-75

SRBDs

- CPAP is indicated for the treatment of moderate to severe OSA (STANDARD)
- CPAP therapy targeted to normalize the apnea-hypopnea index (AHI) is indicated for the initial treatment of CSAS related to CHF (STANDARD)

AASM practice parameters.
Kushida CA et al. Sleep. 2006 Mar;29(3):375-80

AASM practice parameters.
Aurora RN et al. Sleep. 2012 Jan 1;35(1):17-40

COPD

- Failure of weaning from invasive mechanical ventilation is one of the major clinical problems in COPD patients. In one study these “chronically critically ill” patients, representing only 3% of the total number of patients admitted to the ICU, used almost 40% of the total patient days of care
- Long-term NIV produced no improvement in QoL or dyspnoea (MRC scale)

Carlucci A, et al. Eur Respir Rev. 2012 Dec 1;21(126):347-54. PMID: 23204123

Indications for home NIPPV in COPD

- Symptoms: Fatigue, dyspnea, morning headache
- Physiological criteria
  - $PaCO_2 \geq 55mmHg$
  - $PaCO_2 = 50\text{-}54mmHg$ with nocturnal desaturation ($SaO_2 \leq 88\%$ for 5 continuous minutes while receiving oxygen therapy ≥ 2L/min
  - $PaCO_2 = 50\text{-}54mmHg$ with history of hospitalization (>1 episode in a year) related to recurrent episodes of hypercapnic respiratory failure

Chest. 1999 Aug;116(2):521-34. PMID: 10453883
Antoniadis A. Pneumon 2009; 22(Suppl 2):103-111

Stable COPD: (NIV + LTOT) vs. (LTOT alone)

	n	IPAP/EPAP (cmH2O)	ΔPaCO2 (mmHg)	Survival	Other
Casanova 2000	**52** NIV: 26 LTOT: 26	12/4	NIV: +0.4 LTOT: -0.9	No benefit (at 1 year)	- Improved dyspnoea and psychomotor coordination - No improvement in exacerbations
Clini 2002	**90** NIV: 43 LTOT: 47	14/2	No difference* (at 2 years)	No benefit (at 2 years)	- Improved dyspnoea and HRQoL - No improvement in lung function, 6MWD, sleep quality, exacerbations
McEvoy 2009	**144** NIV: 72 LTOT: 72	12.9/5.1	NIV: -0.9 LTOT: -2.0 (at 1 year)	No benefit** (2.2 years)	- No improvement in lung function, HRQoL***, exacerbations

Chest. 2000 Dec;118(6):1582-90 Eur Respir J. 2002 Sep;20(3):529-38 Thorax. 2009 Jul;64(7):561-6

*There was no difference in PaCO2 between both the groups when breathing room air. However, PaCO2 was 5 mmHg lower (already 1mmHg lower at baseline) in the NIV group while breathing usual oxygen

**Adjusted HR 0.63, 95% CI 0.40 to 0.99, p = 0.045; Unadjusted HR 0.82, 95% CI 0.53 to 1.25, p = NS

***Patients treated with NIV had poorer general and mental health and reported less vigour and more confusion and bewilderment

Baseline differences in McEvoy's study

	LTOT (n = 72)	NIV+LTOT (n = 72)
Age (years)	68.8 (67.1 to 70.5)	67.2 (65.3 to 69.1)
Gender (% male)	61%	69%
BMI (kg/m^2)	25.4 (24.0 to 26.8)	25.5 (24.3 to 26.7)
$FEV_{1.0}$ (litres)	0.55 (0.51 to 0.59)	0.63 (0.57 to 0.69)
$FEV_{1.0}$ (% predicted)	23.1 (21.4 to 24.8)	25 (22.4 to 27.6)
FVC (litres)	1.76 (1.60 to 1.92)	1.98 (1.80 to 2.16)
FVC (% predicted)	54.8 (51.0 to 58.6)	57.5 (53.9 to 61.1)
$FEV_{1.0}$/FVC (%)	32.9 (30.9 to 34.9)	32.9 (30.3 to 35.5)
T_{LCO} (ml/min/mmHg)	6.76 (5.96 to 7.56)	8.61 (7.49 to 9.73)
T_{LCO} (% predicted)	30.7 (27.9 to 33.5)	37.2 (33.2 to 41.2)
Oxygen treatment (h/day)	20.5 (19.5 to 21.5)	20 (18.8 to 21.2)
Pao_2 (mm Hg, air)	52.5 (50.1 to 54.9) (n = 62)	54.8 (52.4 to 57.2) (n = 61)
$Paco_2$ (mm Hg, air)	54.4 (52.6 to 56.2) (n = 62)	52.6 (51.0 to 54.2) (n = 61)
SGRQ	64.1 (49.9–70.8)*	69 (57.2–77.2)*

Values are mean (95% CI) or *median (interquartile range).

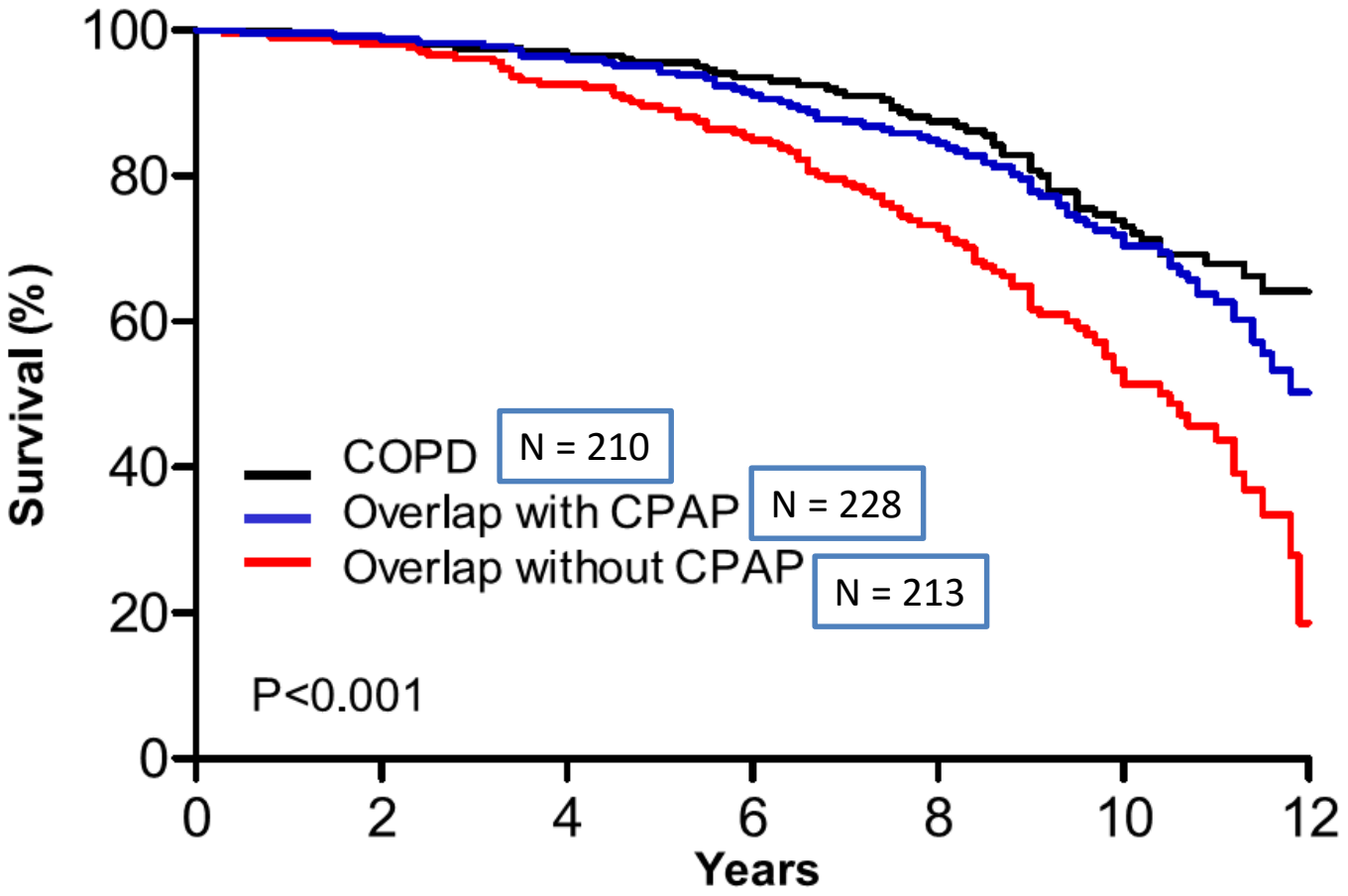
McEvoy RD et al. Thorax. 2009 Jul;64(7):561-6. PMID: 19213769

Meta-analysis: Nocturnal NIV for stable COPD

- Population: Hypercapnic patients with stable COPD
- Intervention: Nocturnal-NIPPV at home for at least 3 months
- 7 studies, 245 people
- **Meta-analysis of individual patient data**
- Outcome measures: PaCO2, PaO2, 6MWD, SGRQ, FEV1, FVC, PImax, sleep efficiency
- Result: **No consistent clinically or statistically significant effect on any parameter** (95% CI of all outcomes included zero)

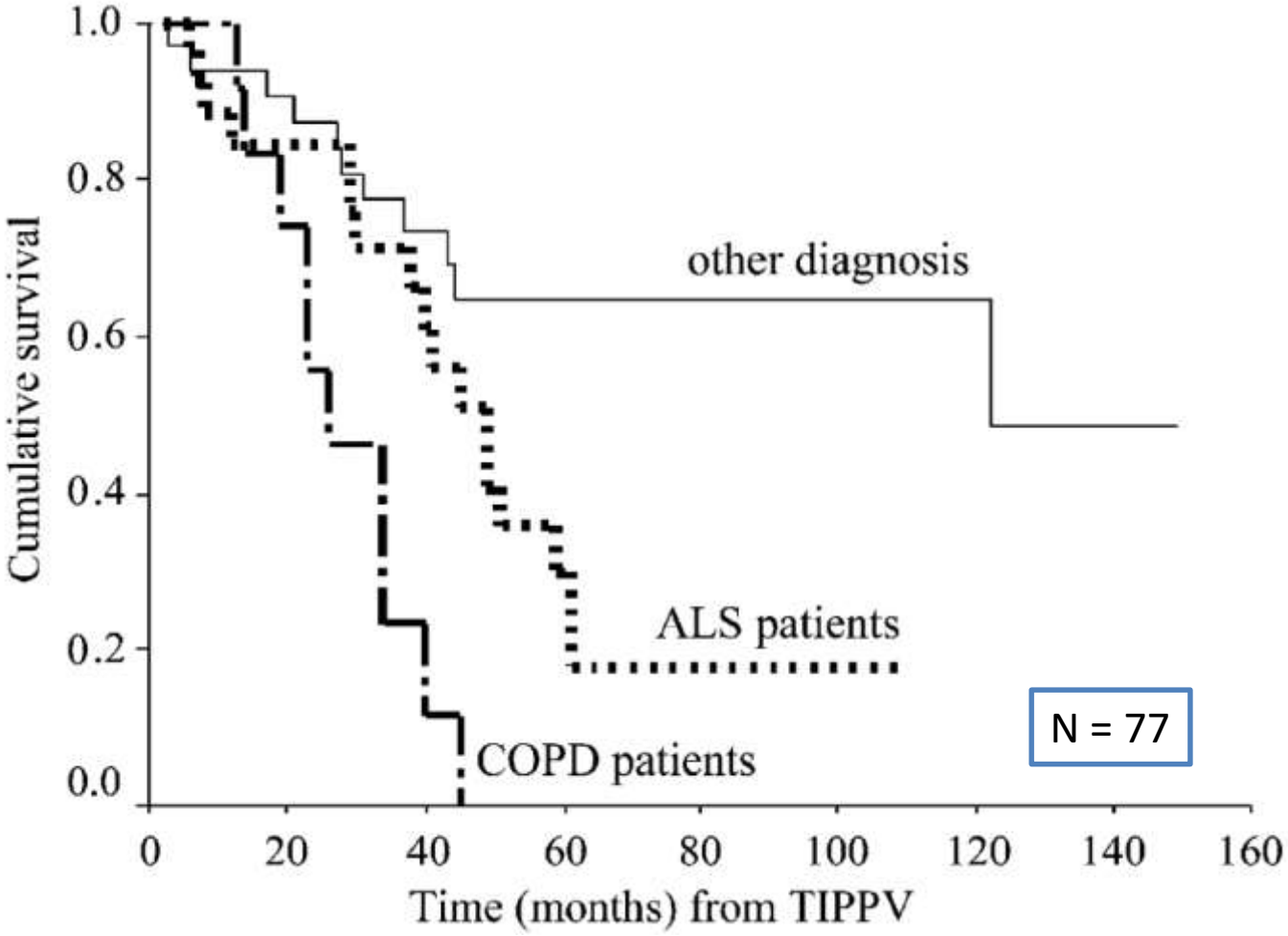
Struik FM et al. Cochrane Database Syst Rev. 2013 Jun 13;6:CD002878

Overlap syndrome (COPD + OSA)



Marin JM et al. Am J Respir Crit Care Med. 2010 Aug 1;182(3):325-31

Tracheostomy IPPV at home (Palermo, Italy 1995-2004)



Marchese S, Lo Coco D, Lo Coco A. Respir Med. 2008 Mar;102(3):430-6

Equipment selection

Closed circuit

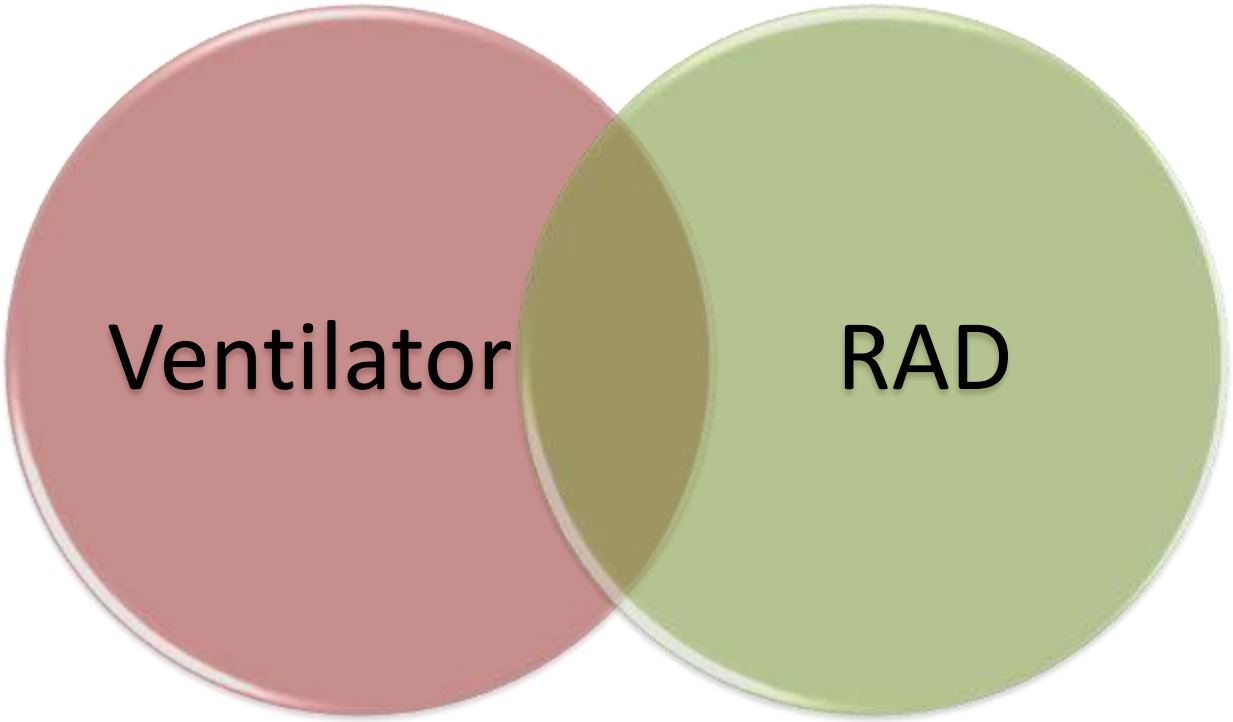
- Usually has 2 limbs
- Exhalation via ‘valves’
- Allows higher level of support
- Allows more extensive monitoring
- Tighter control of ventilator variables

Open circuit

- Single limb
- Exhalation via ‘ports’
- Lesser level of support
- Lesser/less acurate monitoring options
- Poorer control of ventilator variables

King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967

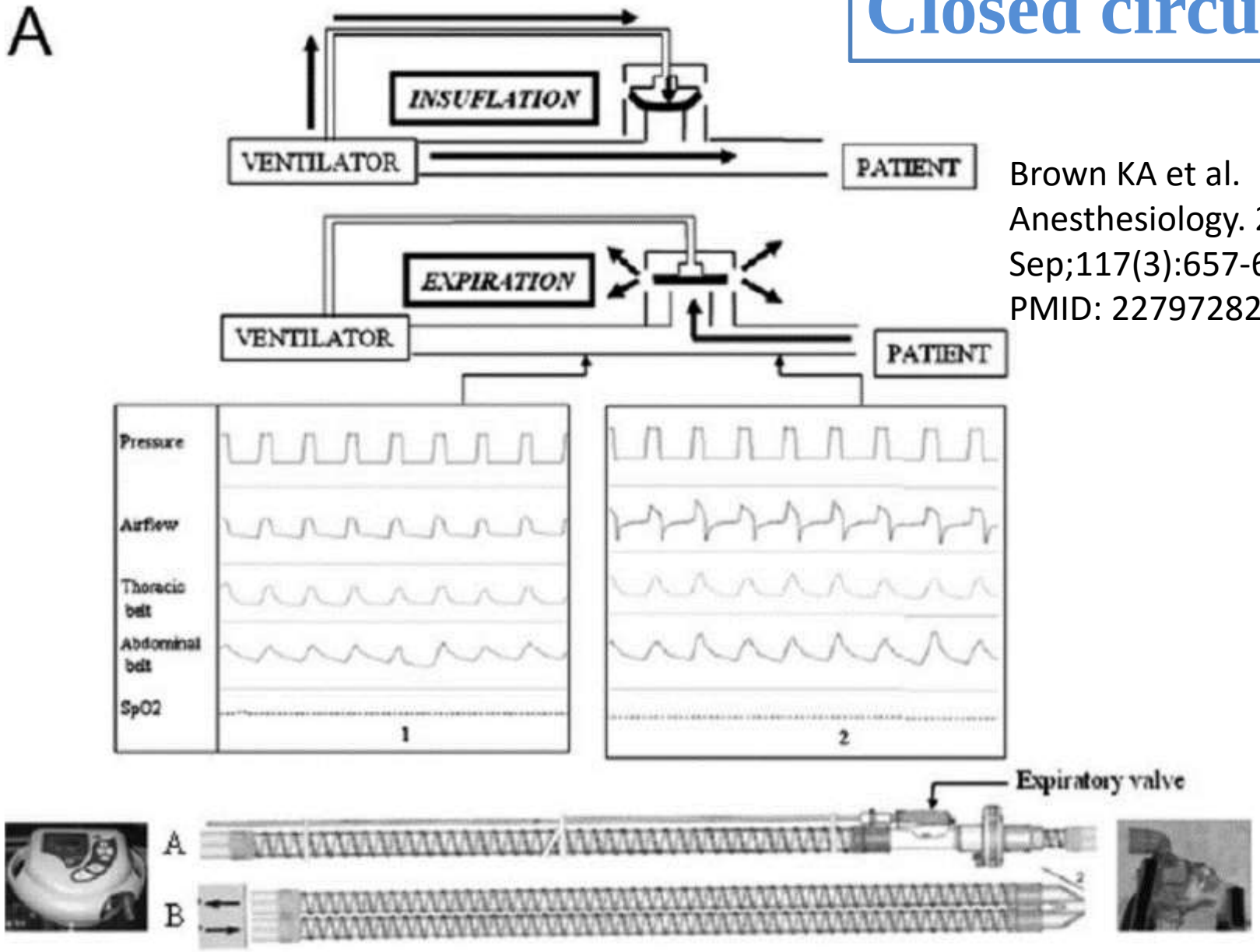
Blurring boundaries…



RAD = Respiratory assist device

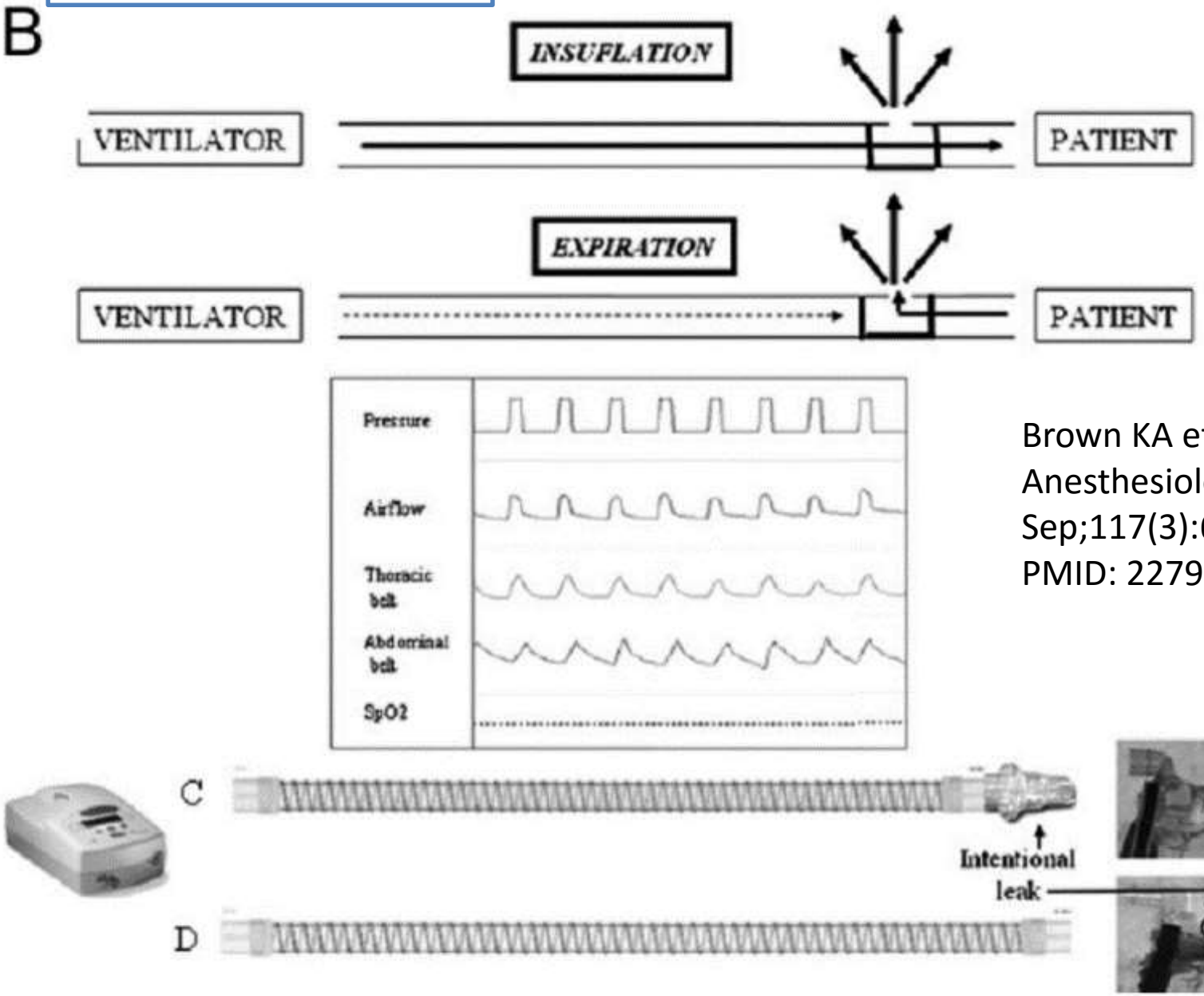
King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967

Closed circuit



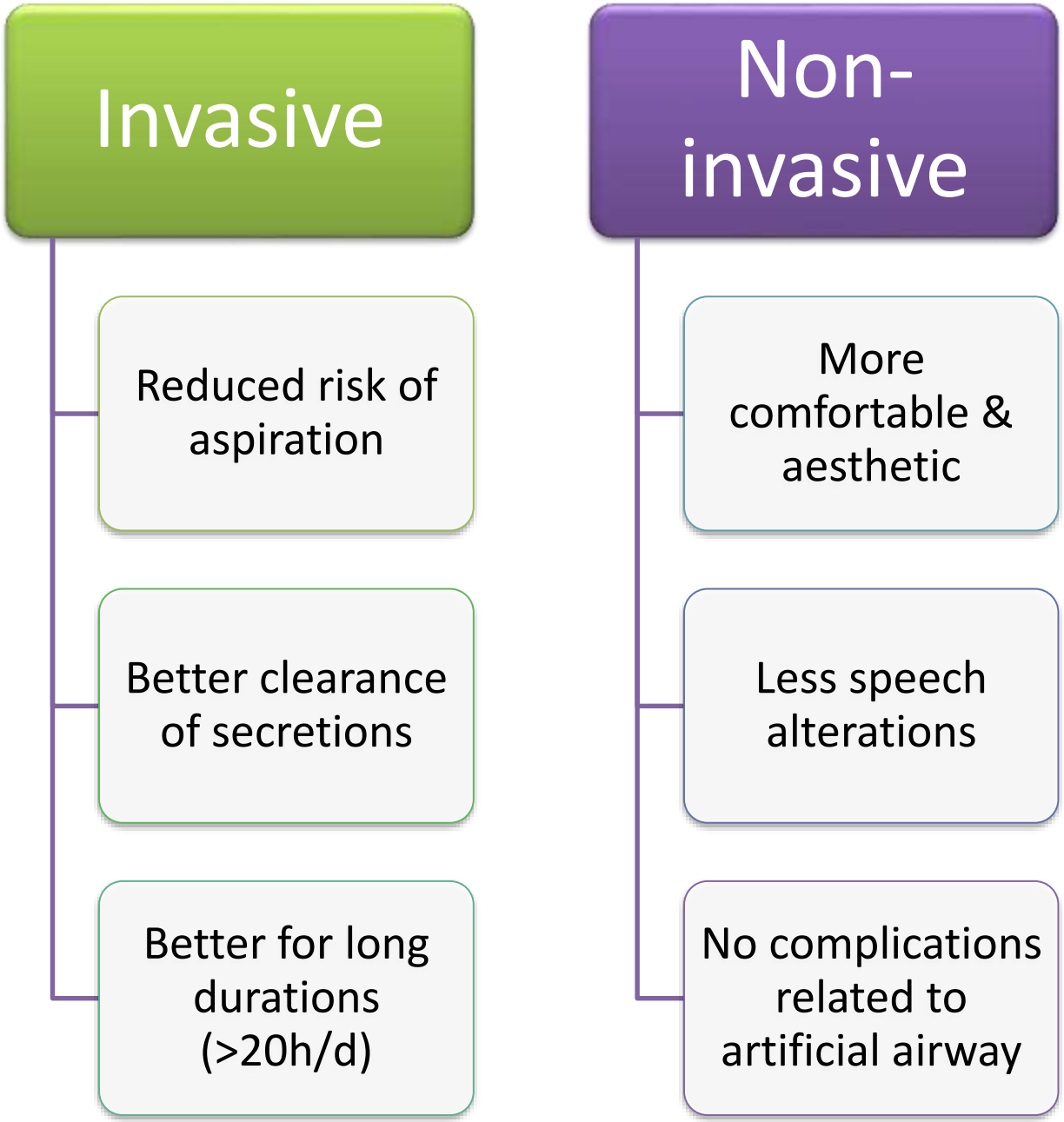
Brown KA et al. Anesthesiology. 2012 Sep;117(3):657-68. PMID: 22797282

Open circuit

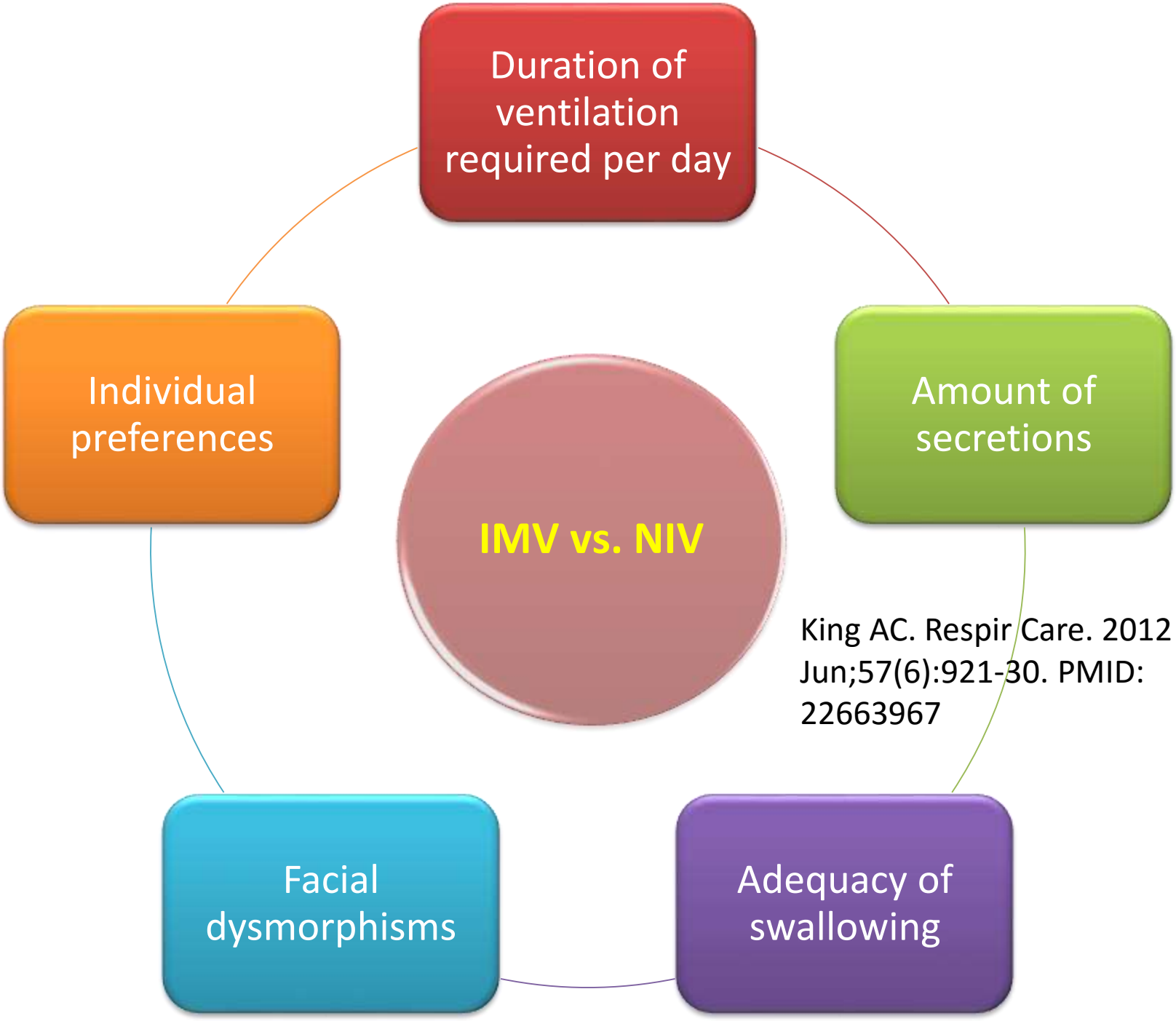


Brown KA et al. Anesthesiology. 2012 Sep;117(3):657-68. PMID: 22797282

Interface selection



King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967



King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967

Medicare Ventilator Support Claims Data 2010

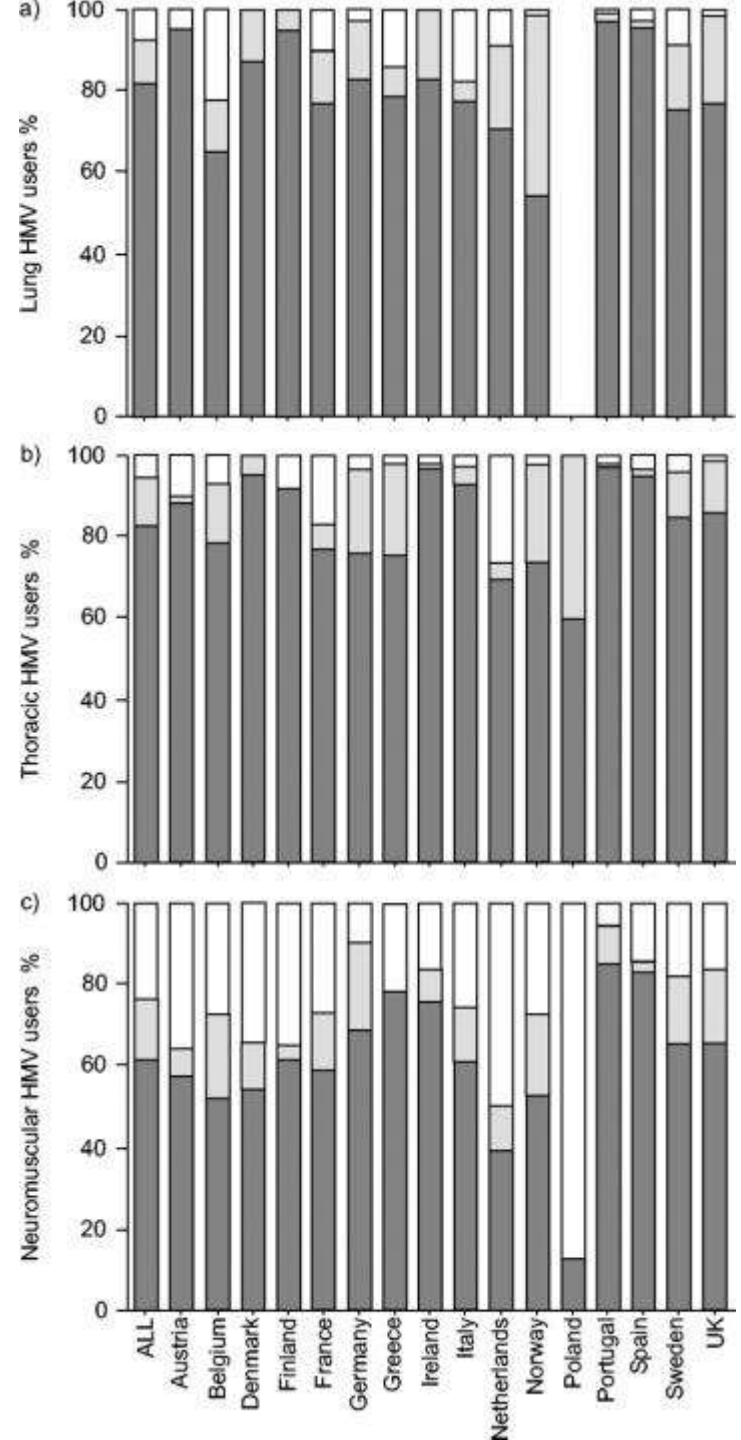
Total all forms ventilation (RAD and all forms of mechanical ventilator)	47,981
Total invasive mechanical ventilator	3,172
Total noninvasive mechanical ventilator	899
Total noninvasive RAD	43,910
Invasive Ventilator Support by Region (%)	
United States (total all invasive/total all forms)	6.6
Europe (EuroVent survey data)†	13

* Centers for Medicare and Medicaid Services claims data, Noridian Administrative Services, accessed 7/29/2011.

King AC. Respir Care. 2012 Jun;57(6):921-30

	Oral*	Nasal masks	Nasal pillows	Oronasal	Full-face	Helmet
Air leak	Mouth, nose leaks	In mouth-breathers	In mouth-breathers	Less	Less	Less
Influence by dental status	+	-	-	+	+	-
Dead space and CO_2 rebreathing	-	-	-	+	+	+++
Difficulty in communication & feeding	++	+	+	++	++	++
Patient comfort	+	+++	+++	+	+	++
Risk of aerophagia	+	Less	Less	+	+	+
Risk of skin damage	-	++	+	++	++	+
Claustrophobia	+	Less	Less	+	++	+

*Excessive salivation, gag reflex and vomiting & orthodontic deformities (with long-term use)



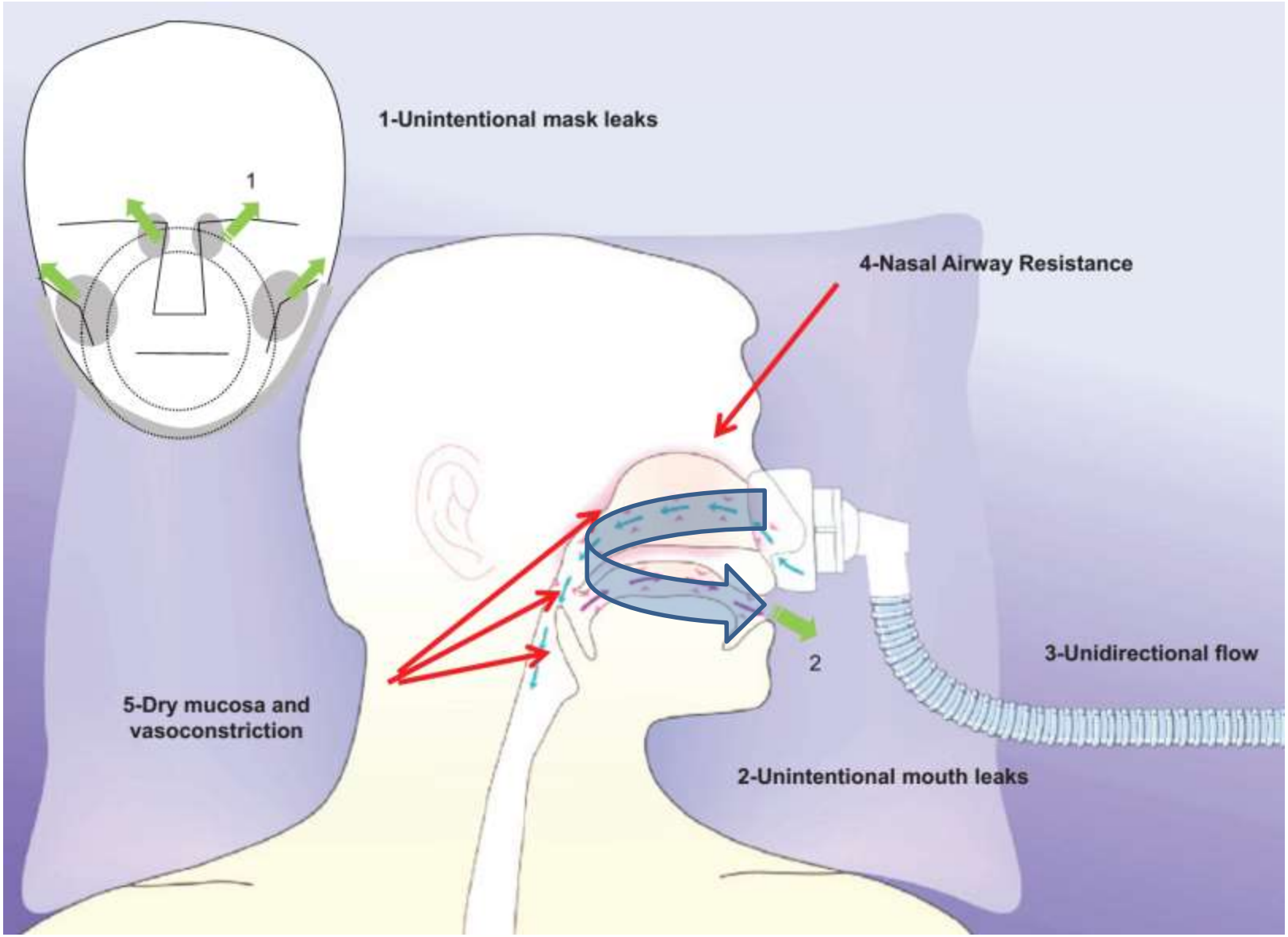
EuroVent 2002: Interface preference

Nasal mask is the most widely used NIV interface for HMV

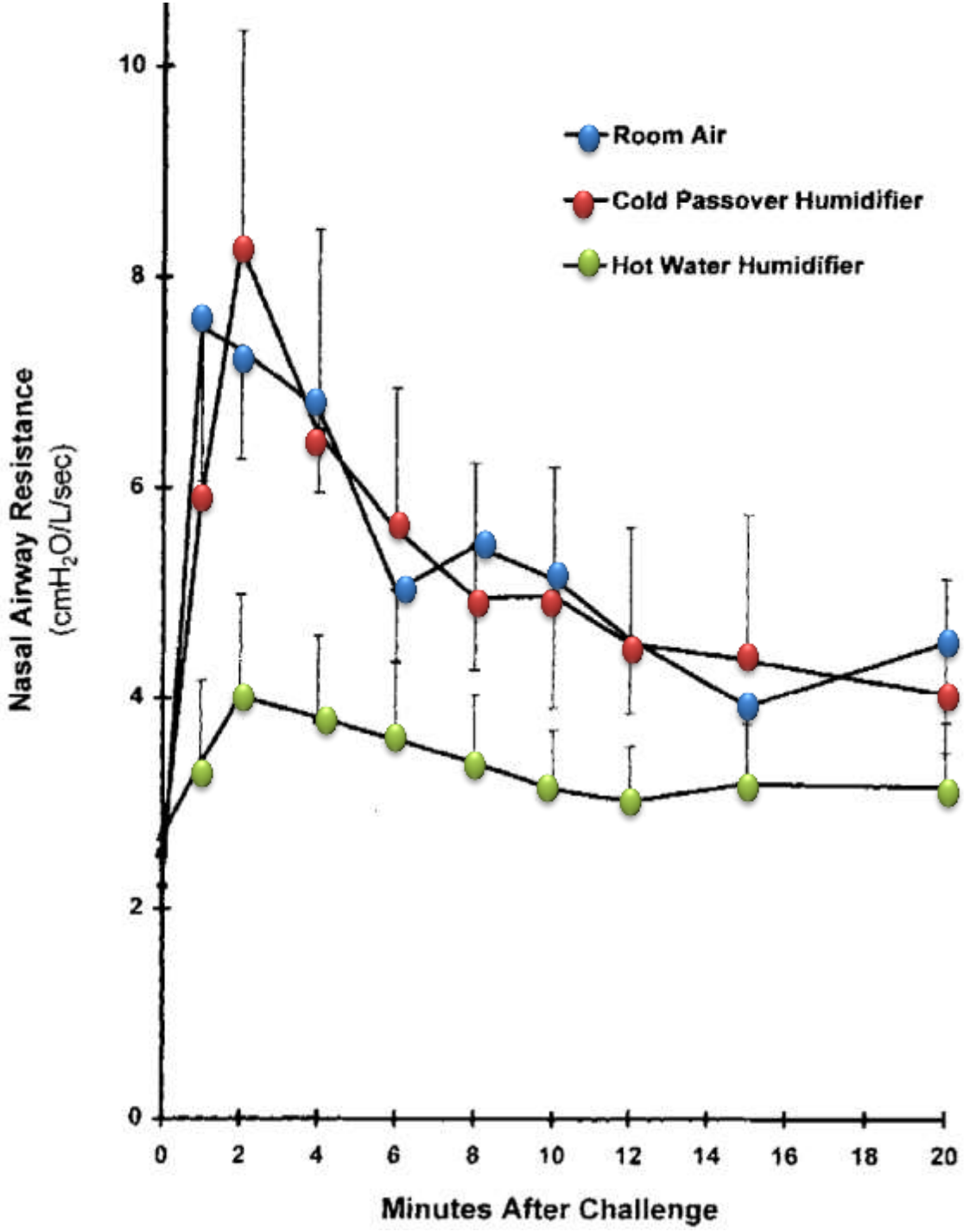
Dark grey: Nasal mask
Light grey: Facial mask
White: Tracheostomy

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

Humidification



Esquinas Rodriguez AM et al. Crit Care. 2012 Feb 8;16(1):203. PMID: 22316078



- Nasal CPAP with mouth leak resulted in nearly three-fold increase in nasal airway resistance
- This was substantially attenuated by effective humidification

Richards GN et al. Am J Respir Crit Care Med. 1996 Jul;154(1):182-6

Mode selection

Controlled vs. Spontaneous

- Spontaneous: Better synchrony and comfort
- Controlled/Mandatory: Safer when patient's breathing is erratic

Chatburn RL. Respir Care. 2009 Jan;54(1):85-101. PMID: 19111109

Home NIV

VCV

Stable VT despite varying patient effort, airway resistance, chest wall compliance

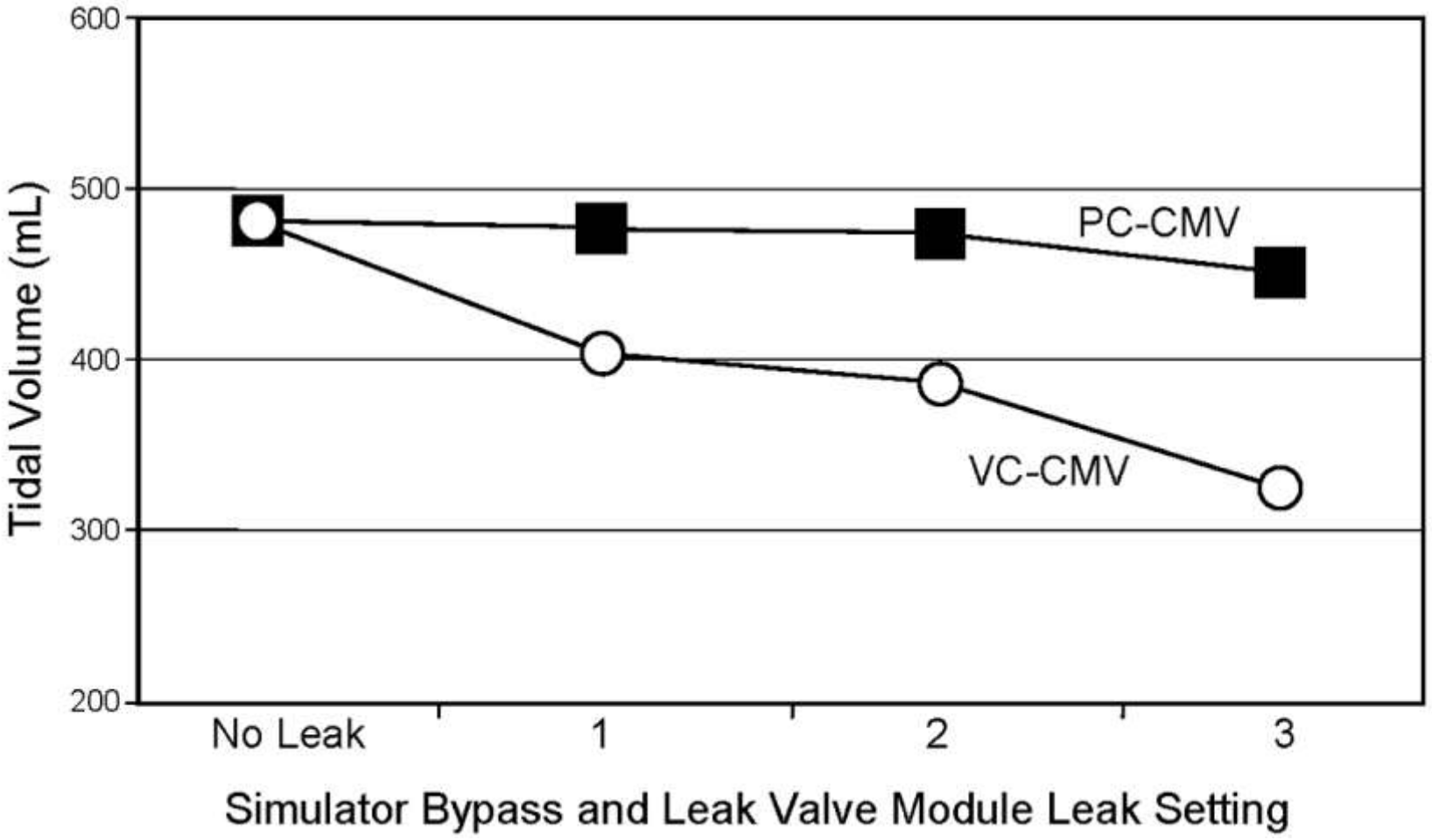
Poor performance during leak

PCV

Better patient synchrony and comfort

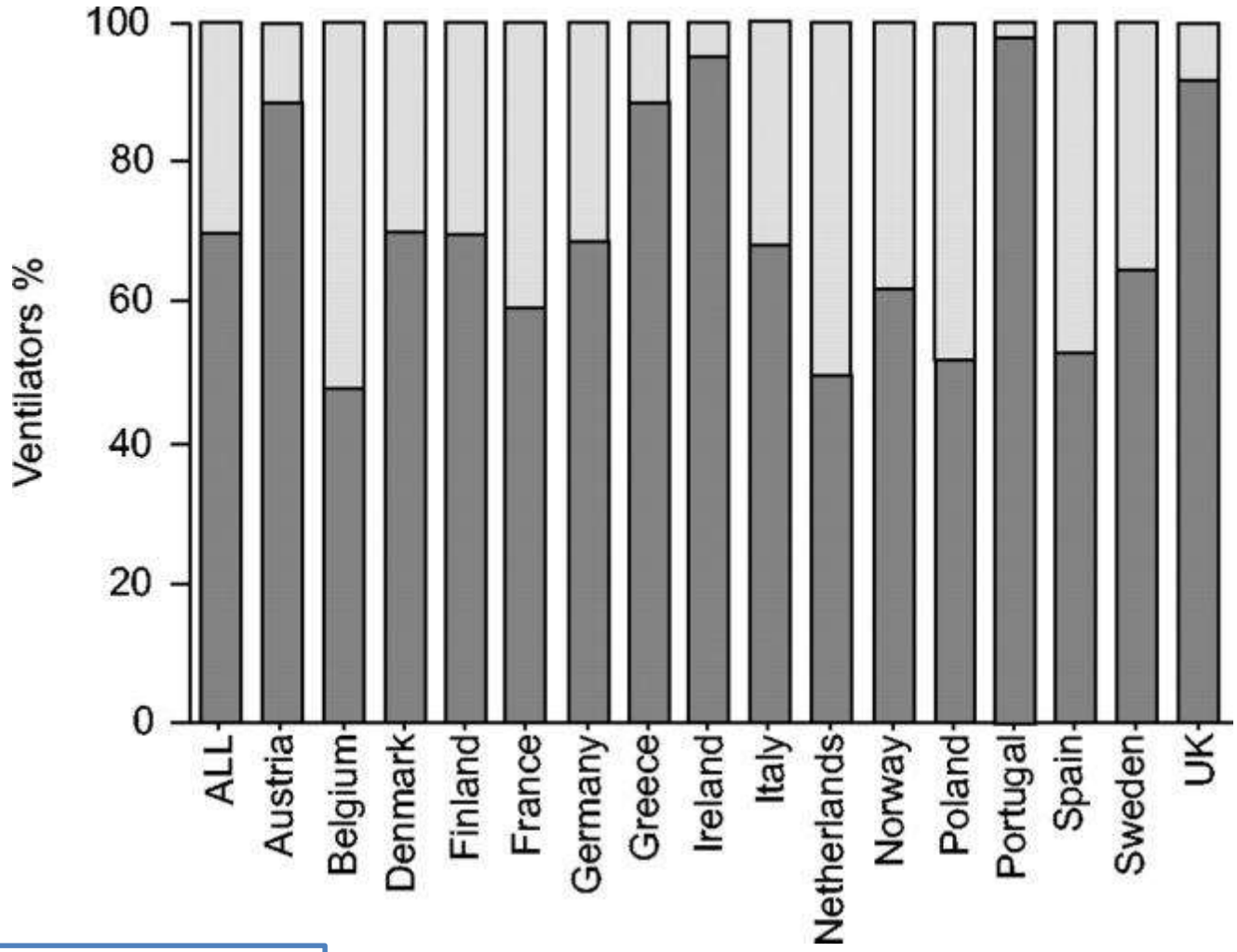
Stable ventilation despite leak

VCV vs. PCV during leak



Chatburn RL. Respir Care. 2009 Jan;54(1):85-101

EuroVent: Pressure vs. Volume



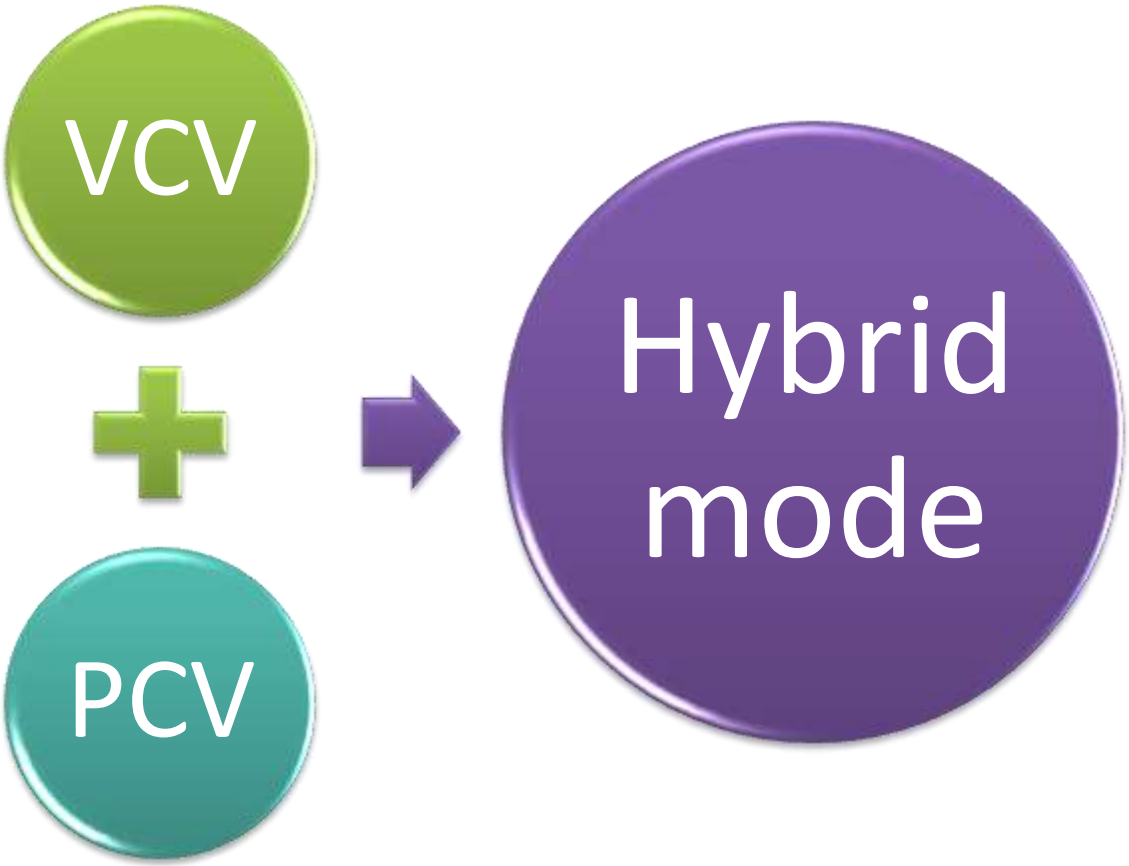
Dark grey: Pressure preset
Light grey: Volume preset

Lloyd-Owen SJ et al. Eur Respir J. 2005 Jun;25(6):1025-31

Major NIV modes

- **Continuous positive airway pressure (CPAP)**: Similar to PEEP in IMV
  - With or without auto-titration feature (**APAP**)
- **Bi-level positive airway pressure (BPAP)**
  - **BPAP-S**: Patient-triggered, flow-cycled; Similar to PSV in IMV
  - **BPAP-T**: Time-triggered, time-cycled; Similar to PCV in IMV
  - **BPAP-ST**: Additional time-triggered, but flow-cycled breaths delivered when patients' spontaneous rate falls below the set rate; Similar to PSV with PCV backup in IMV
- **Newer modes**
  - **Adaptive servo ventilation (ASV)**: Similar to PRVC, Adaptive support ventilation (ASV) in IMV
  - **Averaged volume assured pressure support (AVAPS)**: Similar to volume assured PSV in IMV

Chatburn RL. Respir Care. 2009 Jan;54(1):85-101. PMID: 19111109



Pressure controlled inspiration (with variable pressure limit) to achieve a volume target

Adaptive Servo Ventilation (ASV)

- Closed-loop mechanical ventilation, pressure preset, and volume or flow cycled
- **Breath-by-breath adjustment of inspiratory pressure support** with a back-up rate to normalize breathing patterns relative to a **predetermined target**
- Examples
  - ***ResMed ASV*** (ASV, iVAPS, AdaptSV) targets 90% of the calculated **minute volume** and adjusts IPAP and ventilator rate accordingly
  - ***Respironics ASV*** (AutoSV) targets an **average peak flow** and adjusts IPAP accordingly
- Use: Central sleep apnea

ASV/iVAPS (ResMed)

- Targets Minute Ventilation (MV) and adjusts pressure support and back-up rate accordingly
- Settings
  - Height
  - Target Ve
  - EPAP
  - Minimum pressure support

Table 1. Commercial names for Modes That Use Adaptive Control

Ventilator	Adaptive Control Mode
Dräger Evita 4 and XL	AutoFlow
Hamilton Galileo	Adaptive Pressure Ventilation
	Adaptive Support Ventilation*
Maquette Servo-*i*	Pressure Regulated Volume Control
	Volume Support
Puritan Bennett 840	Volume Control +
Newport E500	Volume Target Pressure Control
Viasys/Pulmonetics PalmTop Ventilator	Pressure Regulated Volume Control
Viasys Avea	Pressure Regulated Volume Control

*Adaptive support ventilation uses optimal control, an advanced form of adaptive control.

Branson RD, Chatburn RL. Respir Care. 2007 Apr;52(4):478-85

ASV in CSAS

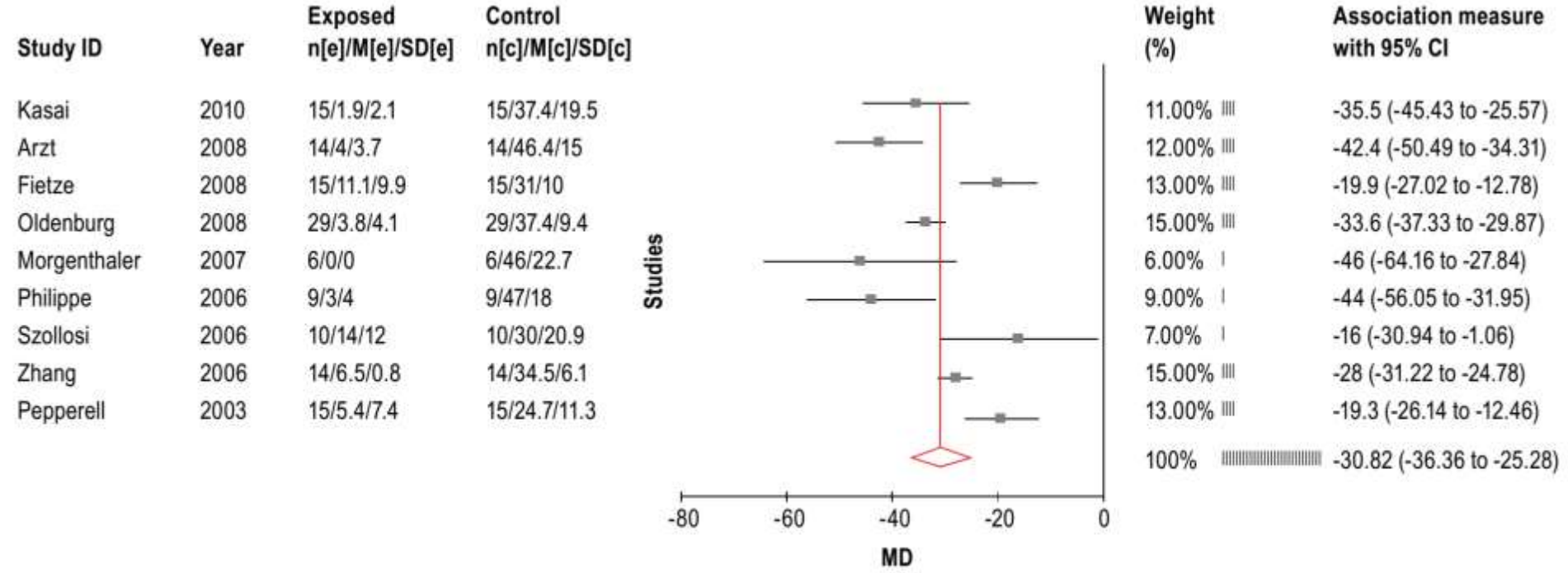


Figure 6—Meta-analysis of AHI from before-after ASV treatment trials

n/M/SD" = "number/mean/standard deviation
MD = Mean difference

Aurora RN et al. Sleep. 2012 Jan 1;35(1):17-40

ASV in CSAS

"While there is no survival or long-term data available for ASV at this time, there is a sufficient amount of data consistently demonstrating improvement in both the AHI and LVEF"

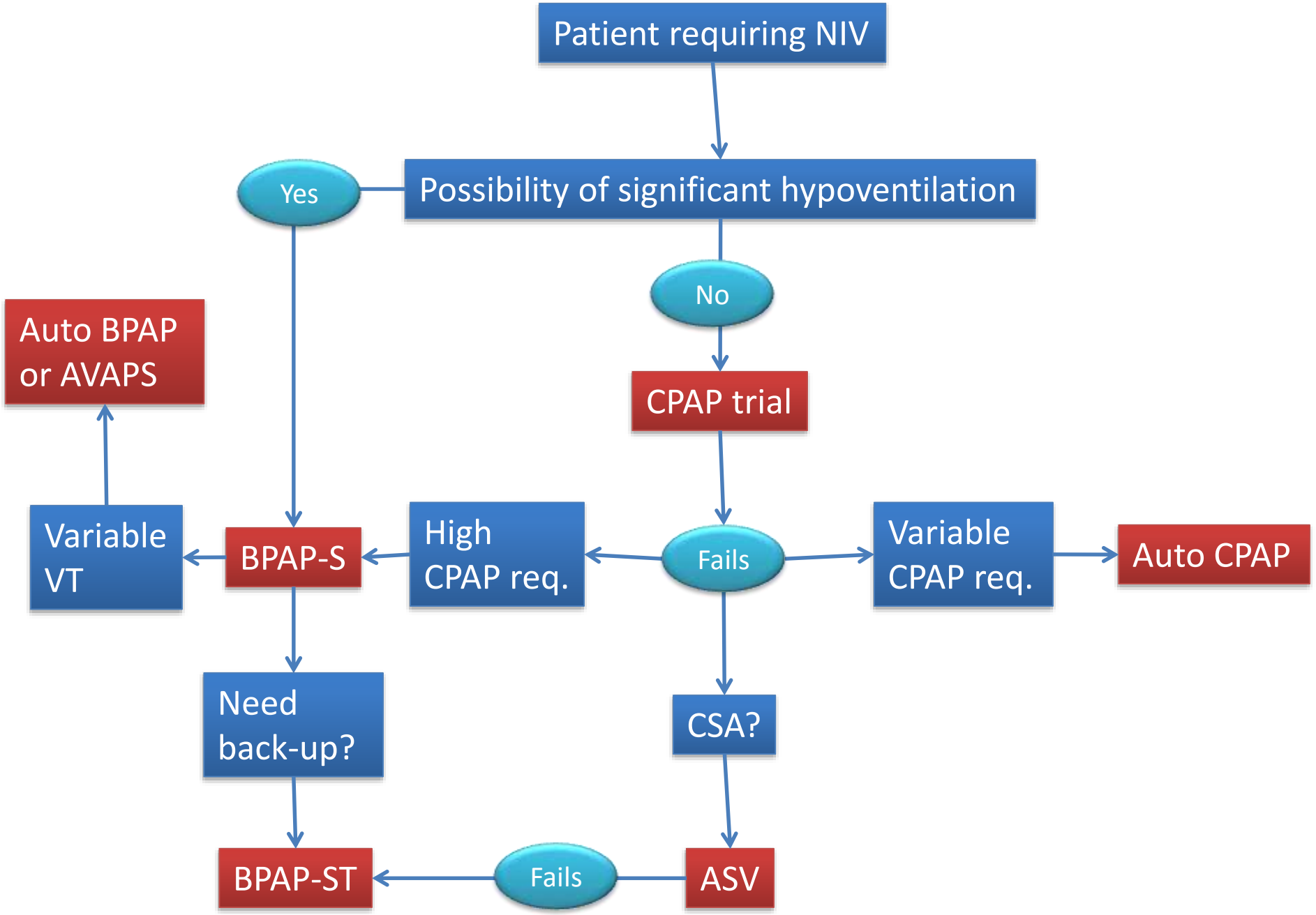
AASM practice parameters.
Aurora RN et al. Sleep. 2012 Jan 1;35(1):17-40

AVAPS (Philips Respironics)

- AVAPS (Average Volume Assured Pressure Support) is similar to VAPSV (Volume assured pressure support ventilation) in invasive MV
- **Automatically adjusts the pressure support level (IPAP) to maintain a consistent tidal volume**
- Settings:
  - Set target tidal volume to 110% of displayed patient tidal volume in the S/T mode or 8 cc per kg of ideal body weight.
  - IPAP Max = 25-30 cm H20
  - IPAP Min = EPAP + 4 cm H2O
- Candidates: Patients with risk of hypoventilation due to respiratory muscle weakness, restrictive disorders (kyphoscoliosis, obesity hypoventilation), obstructive lung diseases (COPD, CF)

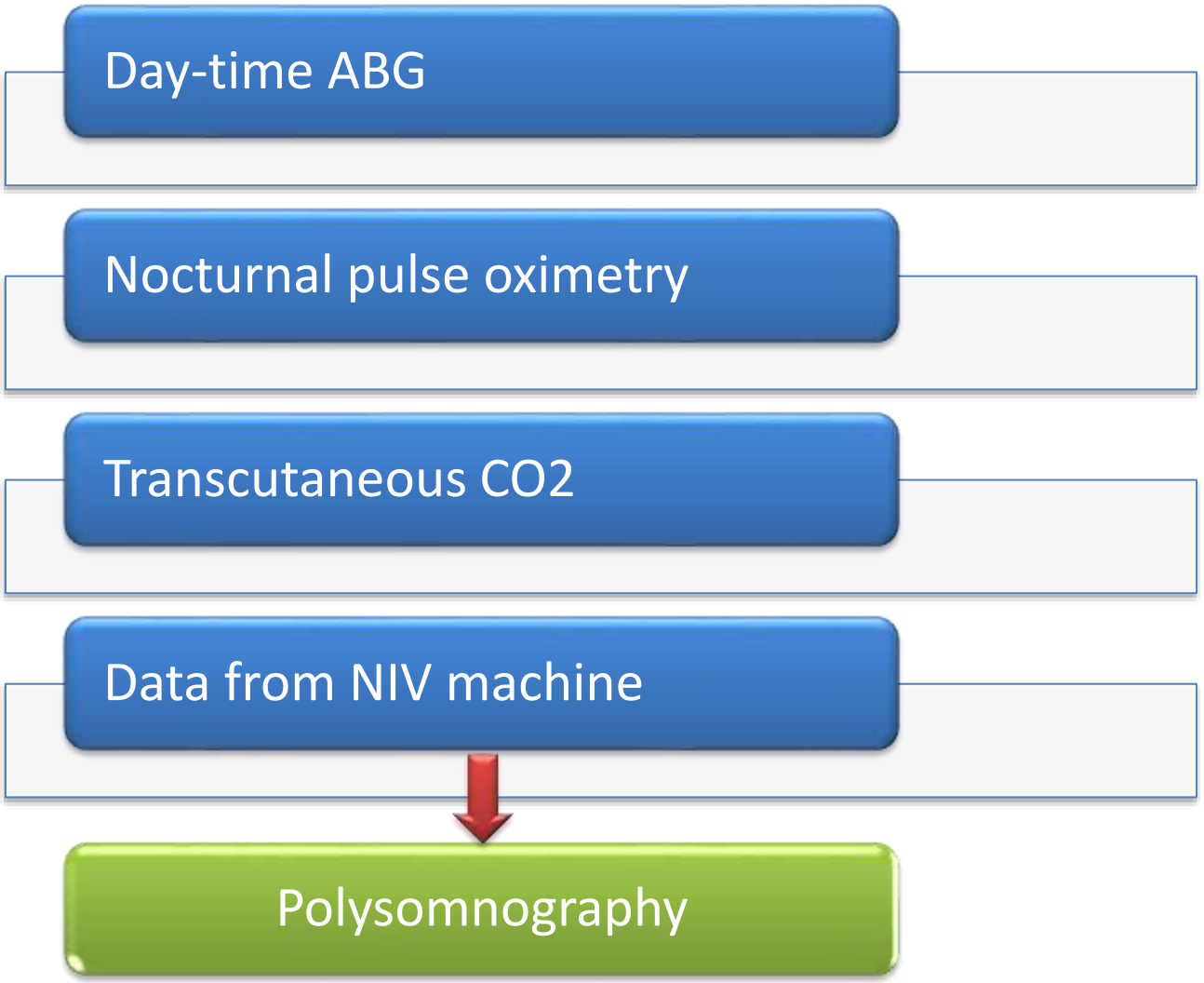
Auto-titration

- Use: Titration of CPAP/EPAP/IPAP according to airway resistance
- Nomenclature
  - ResMed: APAP, AutoSet
  - Respironics: Auto CPAP
- Principle: **Forced oscillation technique**
- Involves the production of high frequency, low amplitude pressure waves during apneas, and the measurement of the changes in flow (If airway is open, flow increases with increase in presure)


Patient requiring NIV
Possibility of significant hypoventilation
Yes
No
Auto BPAP or AVAPS
CPAP trial
Variable VT
BPAP-S
High CPAP req.
Fails
Variable CPAP req.
Auto CPAP
Need back-up?
CSA?
BPAP-ST
Fails
ASV

Monitoring

Monitoring


Day-time ABG
Nocturnal pulse oximetry
Transcutaneous CO2
Data from NIV machine
Polysomnography

Monitoring

- Day-time ABG
- Nocturnal pulse oximetry
- Transcutaneous CO2
- Data from NIV machine
- Polysomnography

Pulse oximetry - Advantages & disadvantages

- Advantages
  - Simple
  - Short set-up time
  - Short response time
  - Sensitive
- Disadvantages
  - Motion artefacts
  - Perfusion dependence
  - Poor accuracy when oxygen saturation <80%
  - Poor specificity

Janssens JP, Borel JC, Pépin JL; SomnoNIV Group. Thorax. 2011 May;66(5):438-45. PMID: 20971980

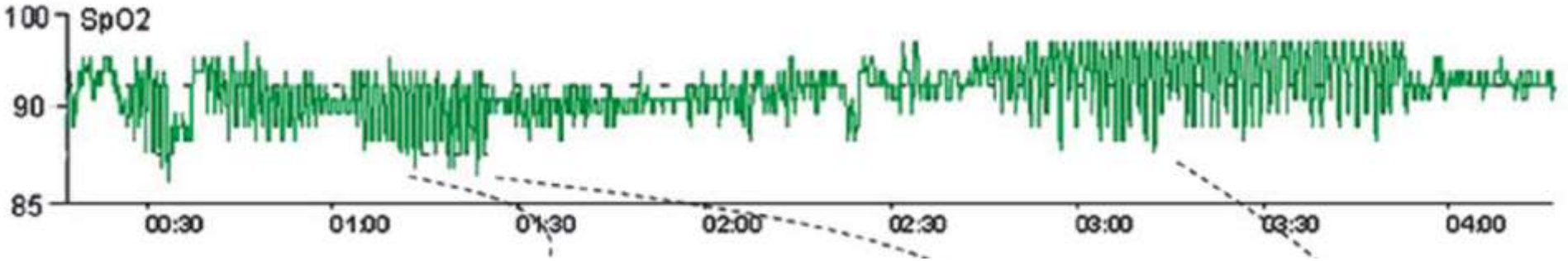
Pulse oximetry

- If normal, cannot exclude alveolar hypoventilation (especially in patients on LTOT)
- Does not identify the mechanisms of SpO2 abnormalities (apneas, leaks, etc.)

Visual inspection of oximetry tracing

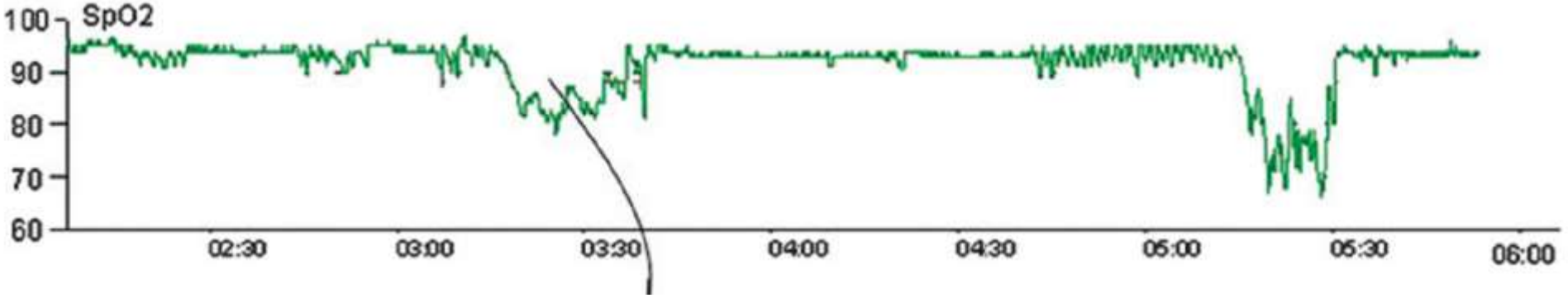
Recurrent oscillations in SpO2

Central/obstructive apneas
Intermittent leaks



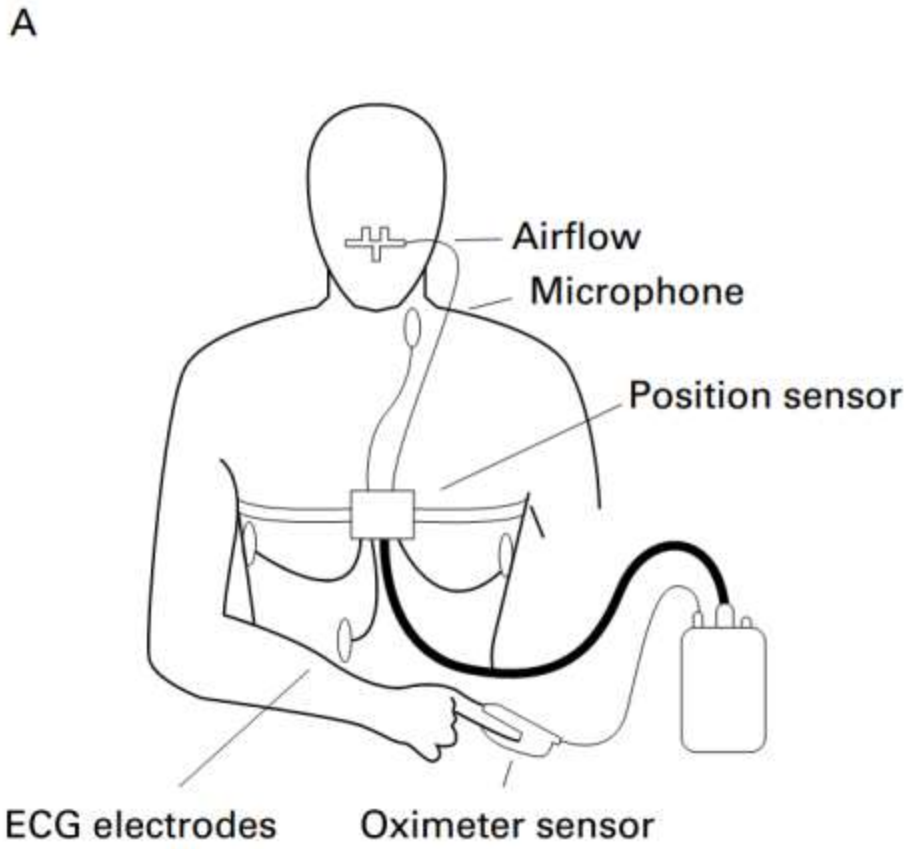
Prolonged desaturation

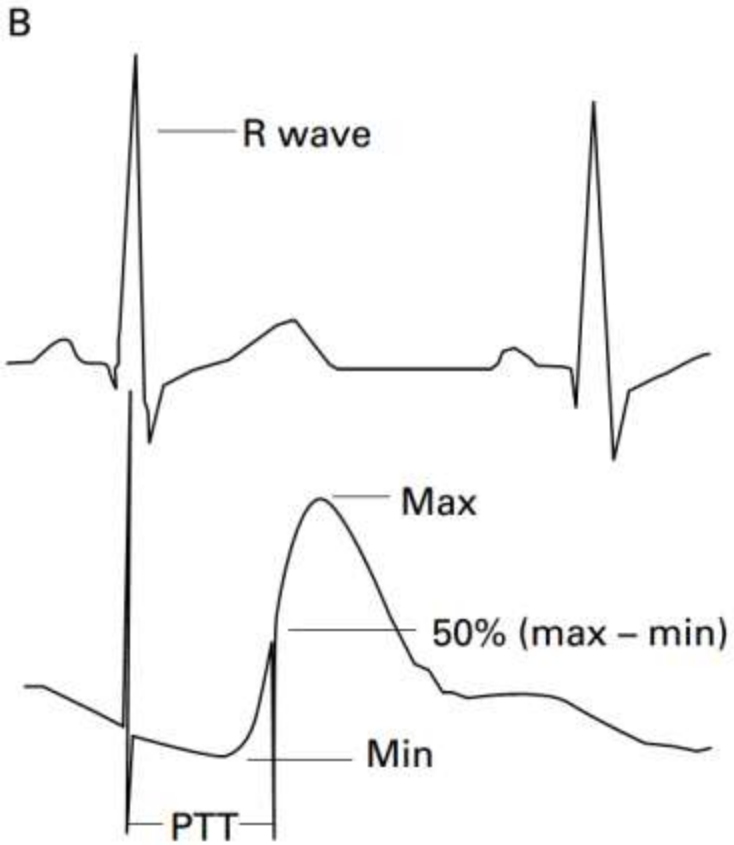
Inadequate pressure support
Prolonged leaks



Janssens JP, Borel JC, Pépin JL; SomnoNIV Group. Thorax. 2011 May;66(5):438-45

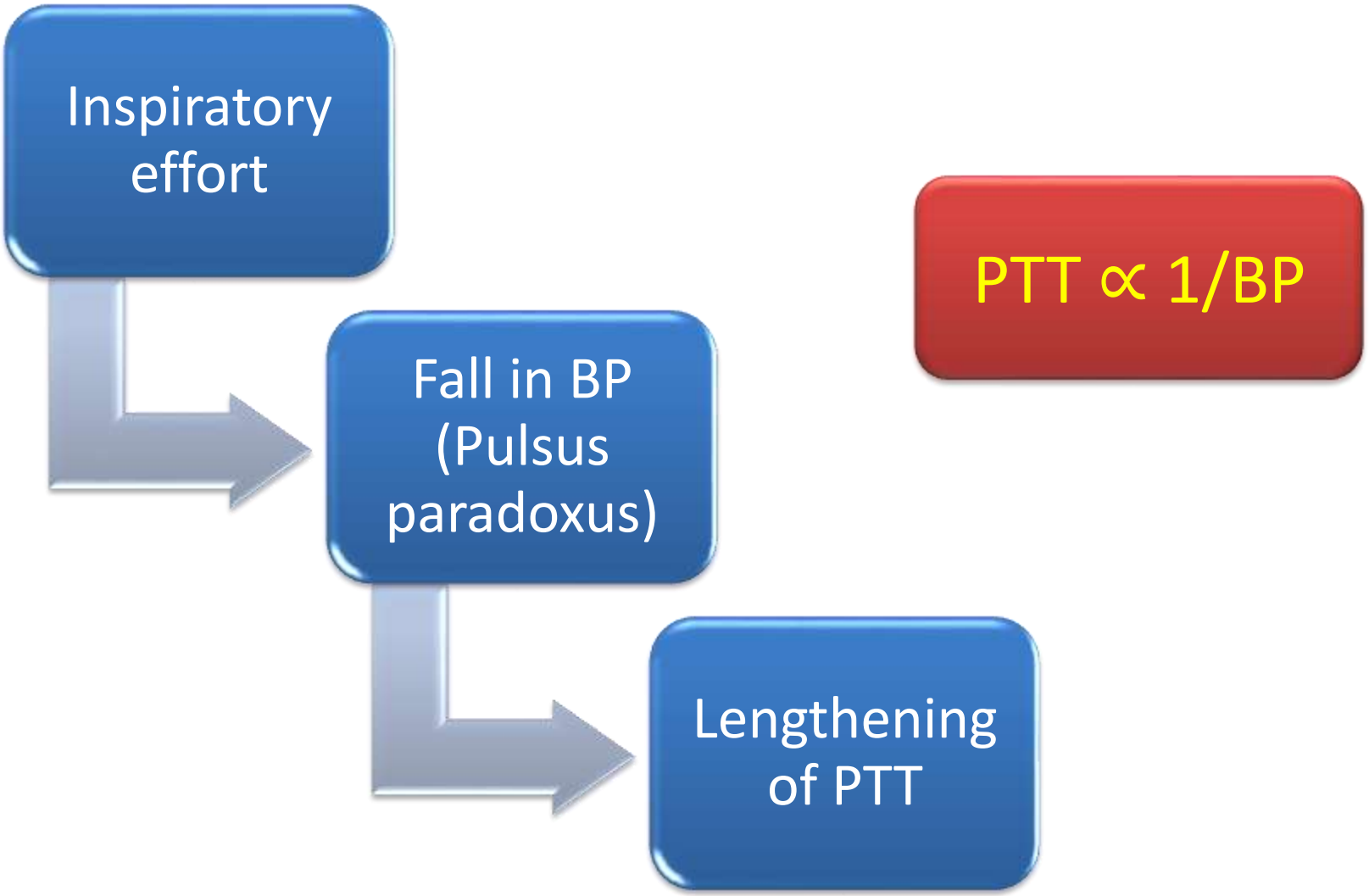
PWA/PTT





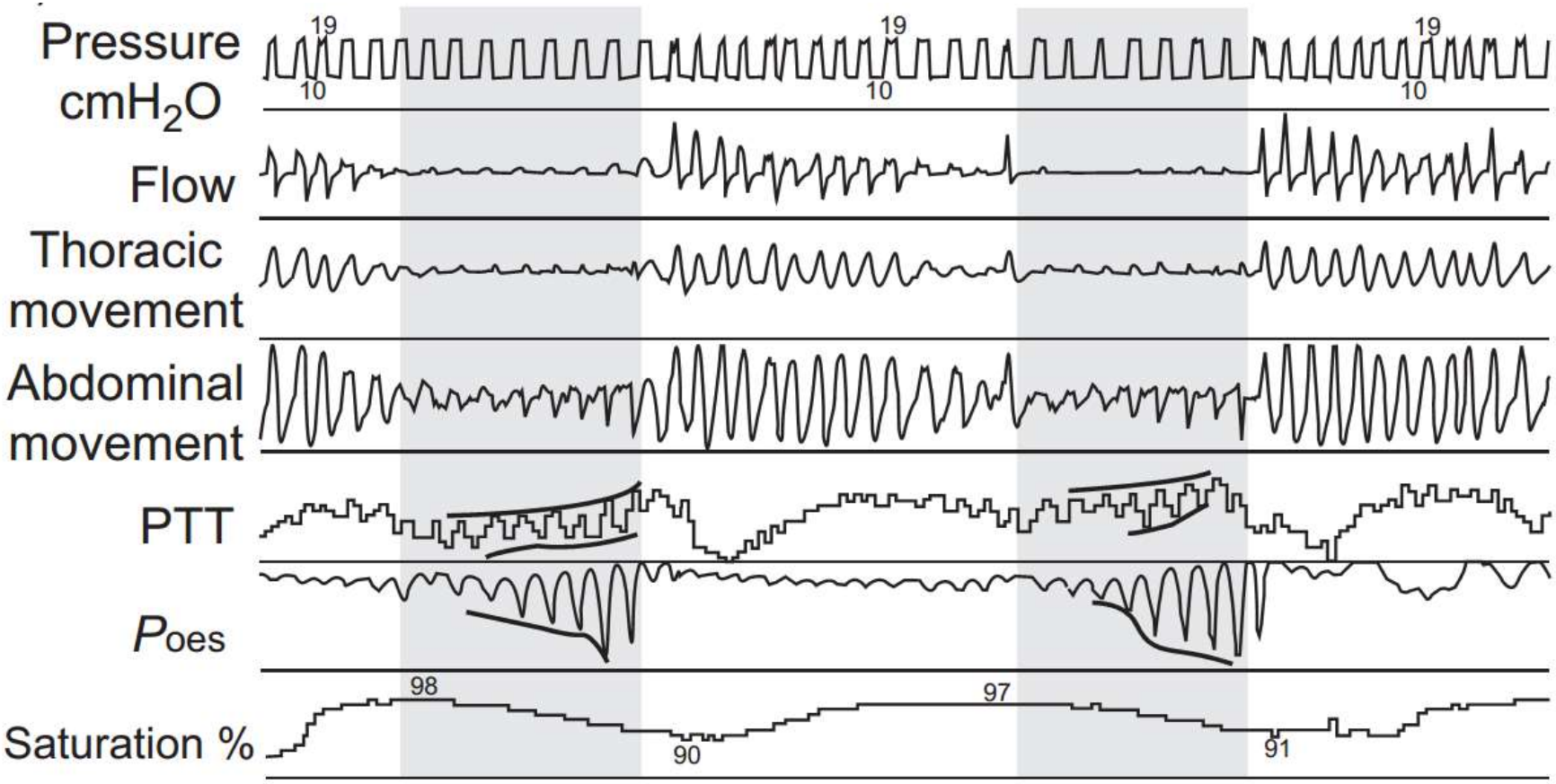
Requirements: ECG + Pulse oximetry

Smith RP et al. Thorax 1999;54:452-457



Non-invasive marker of inspiratory muscle effort

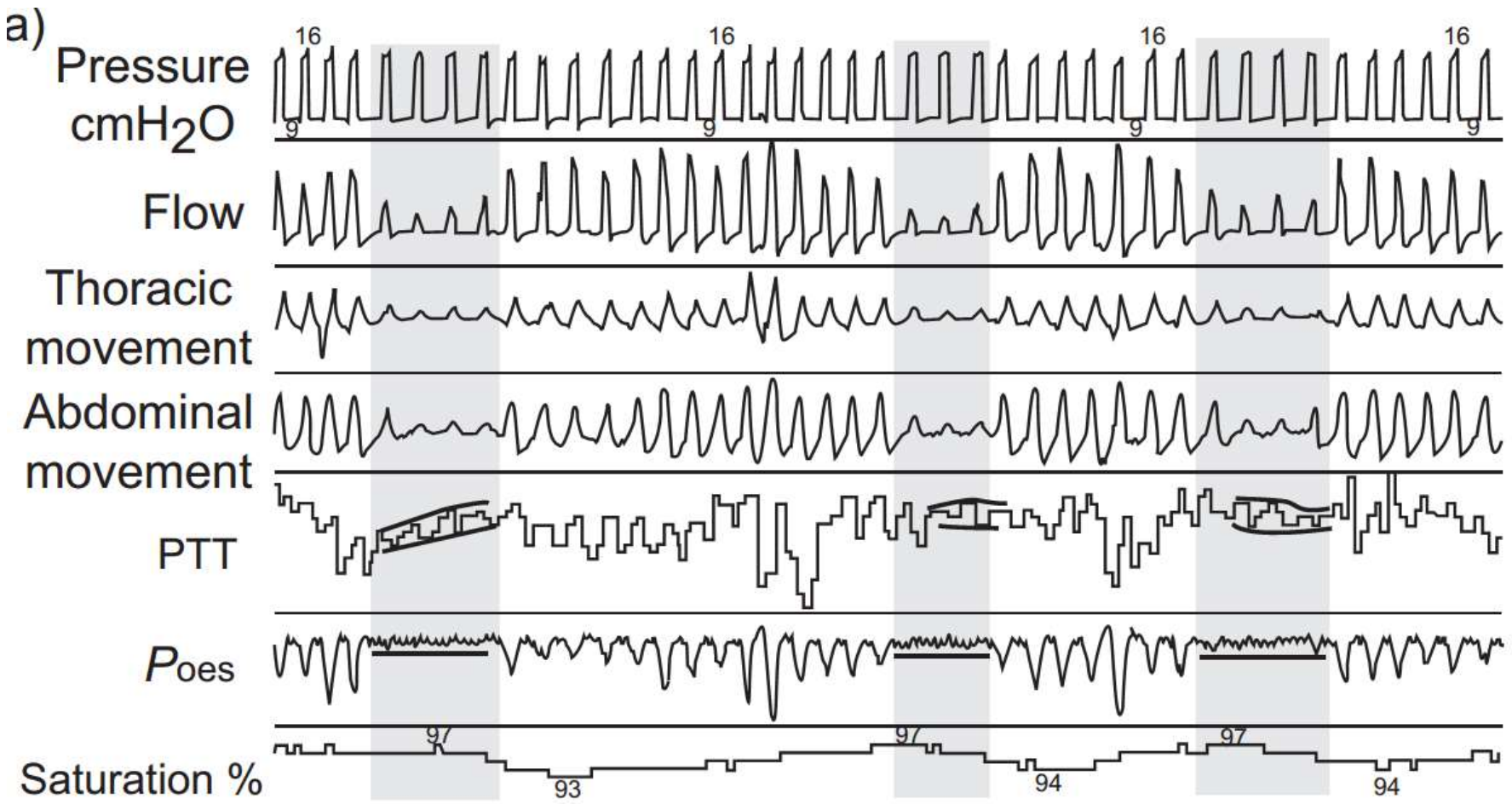
Obstructive apnoea



Swings of Poes become increasingly negative during an obstructive event, with simultaneous increase in oscillations of PTT between inspiration and expiration

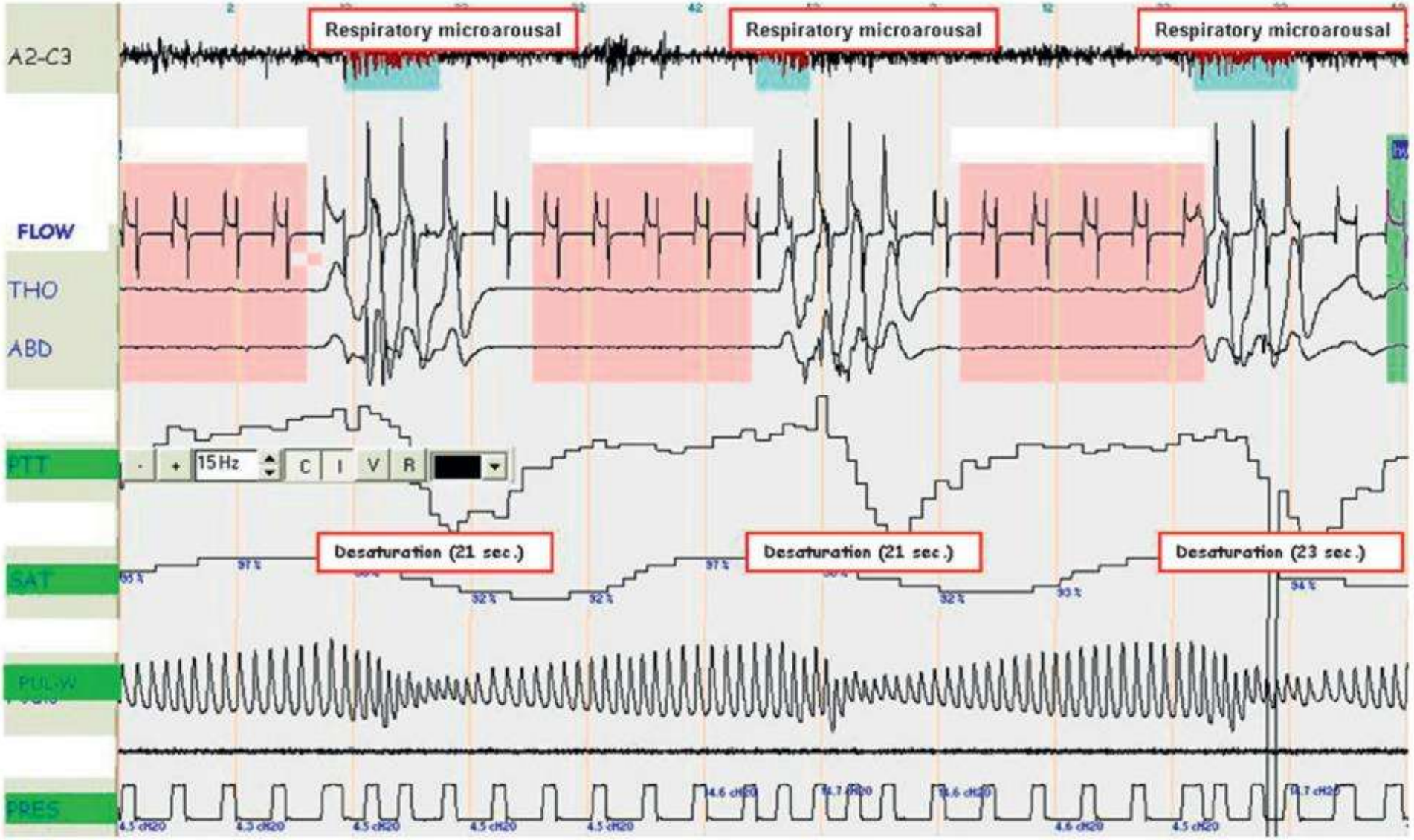
Contal O et al. Eur Respir J. 2013 Feb;41(2):346-53

Central apnoea



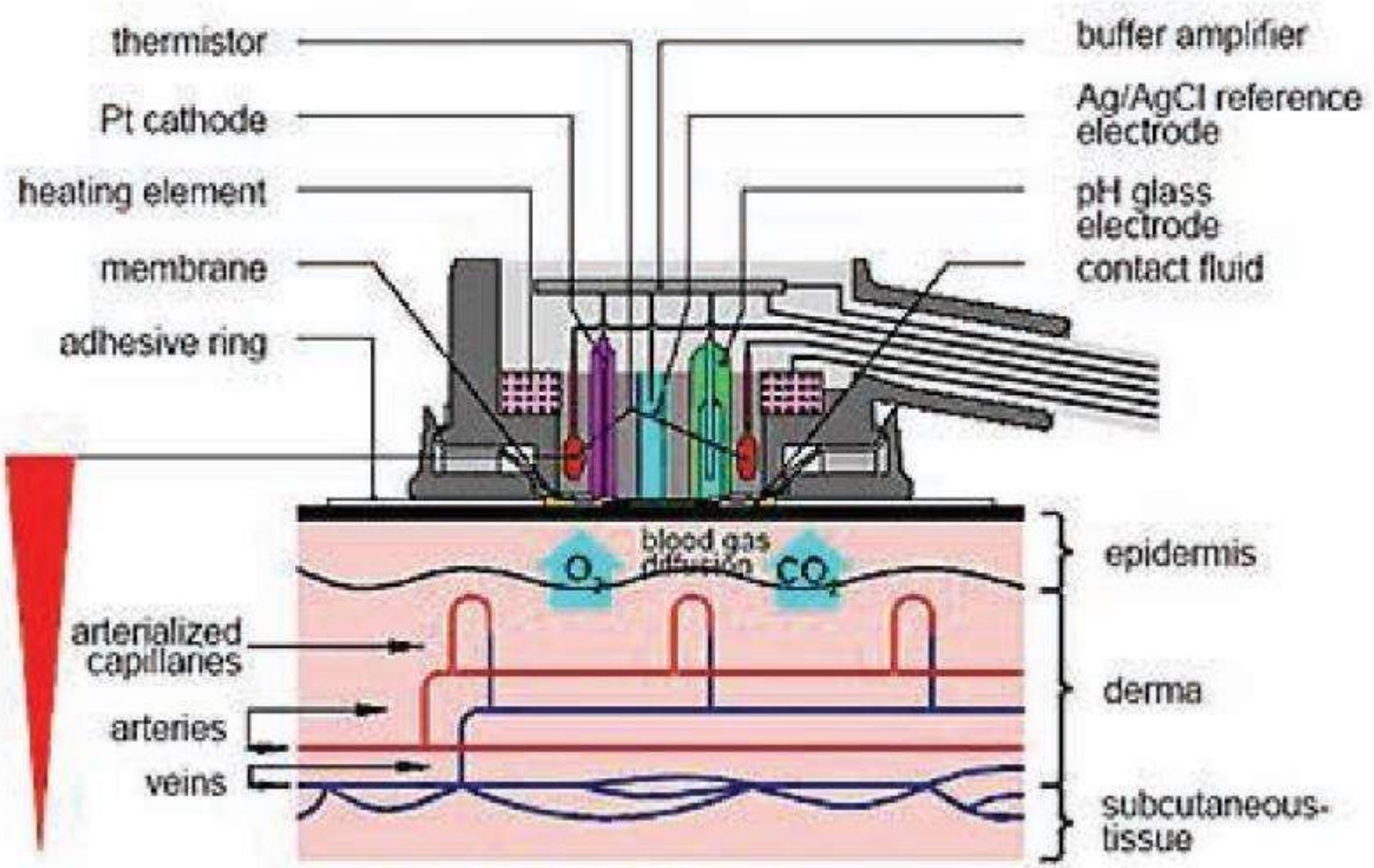
For both Poes and PTT signals, respiratory oscillations are markedly reduced

Contal O et al. Eur Respir J. 2013 Feb;41(2):346-53



Janssens JP, Borel JC, Pépin JL; SomnoNIV Group. Thorax. 2011 May;66(5):438-45

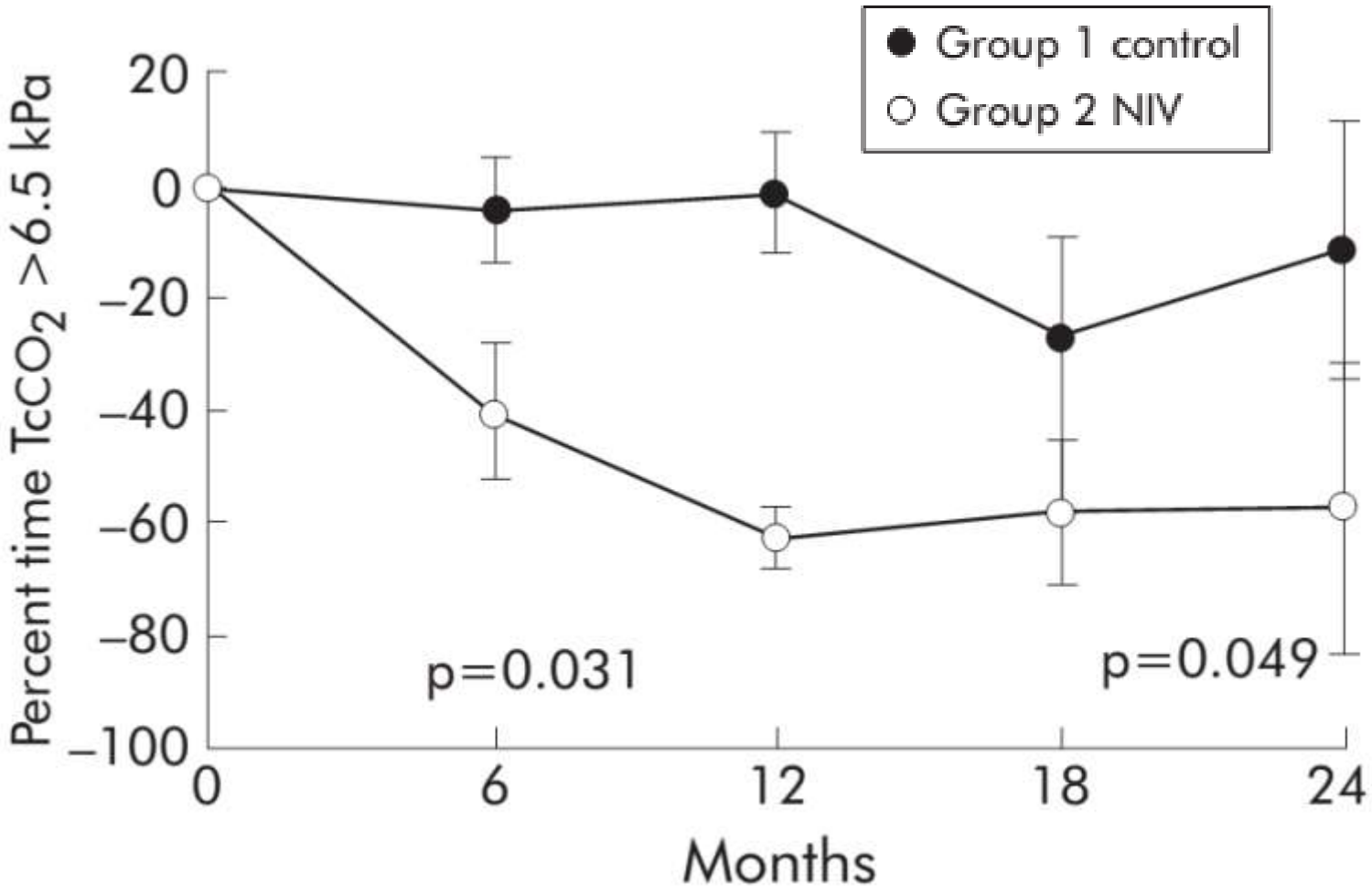
Transcutaneous CO2



Severinghaus electrode

R. Carter. The buyers' guide to respiratory care products

PtcCO2 during HMV

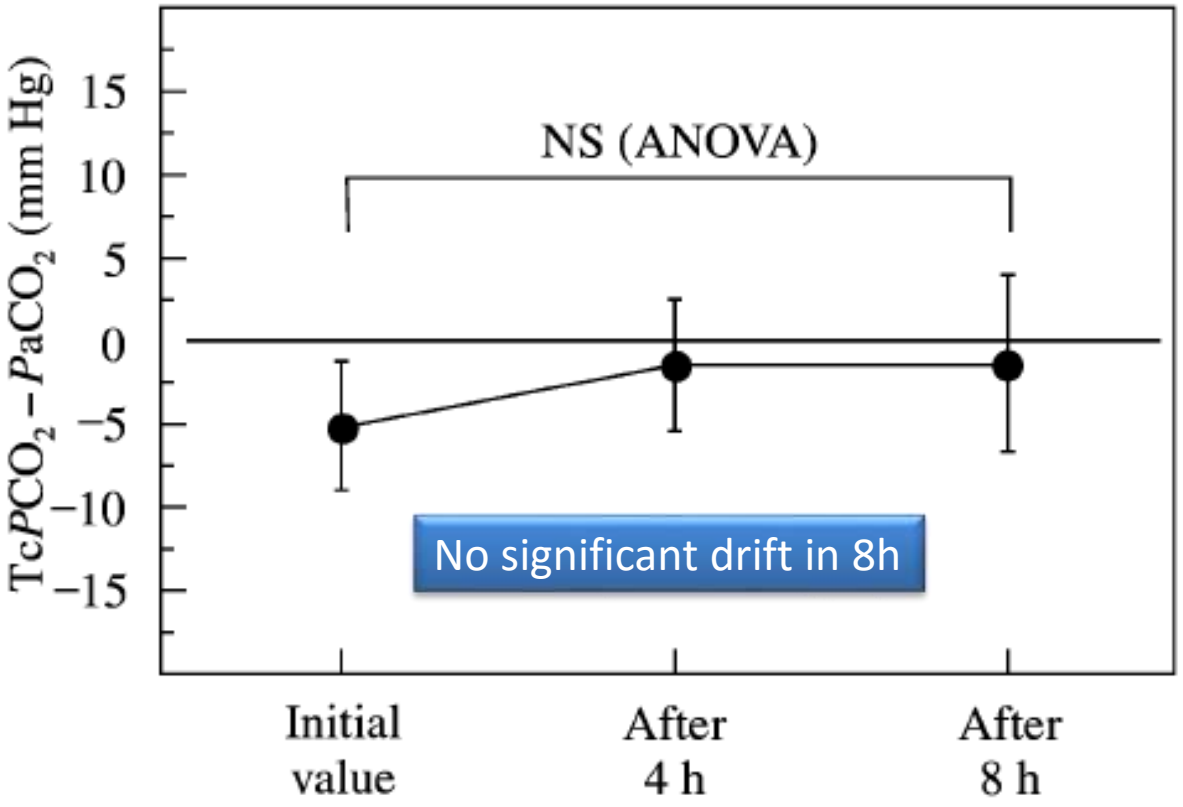


Ward S et al. Thorax. 2005 Dec;60(12):1019-24

Limitations

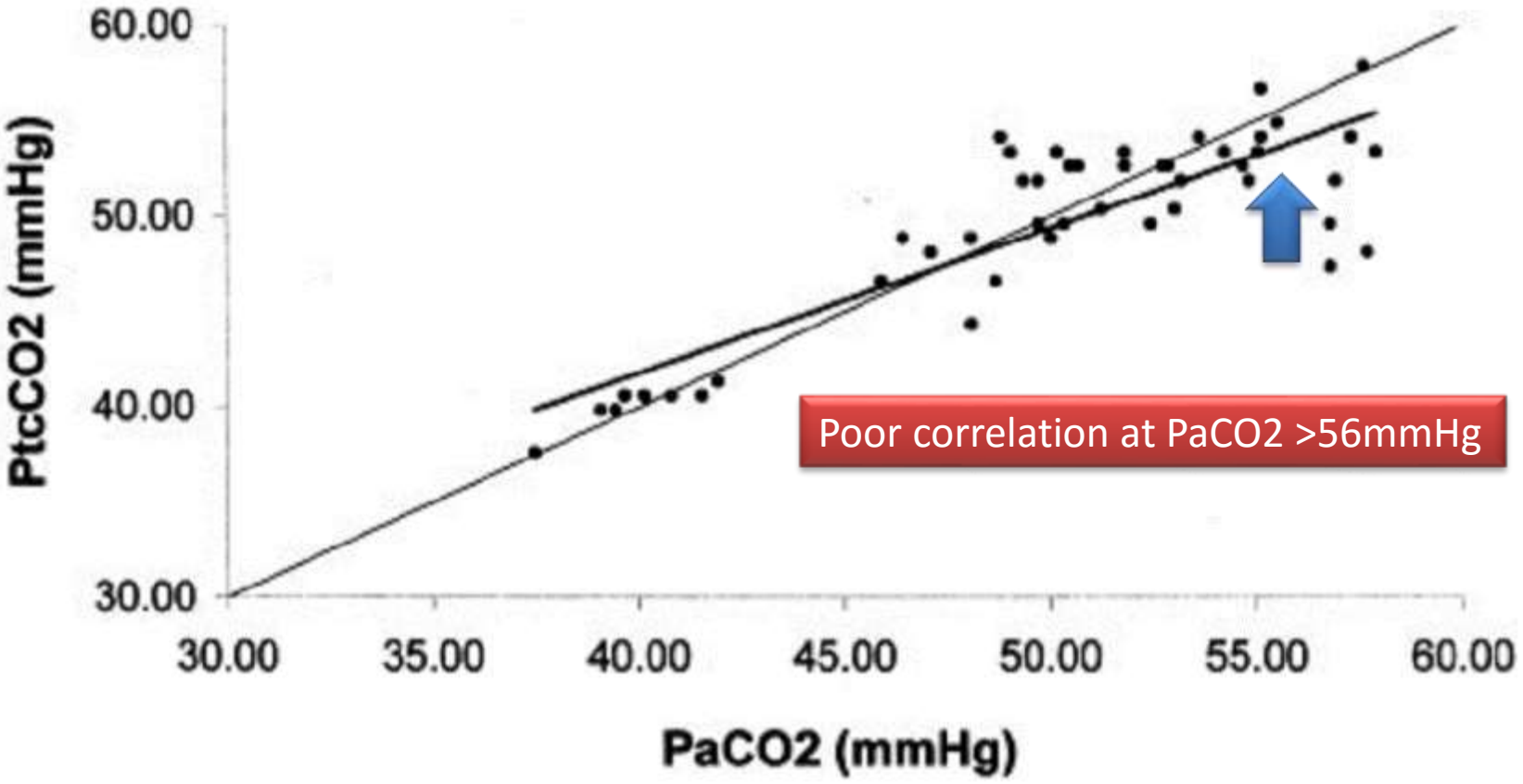
- Slow response time: Usually < 2minutes
- Drift: typically ≤5% per hour (requires calibration q8-12h)
- Membrane needs change every 2-6 weeks
- Can be continuously used at one site for only up to 8 hours
- Cost

PtcCO2 drift



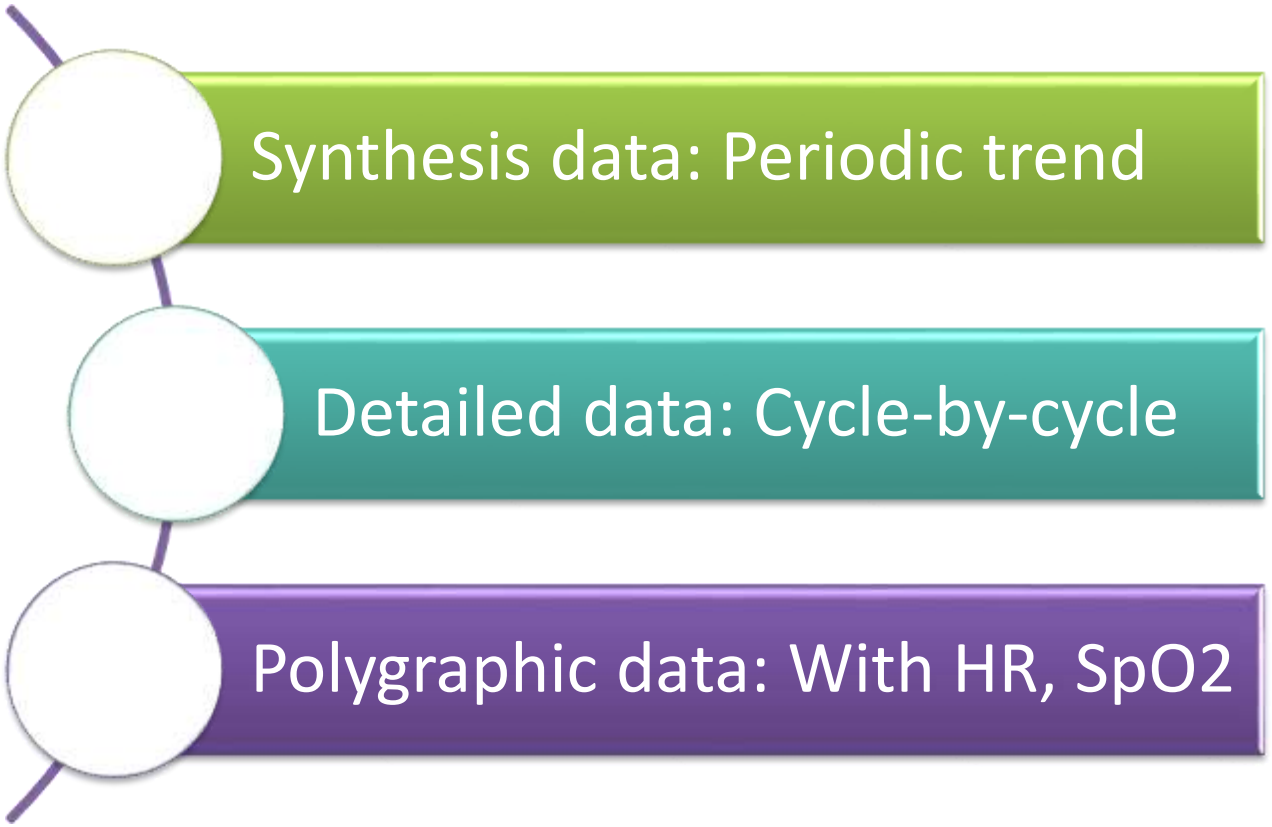
Janssens JP et al. Respir Med. 2001 May;95(5):331-5

Correlation with arterial CO2



Cuvelier A et al. Chest. 2005 May;127(5):1744-8

Data from NIV machine



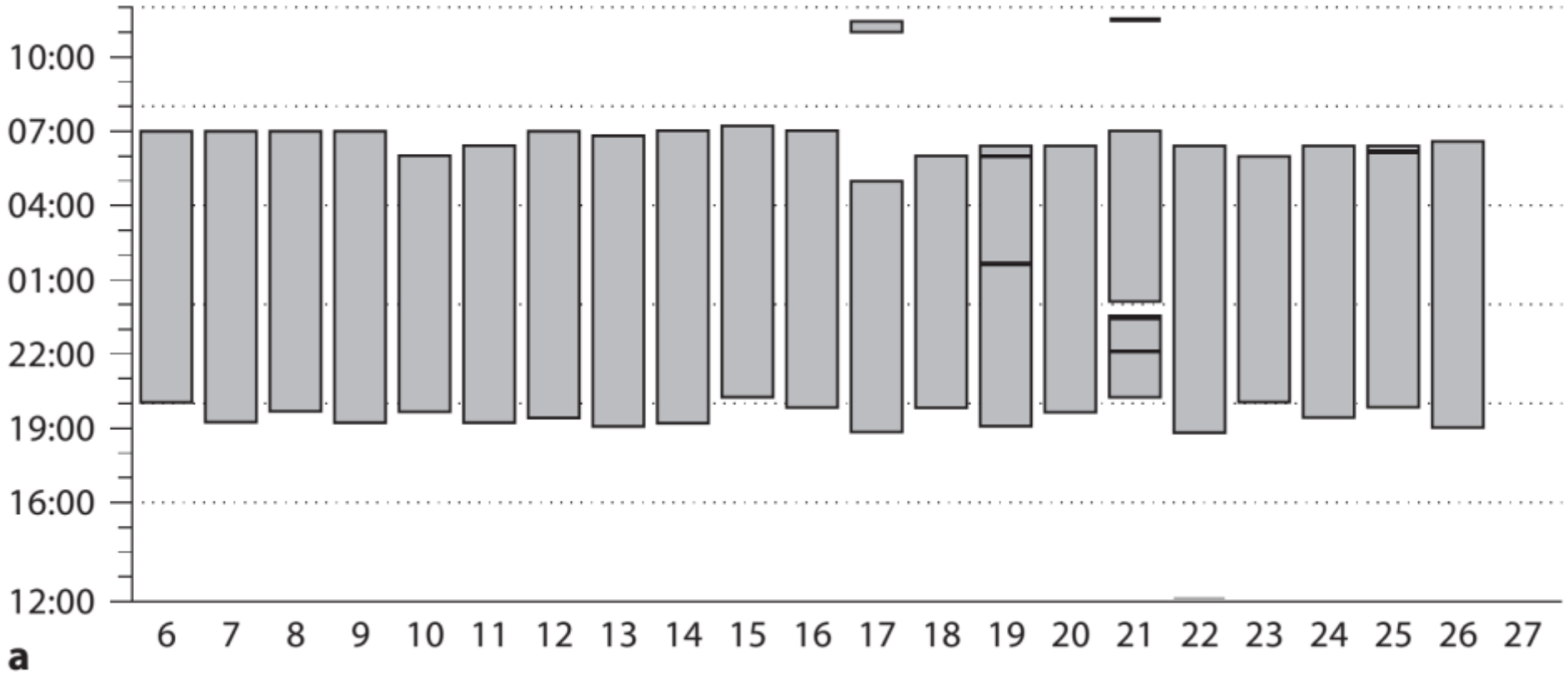
Thorax. 2011 May;66(5):438-45


Compliance
Leaks
Spont. breaths
Tidal volume
Resp. rate
AHI
Minute ventilation

Built-in software

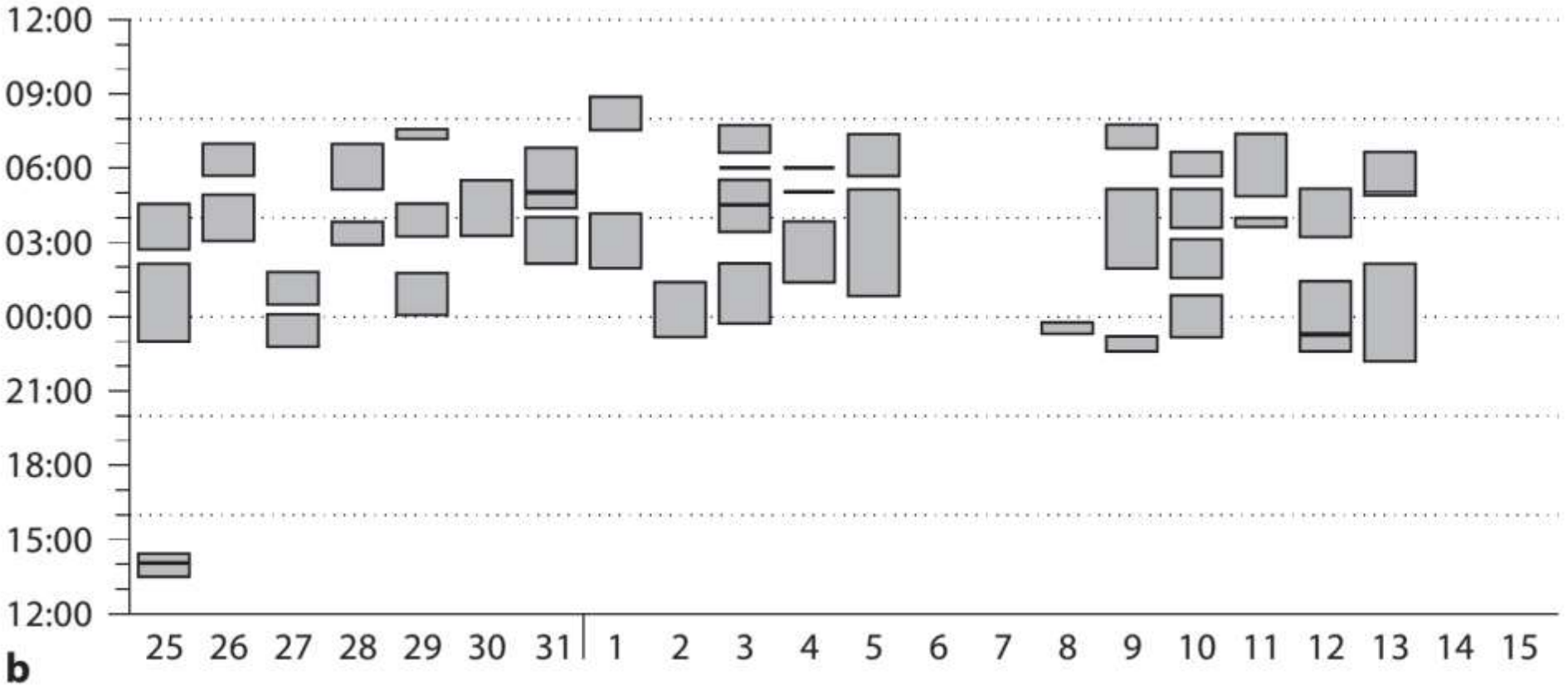
- Compliance
- Tidal volume
- Minute ventilation
- RR
- Number of triggered breaths
- Leaks
- AHI

Pattern of ventilator use: Good compliance



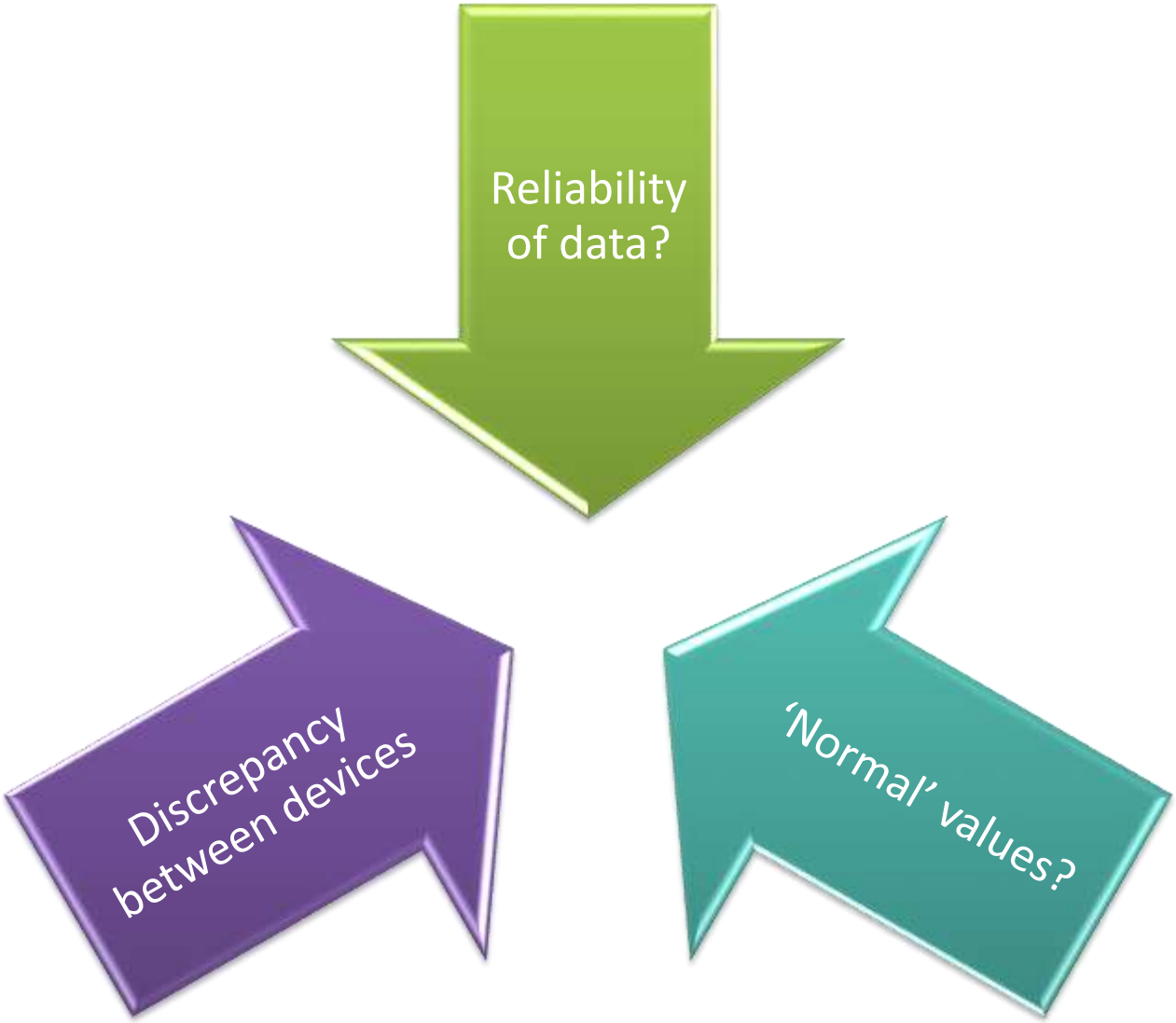
Pasquina P et al. Respiration. 2012;83(4):293-9

Pattern of ventilator use: Poor compliance



Pasquina P et al. Respiration. 2012;83(4):293-9

Problems with data from NIV machines

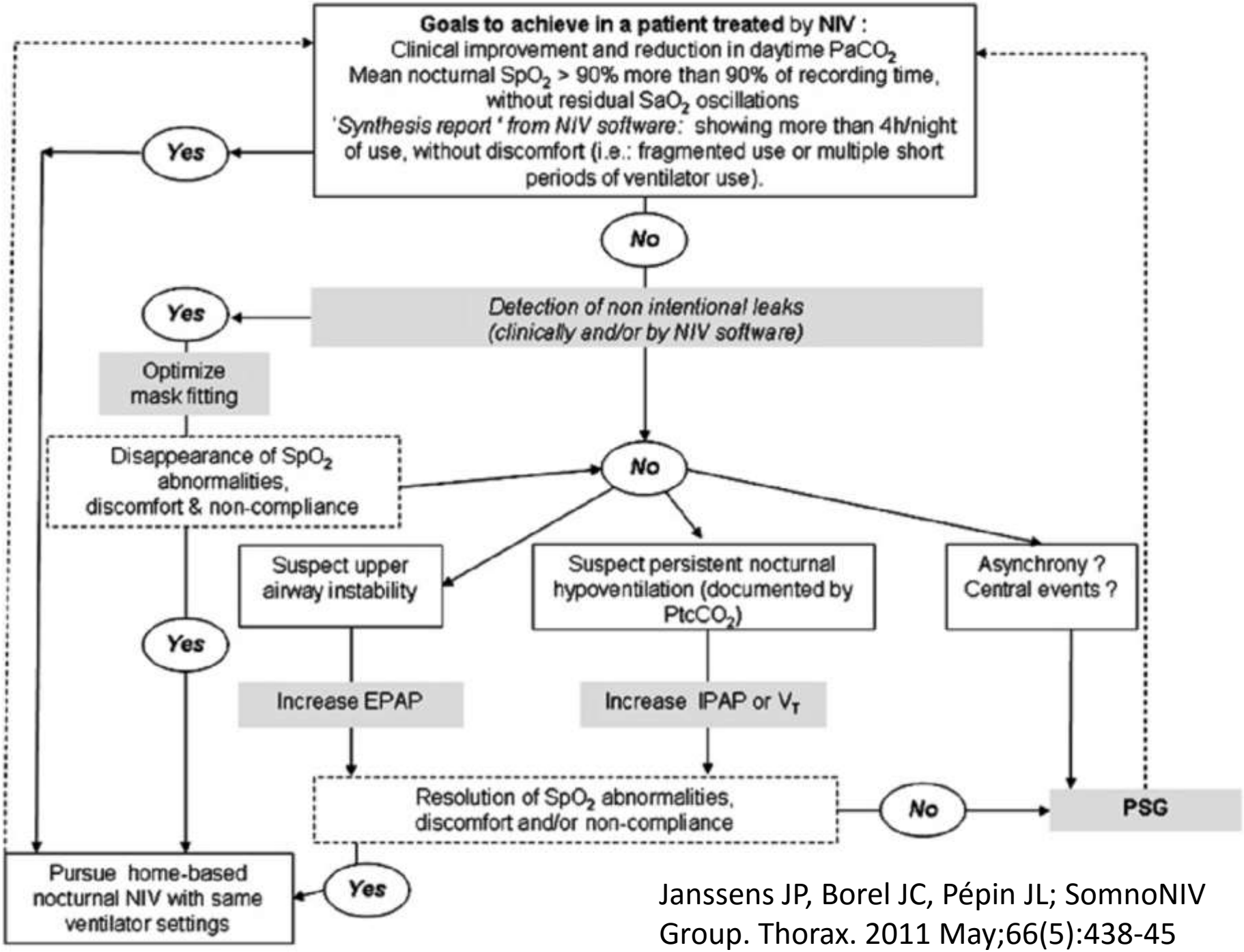


Reliability & Discrepancy

Device	Unintentional leak, 0 L/min: V_T Bench, mL[a]	V_T Software, mL[b]	[V_T Bench] − [V_T Software], mL	Leaks on Bench, L/min[c]	Leaks from Software, L/min[d]	[Leaks on Bench] − [Leaks from Software], L/min
A	912	711	201	52.8	45.0	7.8
B	968	840	128	40.1	35.0	5.1
C	886	797	89	44.8	46.0	−1.2
D	1,033	705	328	38.1	26.2	11.9
E	809	690	119	40.5	20.2	20.3
F[e]	1,015	750	265	0.0	1.2	−1.2
G[e]	1,032	820	212	0.0	2.4	−2.4
	Unintentional leak, 60 L/min					
A	668	547	121	76.8	62.0	14.8
B	800	700	100	65.5	60.0	5.5
C	923	826	97	74.3	75.0	−0.7
D	1,116	712	404	96.2	68.2	28.0
E	763	580	183	91.3	38.2	53.1
F[e]	1,062	900	162	30.4	31.2	−0.8
G[e]	1,228	1,100	128	32.5	33.6	−1.1

- Underestimation of VT by all devices
- Poor leak assessment by most of the devices
- Non-uniformity in methods used for leak assessment

Contal O et al. Chest. 2012 Feb;141(2):469-76



Janssens JP, Borel JC, Pépin JL; SomnoNIV Group. Thorax. 2011 May;66(5):438-45

Transition to home care & follow-up

Transition from hospital to home

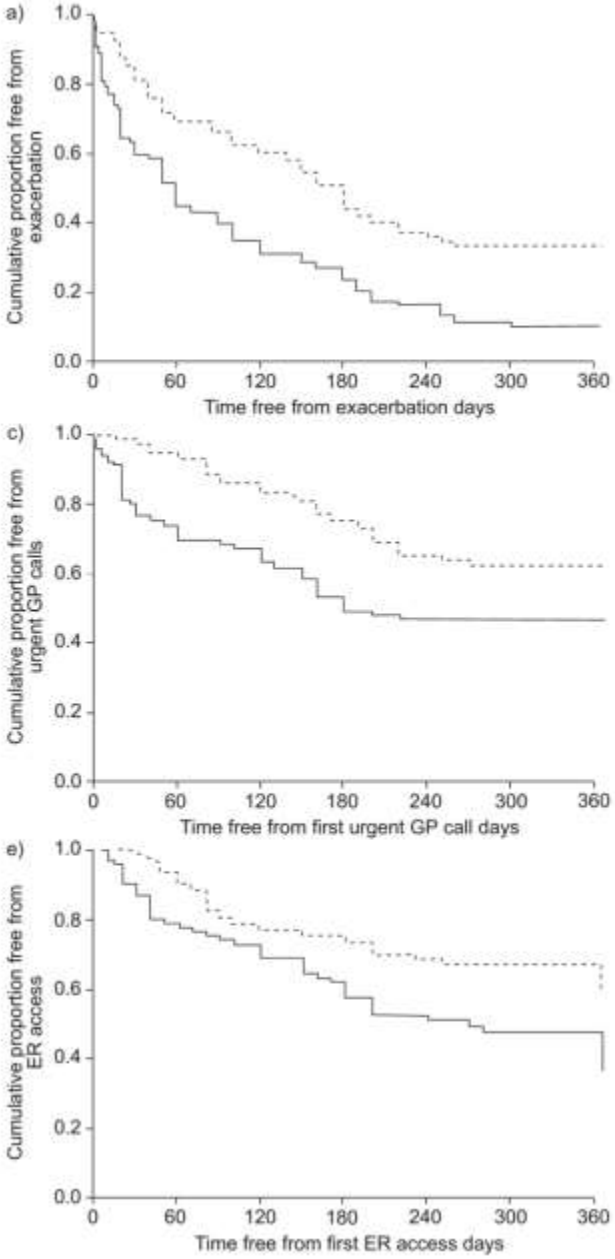
- Patient assessment: Fitness for discharge (clinical stability, secretions, etc.)
- Community assessment: finances, home conditions (power-cuts, battery-backup, access to hospitals, etc.)
- Equipment preparation: procuring ventilator, humidifier, nebuliser, suction device, oxygen source
- Care-giver training: suction, device operation, troubleshooting

What can go wrong?

	No. (%)
Causes of Home Ventilator Failure Reports	
Defective equipment or mechanical failure	73 (39)
Improper care, damage, or tampering by caregivers	25 (13)
Functional equipment improperly used by caregivers	56 (30)
Functional equipment with change in patient's condition mimicking ventilator failure	5 (3)
No problem identified	30 (16)

King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967

Tele-assistance (TA)



Results

- Compared with controls, the TA group experienced significantly fewer hospitalisations (-36%), urgent GP calls (-65%) and acute exacerbations (-71%)
- **After deduction of TA costs, the average overall cost for each patient was 33% less than that for usual care**

Vitacca M et al. Eur Respir J. 2009 Feb;33(2):411-8

Conclusion

- HMV use has increased markedly over the years and is bound to increase further
- Changing trends in usage: Neuromuscular disorders → Sleep-disordered breathing, COPD
- NIV (with nasal masks) is more widely used compared to IMV
- Major improvements in NIV devices/modes: data on clinical impact evolving
- More sophisticated ventilators/modes only add to the cost (and may even be harmful) when used in unnecessary situations
- Proper interface selection, humidificaton, caregiver education and periodic monitoring are essential for success