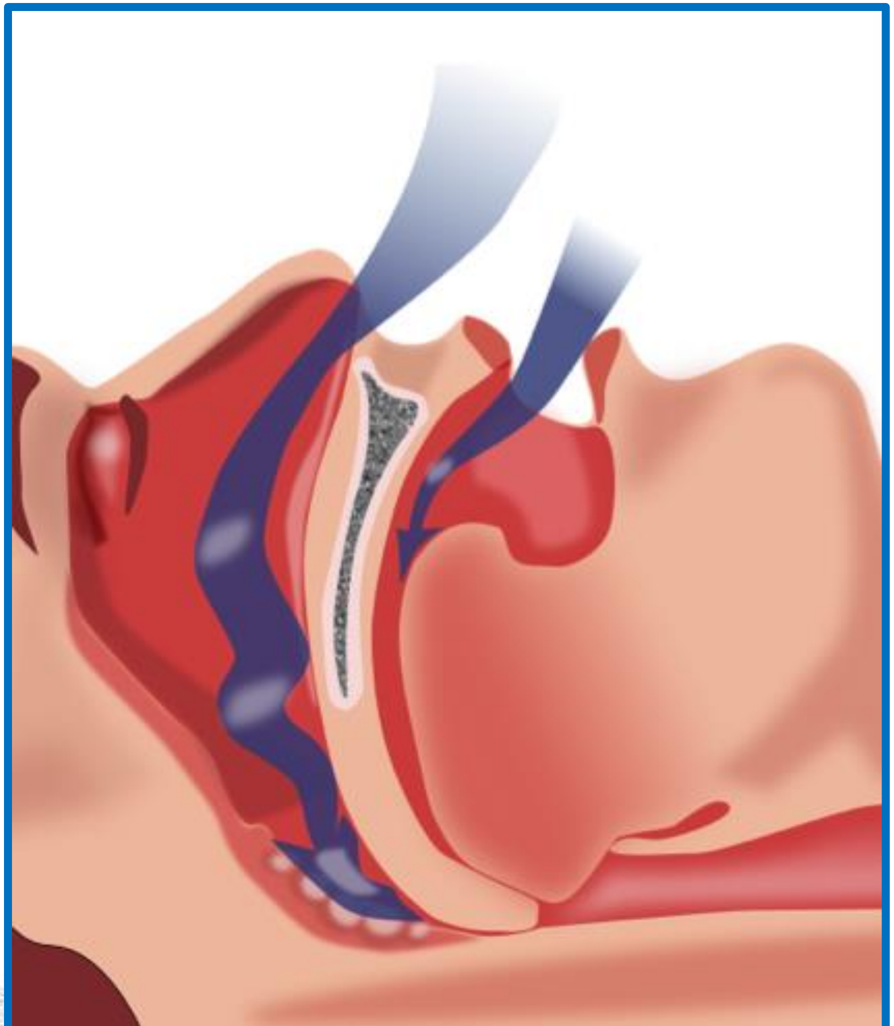
Non-Invasive Ventilation in the Treatment of Sleep-Disordered Breathing

邱國樑 醫師
台中慈濟醫院胸腔內科暨睡眠醫學中心
慈濟大學 學士後中醫學系

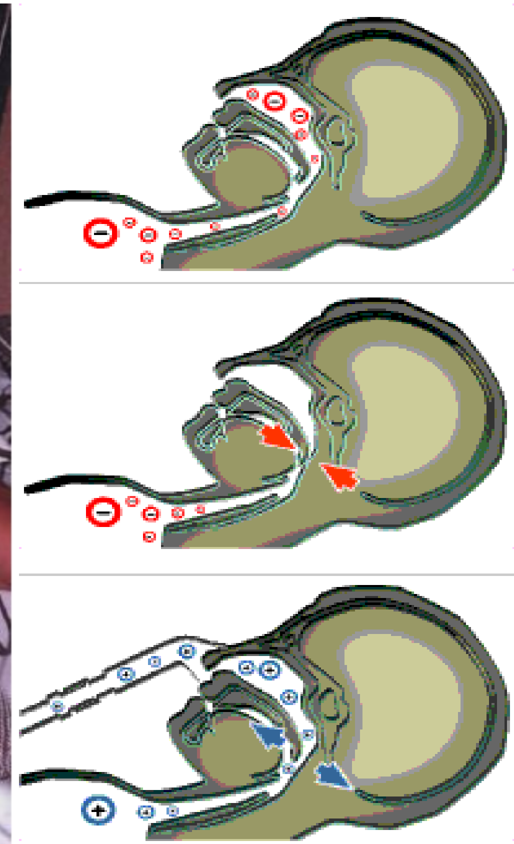
Outlines

- Positive airway pressure for sleep-disordered breathing (SDB)
- Noninvasive ventilation (NIV)
- NIV for SDB
  - Who and why?

Obstructive Sleep Apnea



The First CPAP in 1980 -- A Reversed Vacuum



Sullivan CE, *AJRCCM* 2018

http://www.internetage.ws/general/bellavista-1/

Evolution of CPAP Machines
Improvement in Size, Noise, and More

PAP for SDB

- Continuous positive airway pressure (CPAP)
- Auto-titration (continuous) PAP
- Bilevel PAP
- Adaptive servo-ventilation (ASV)

Non-Invasive Ventilation (NIV)

- To deliver mechanical ventilation to the lungs using techniques that do not require an invasive artificial airway (endotracheal tube, tracheostomy)

- Goals:
  - Provide time for the cause of respiratory failure to resolve and improve gas exchange
  - Overcome auto-PEEP
  - Unload the respiratory muscle
  - Decrease dyspnea
  - Avoid Endotracheal Intubation
  - Avoid complications

Antonello N, *et al.*, *J Gen Pract* 2013

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Types of NIV

Negative Pressure NIV

- Main means of NIV during the early 1900's
- Extensively used during the polio epidemics
- Tank ventilator "iron lung"
- Cuirass, Jacket ventilator, Hayek oscillator

Positive Pressure NIV

- Positive pressure delivered through mask
- CPAP
- AutoCPAP (AutoPAP)
- BIPAP (Bilevel PAP)
- ASV (Adaptive servo-ventilation)
- AVAPS

Indication of NIV in Sleep-disordered Breathing

- Obstructive sleep apnea (OSA)
- Central sleep apnea (CSA), complex sleep apnea
- Chronic obstructive pulmonaryu disease (COPD), COPD-OSA overlap syndrome
- Restrictive thoracic disorders
- Obesity Hypoventilation Syndrome (OHS)

Nicolini A, *et al*. *Rev Port Pneumol*.2014;**20(6)**:324-335

NIV for OSA

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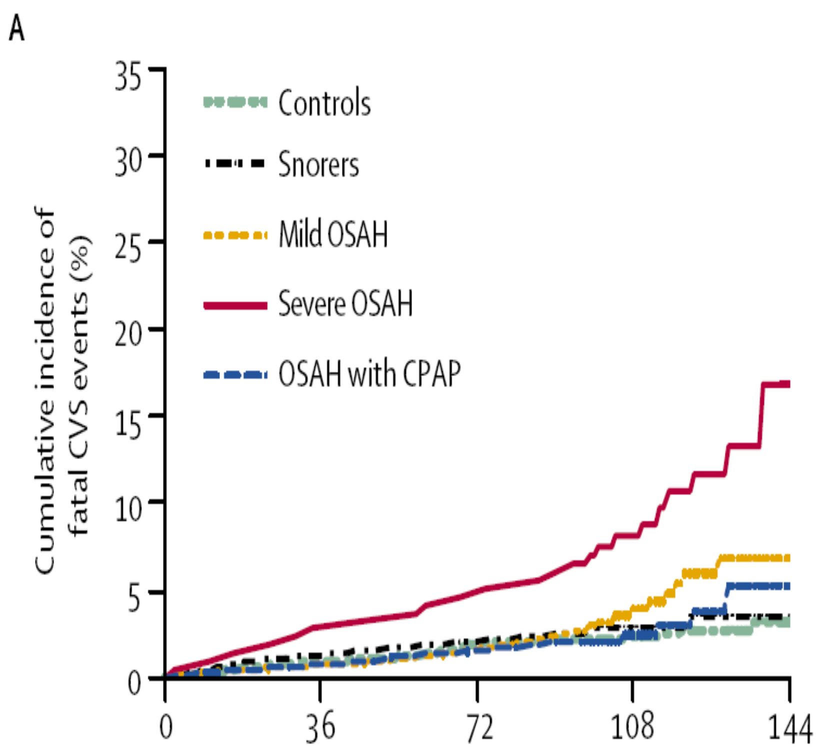
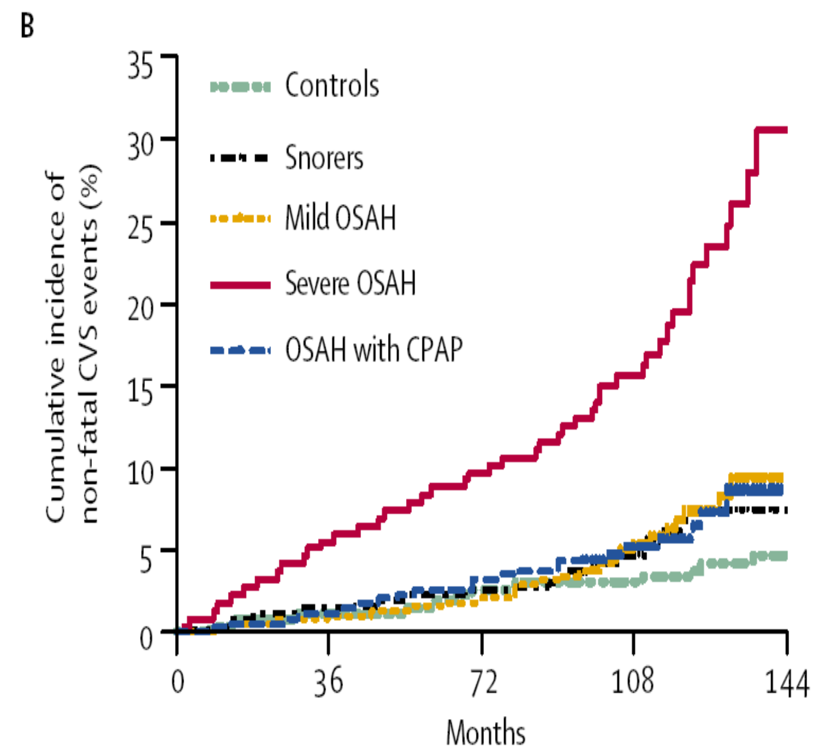
Improvement in Survival of OSA by CPAP

Fatal Cardiovascular Events

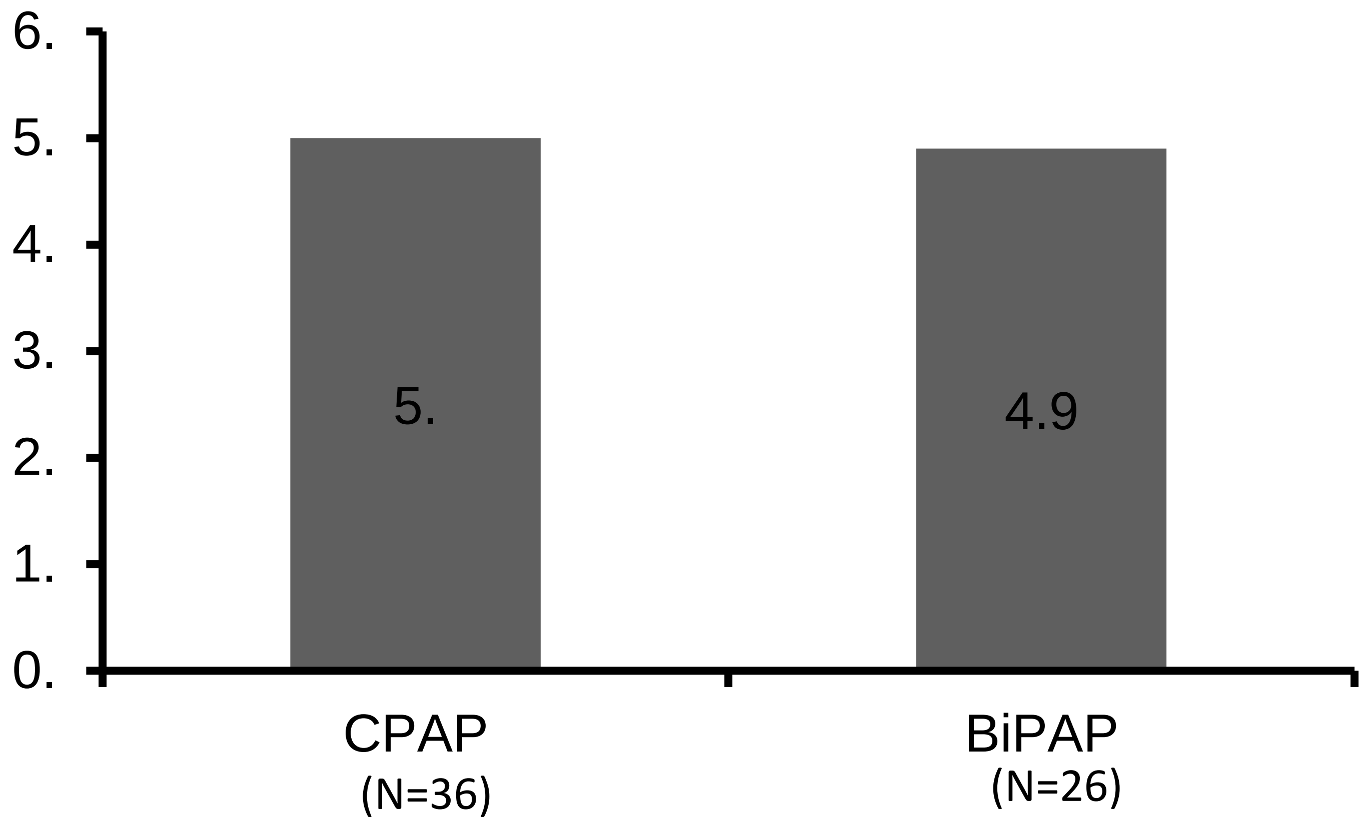


Non-fatal CV Events



Marin *et al*. *Lancet* 2005

Efficacy in Treatment of OSA
No Difference in Use Hours in OSA



Reeves-Hoche MK*, et al. AJRCCM* 1995

CPAP and NIV in Treatment of OSA

	CPAP (n=15)	Novel Bilevel PAP (n=12)
Baseline		
BMI	34.1 ±4.7	36.6 ± 6.0
AHI at PSG night	46.1 ±23.1	41.8 ± 25.8
Titration night		
Optimal Pressure, cmH2O	8.8 ±1.1	8.9 ± 1.6
AHI at titration night	7.6 ± 11.9	3.7 ± 4.4
Sleep efficiency, %	73.4 ±15.0	84.4±14.4
Total sleep time, m	115.2 ±36.9	89.6 ± 42.5
Epworth Sleepiness Scale		
Pretreatment	13.5 ±3.4	14.2 ± 3.4
Posttreatment	8.0 ±4.8	7.8 ± 3.8

Gay PC, *et al. Sleep* 2003

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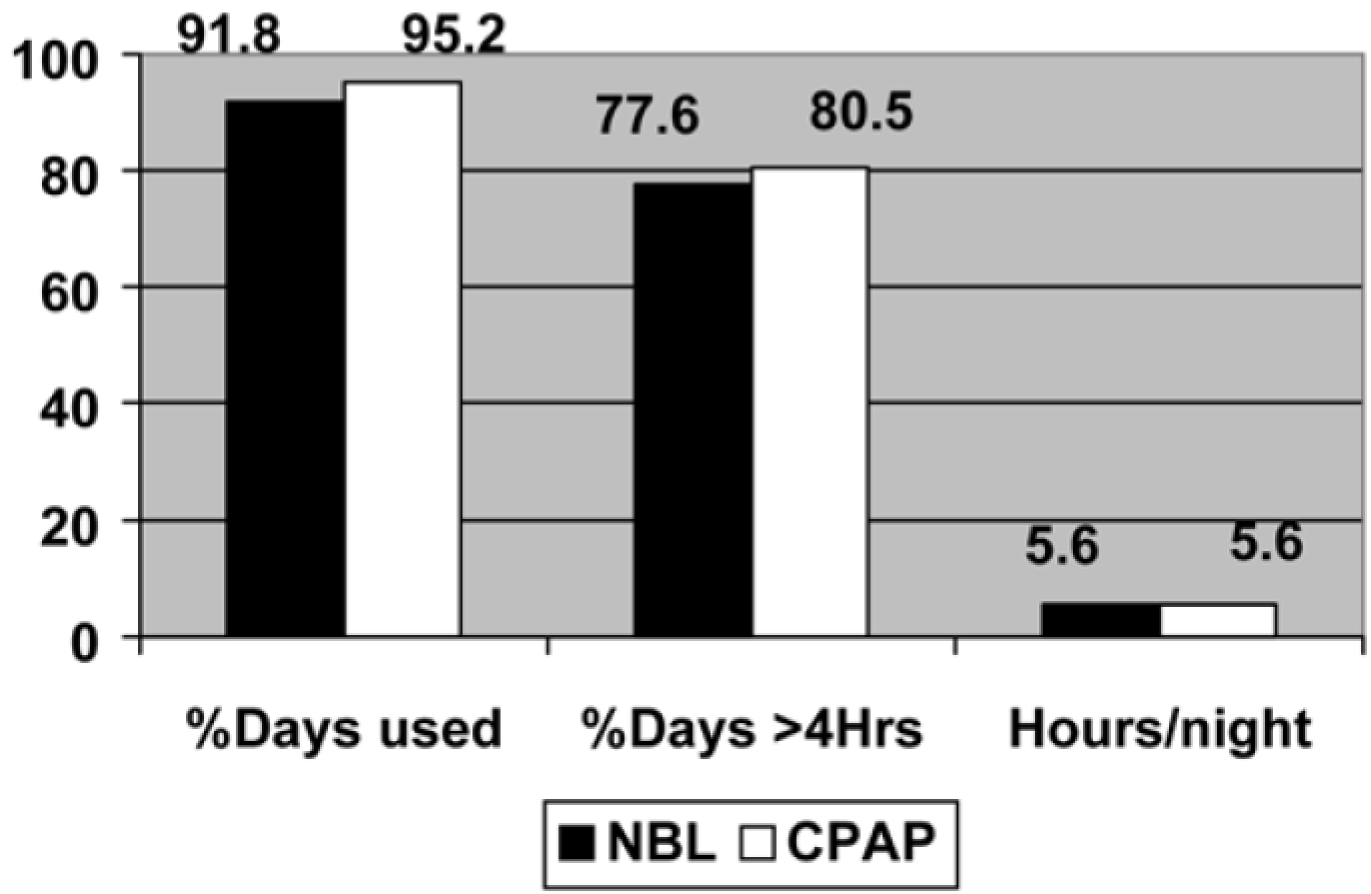
CPAP and NIV in Treatment of OSA



No difference between CPAP and BiPAP in treatment of OSA

Gay PC, *et al. Sleep* 2003

NIV in OSA

- No difference in compliance compared to CPAP
- Maybe considered only in patients needing a high pressure, or CPAP ineffective.

NIV for CSA

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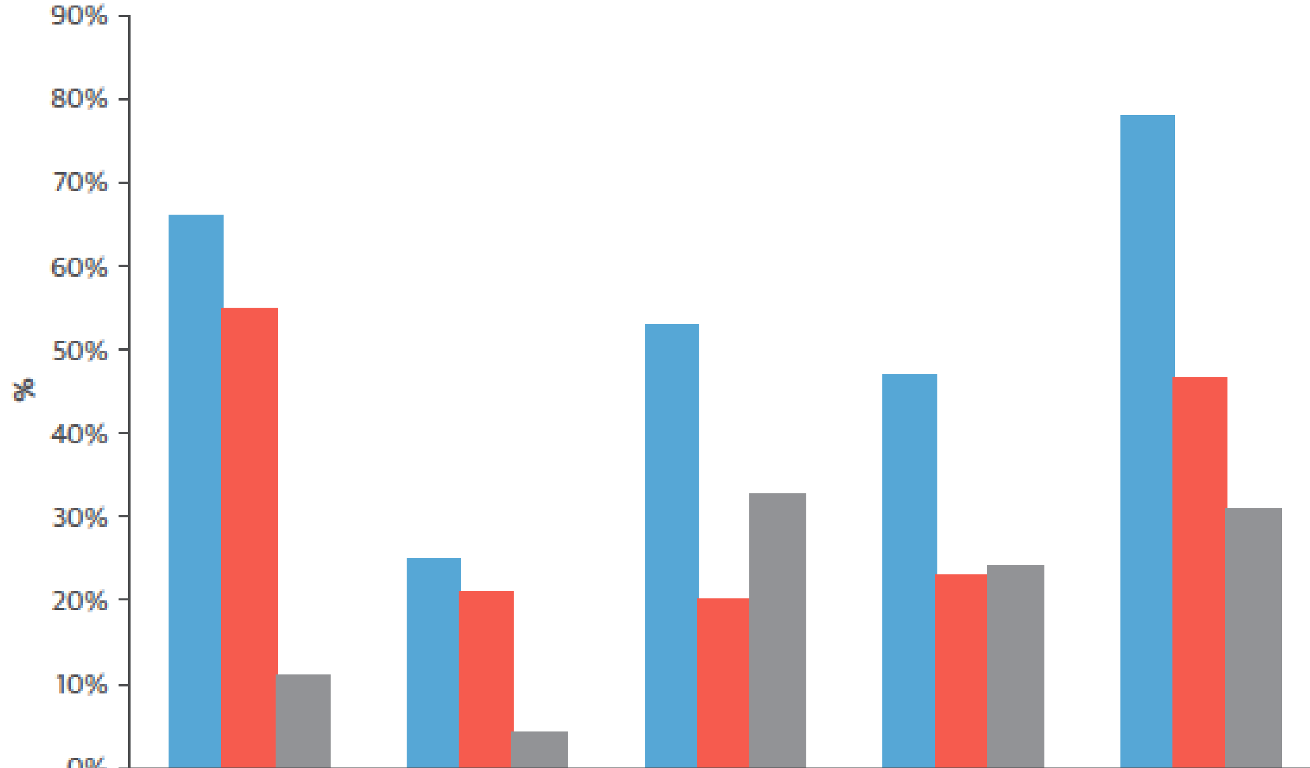
Prevalence of SDB in HF



	LVSD Asymptomatic	LVDD Asymptomatic	HFrEF	HFpEF	ADHF
AHI > 15/h	66%	25%	53%	47%	78%
OSA	55%	21%	20%	23%	47%
CSA	11%	4%	33%	24%	31%

AHI > 15/h OSA CSA

Javaheri S, *et al*, *JACC* 2017

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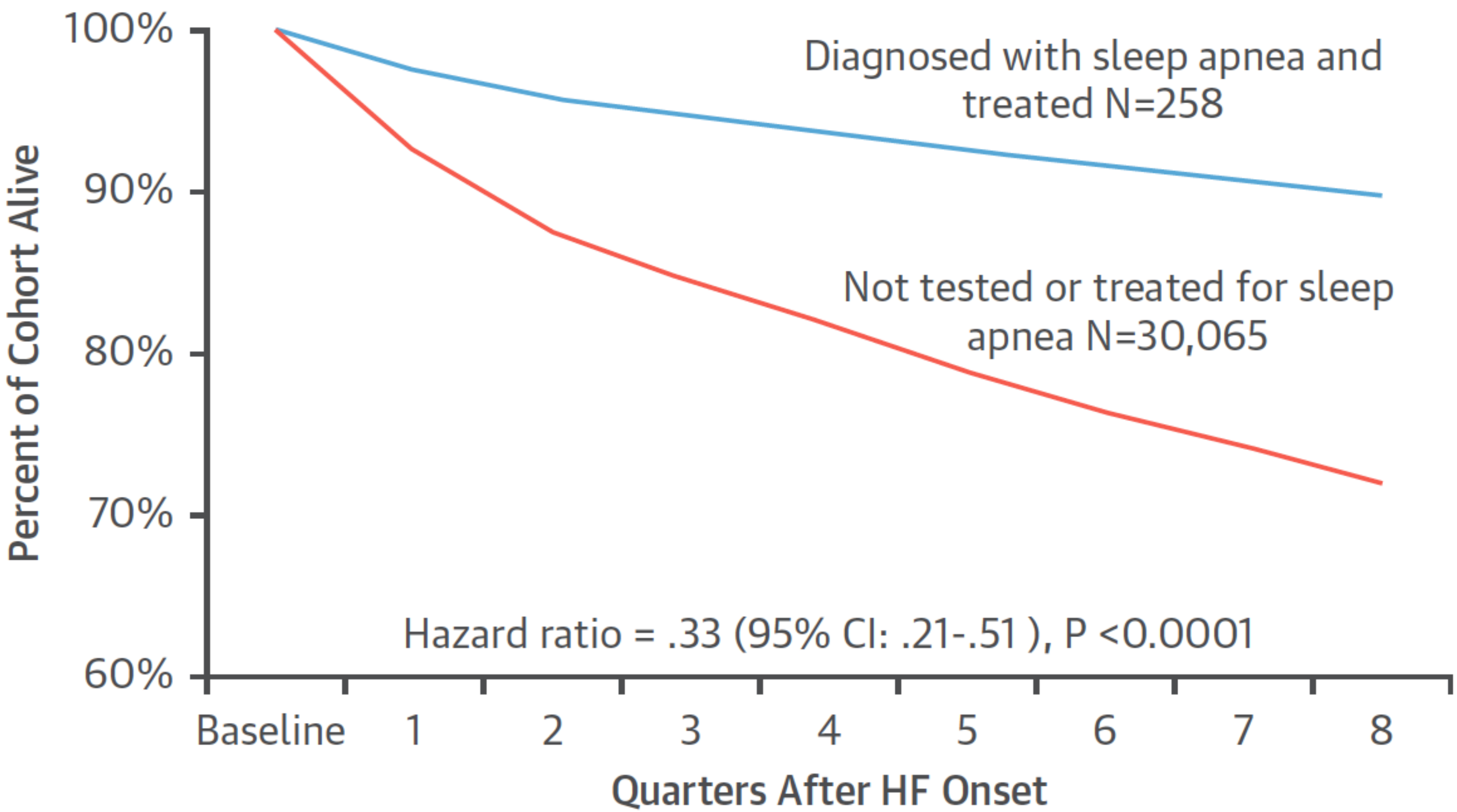
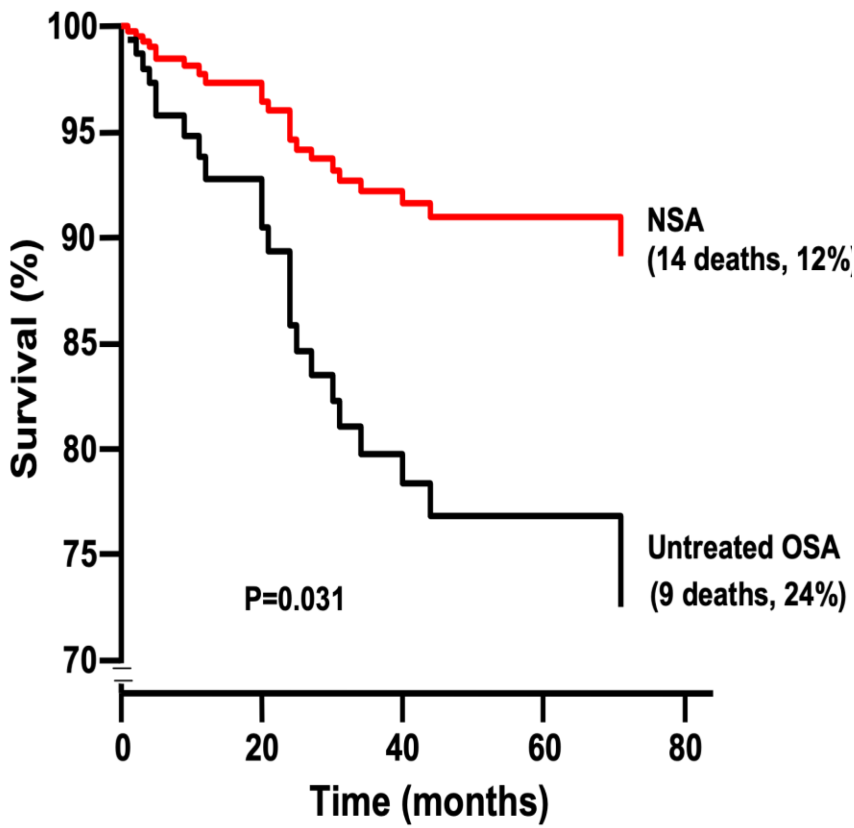
Survival of HF with/without CPAP



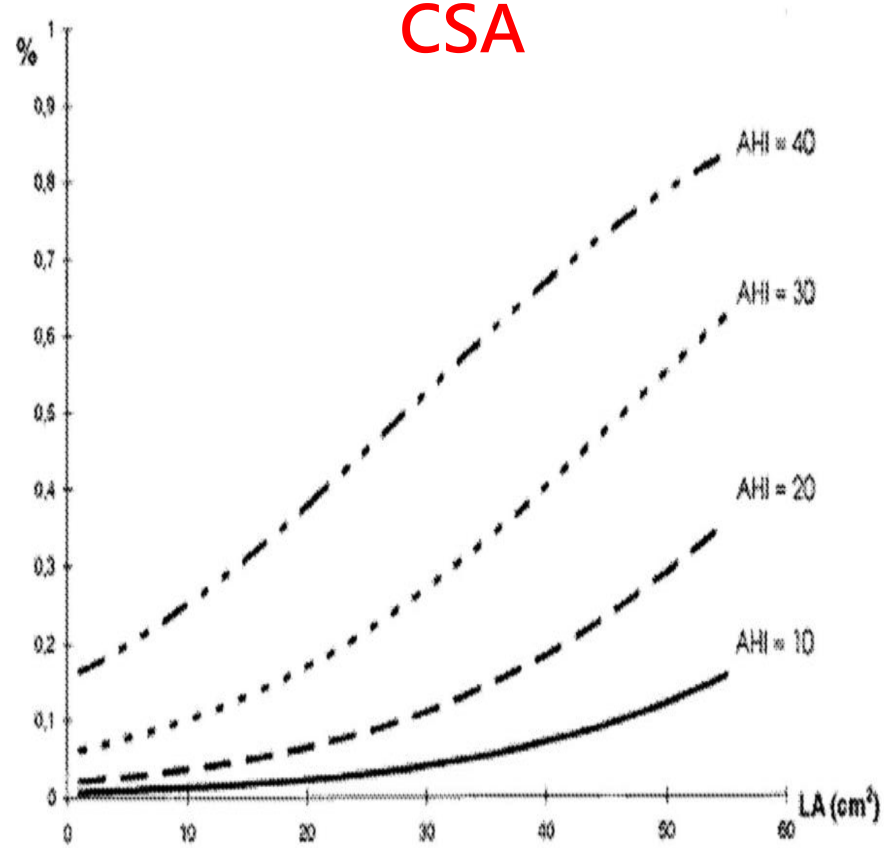
Javaheri S, *et al, AJRCCM* 2011

Survival in HF Patients with SDB

OSA

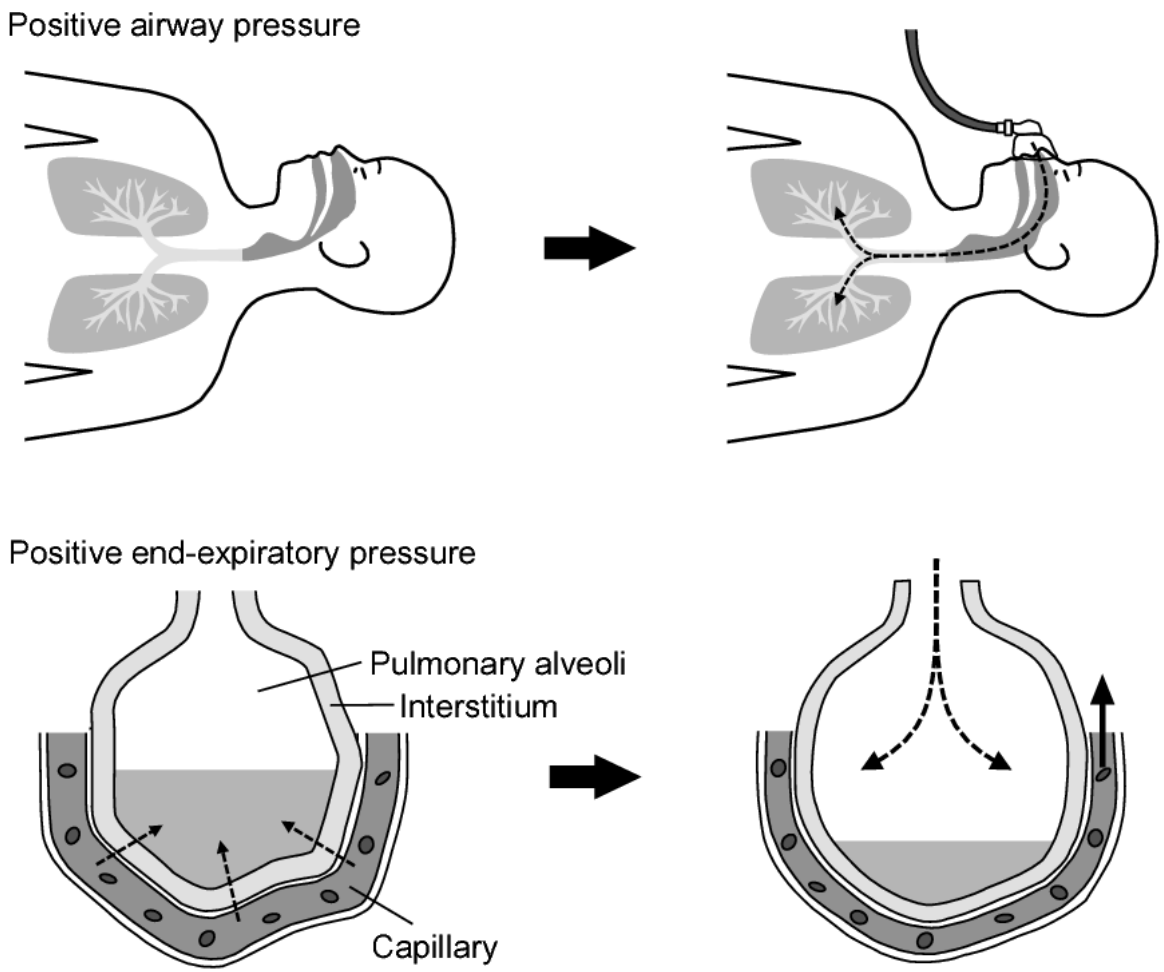


CSA



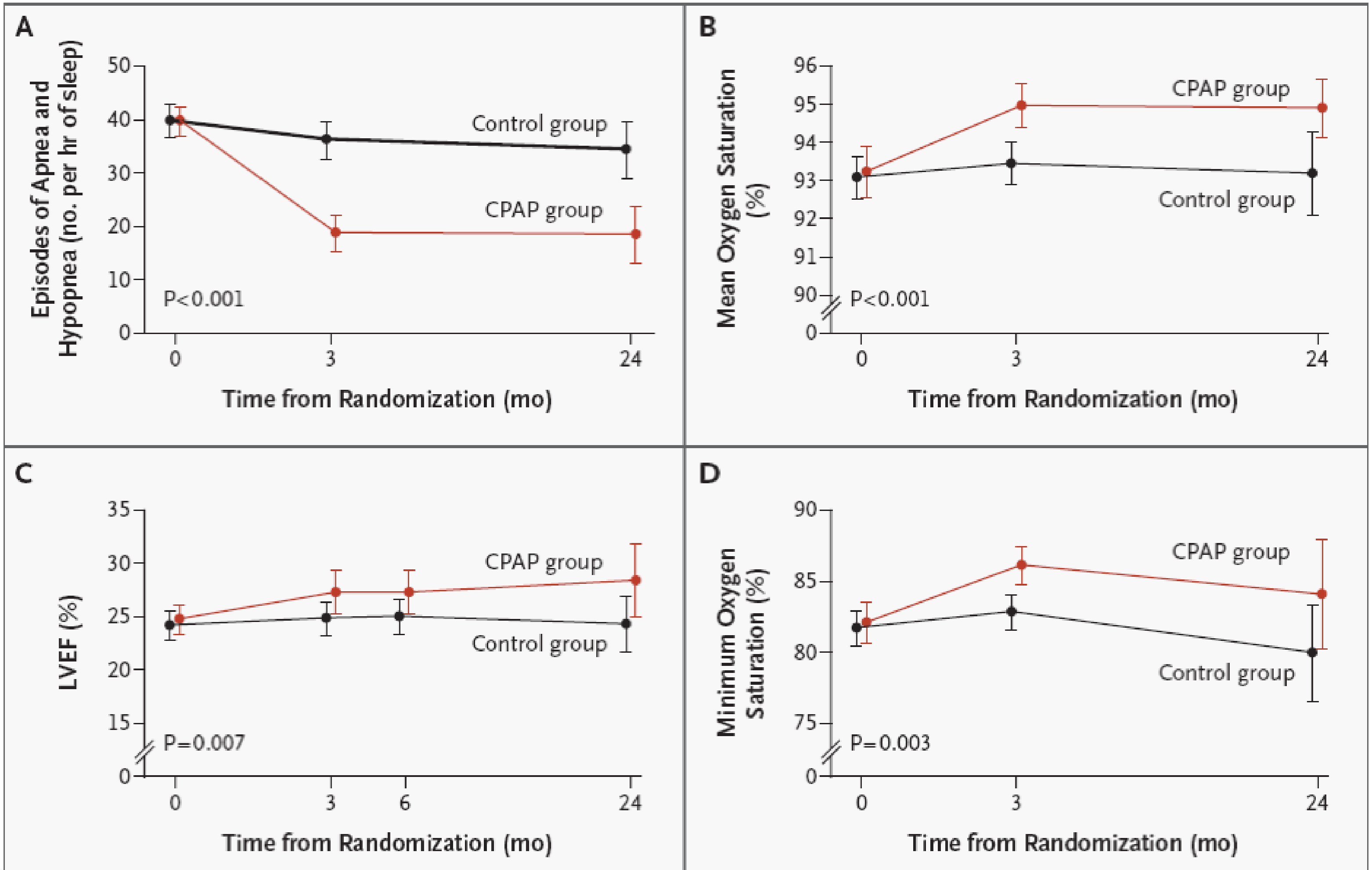
Wang H *et al. JACC 2006;*
Lanfranchi et al. Circulation 1999

Effect of Positive Airway Pressure on Airway and Alveoli



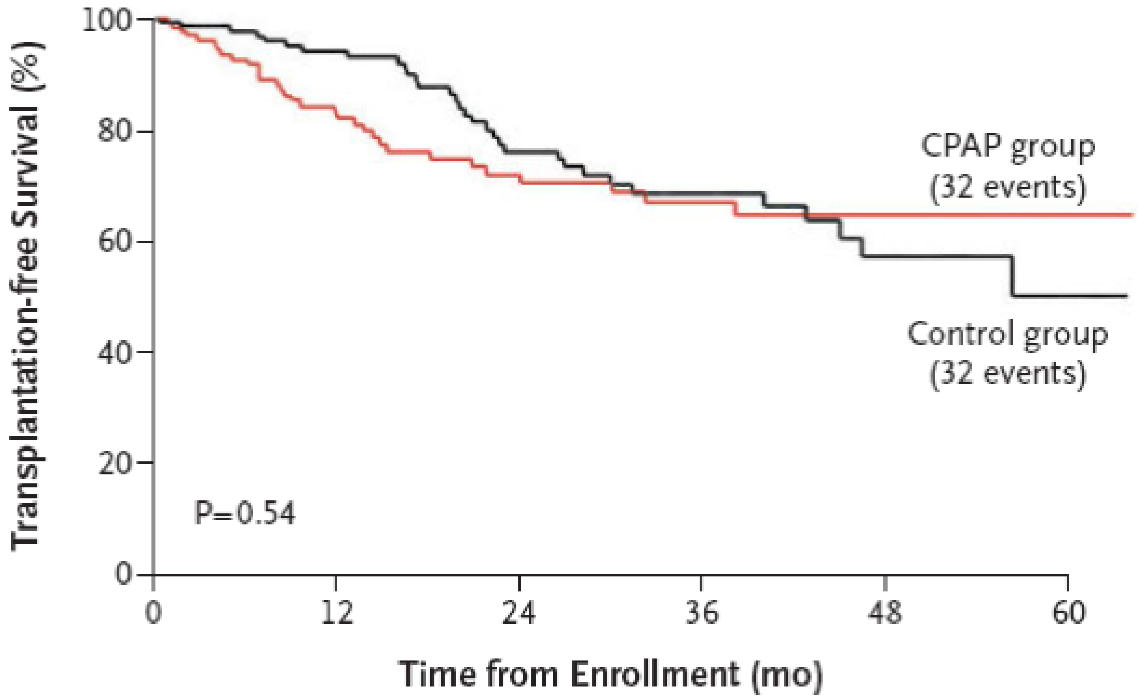
Yoshihisa A, *et al. Fukushima J Med Sci* 2017

Effects of CPAP on HF with CSA



Bradley TD, *et al. NEJM* 2005

Effect of CPAP on HF with CSA on Mortality -- No improvement in survival ???!!!



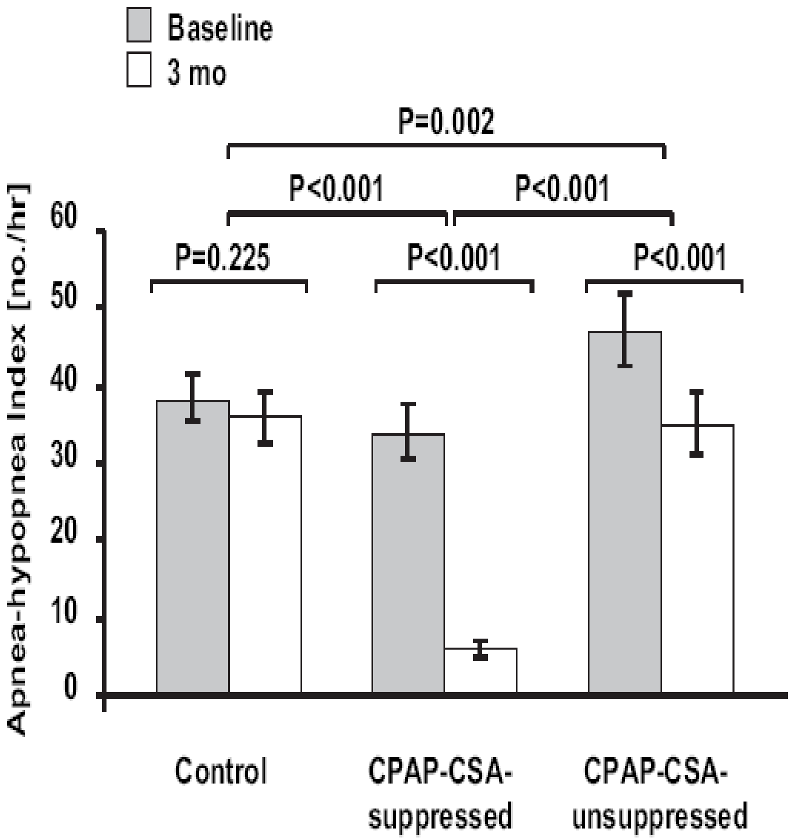
No. at Risk

CPAP group	128	104	79	59	49	42	33	24	20	12	6
Control group	130	117	96	79	59	46	37	27	19	12	4

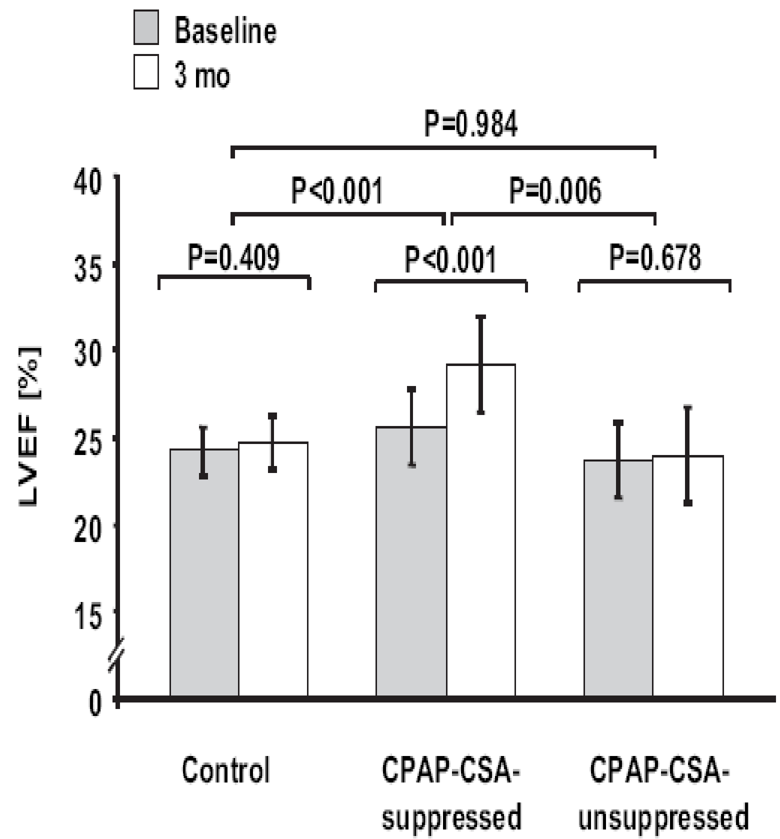
Bradley TD, *et al. NEJM* 2005

Different Effects of CPAP on CSA

AHI



LVEF



Arzt M, *et al. Circulation* 2007

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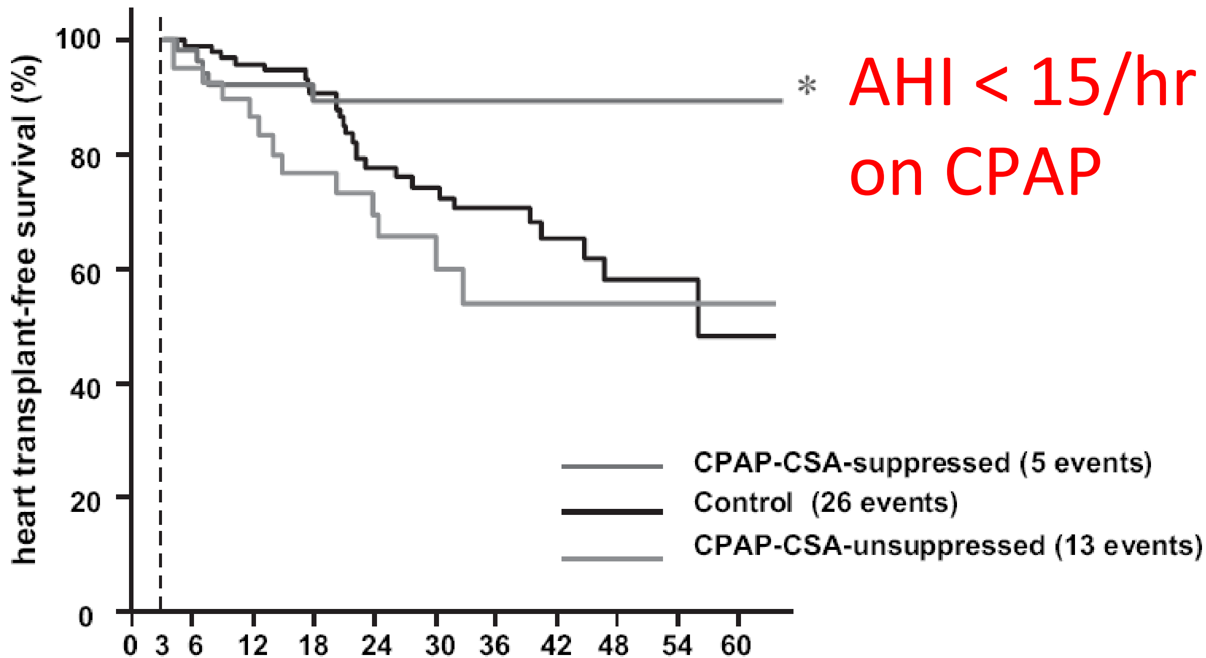
CPAP on Outcomes of CHF-CSA

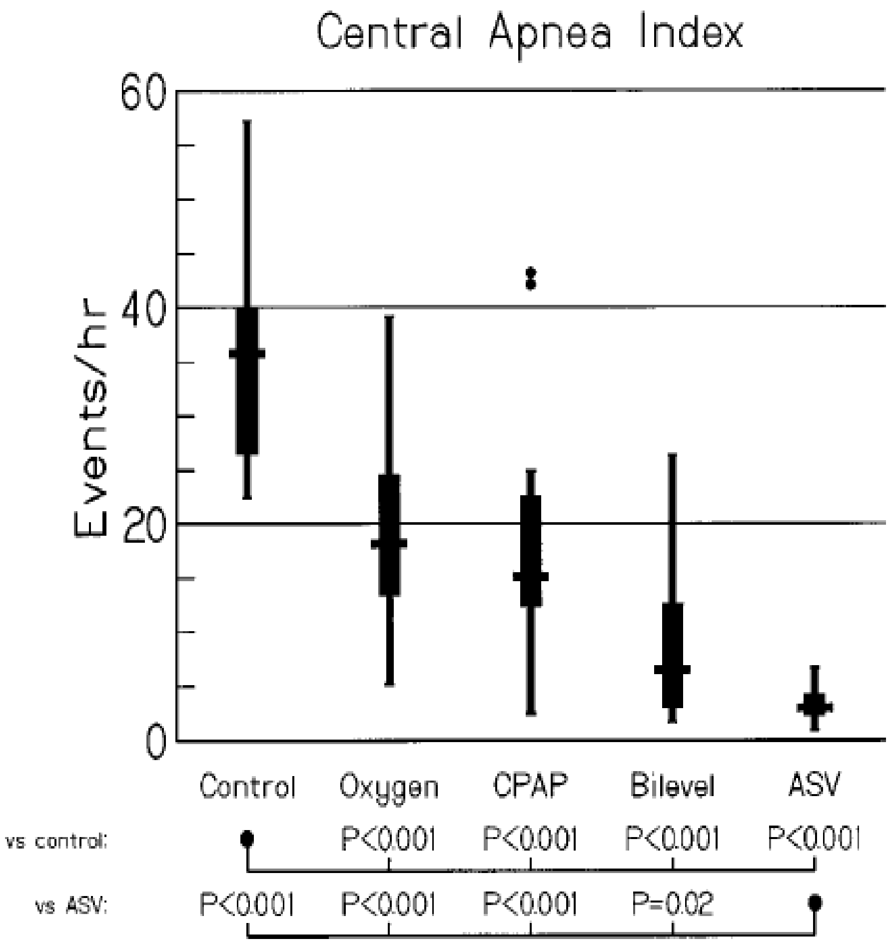


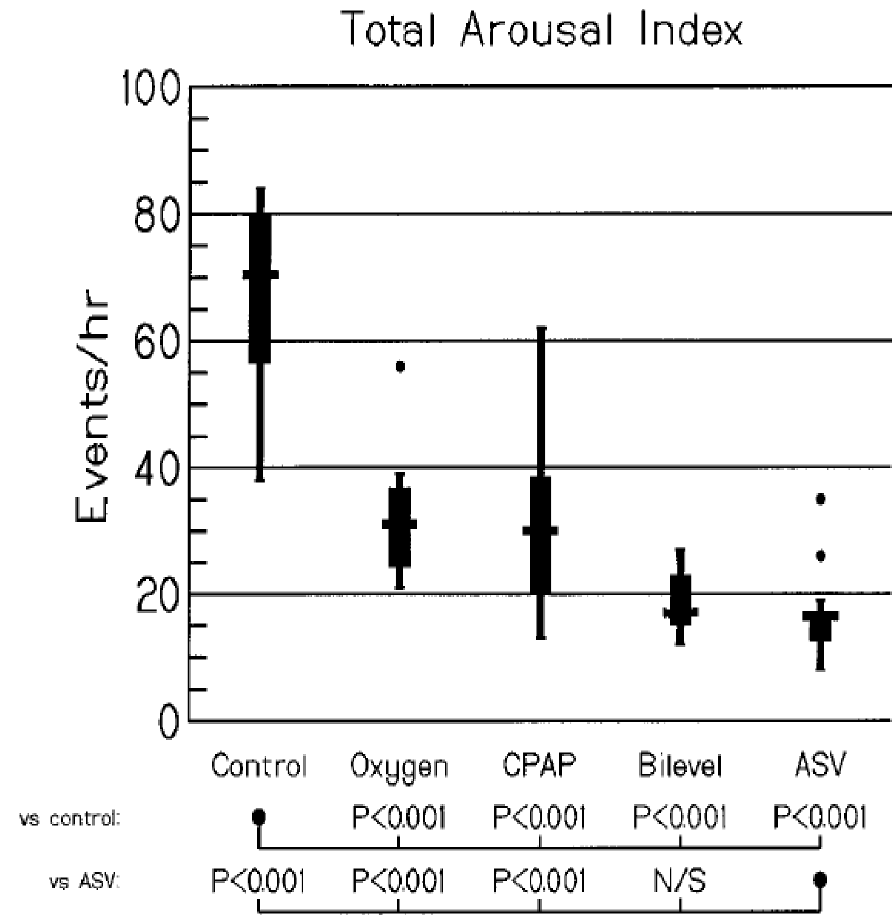
number at risk

CPAP-CSA-suppressed (n=57)	51	38	31	27	23	21	15	11	7	3
Control (n=110)	99	83	71	50	41	33	22	15	9	3
CPAP-CSA-unsuppressed (n=43)	36	27	22	18	12	9	6	6	4	2

Arzt M, *et al. Circulation* 2007

Different Modalities in Tx of CSA





Treschler H, *et al. AJRCCM* 2001

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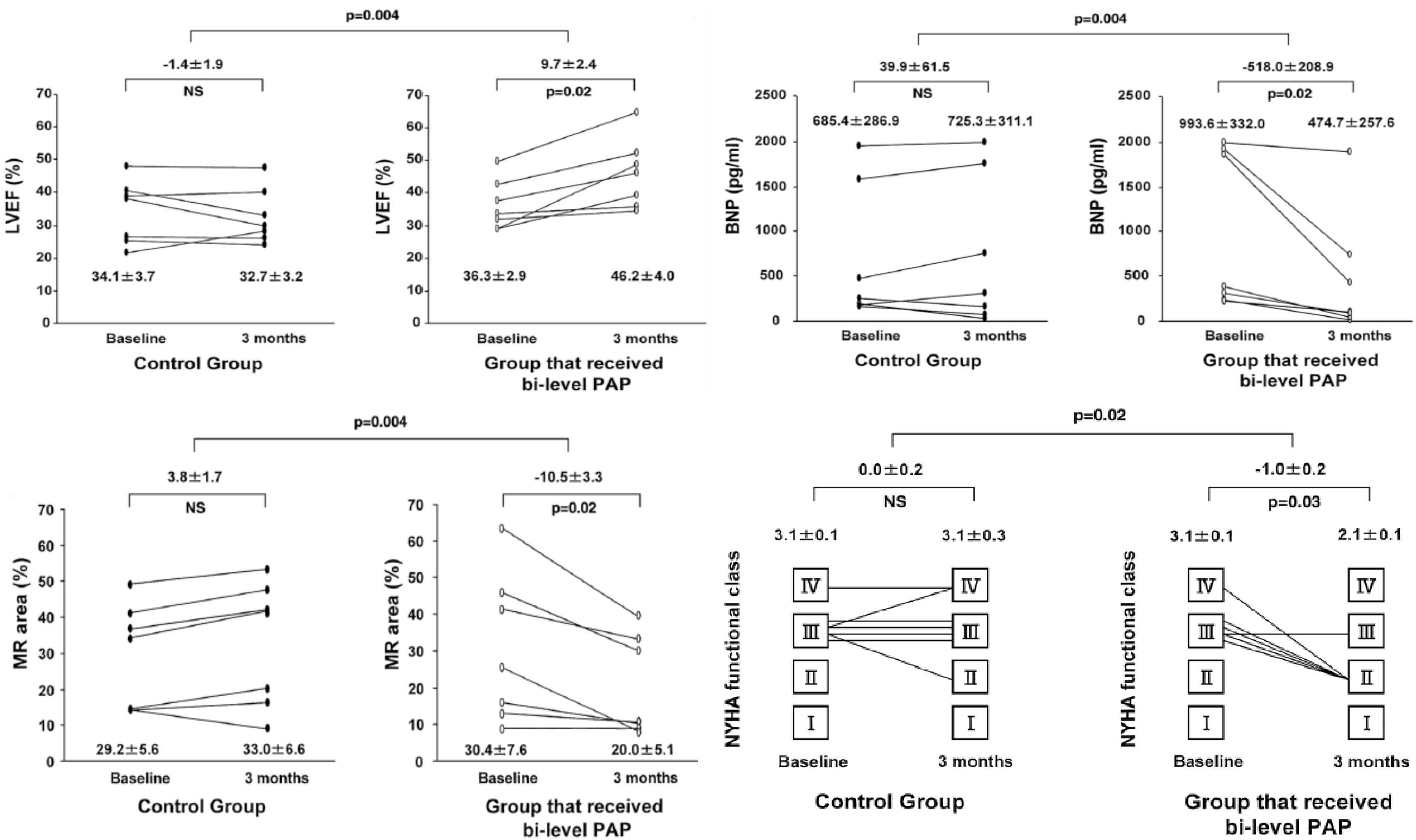
Effects of NIV on Heart Function in HF Patient with CSR-CSA

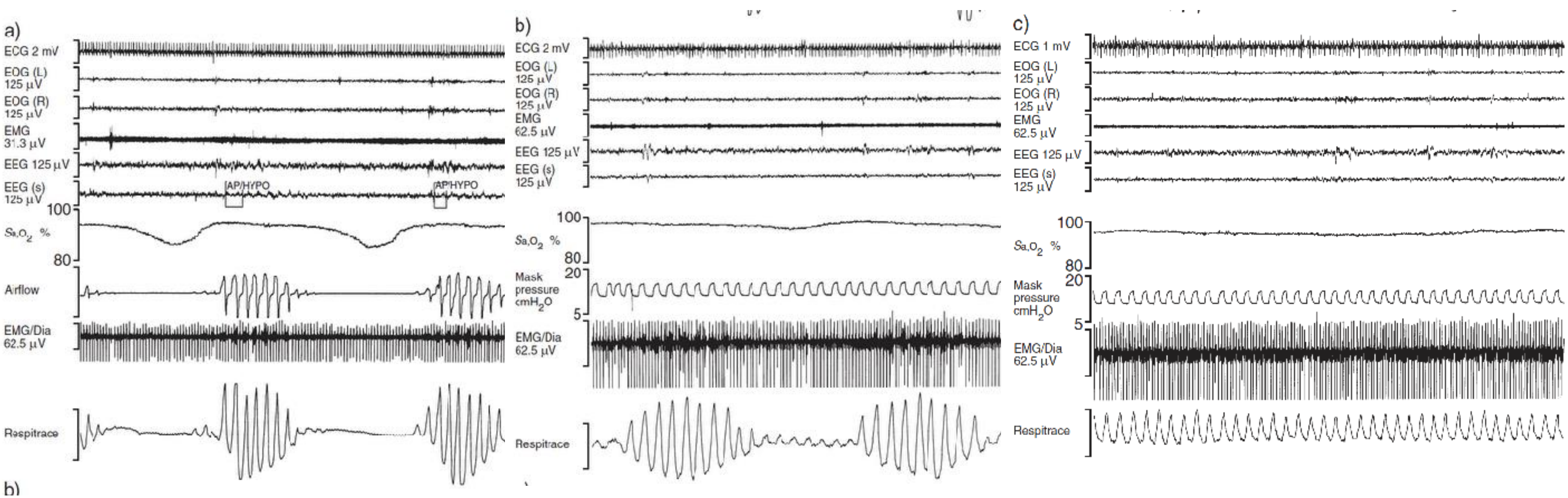


Kasai T, *et al. Circ J* 2005

CSR: Cheyne-Stokes Respiration

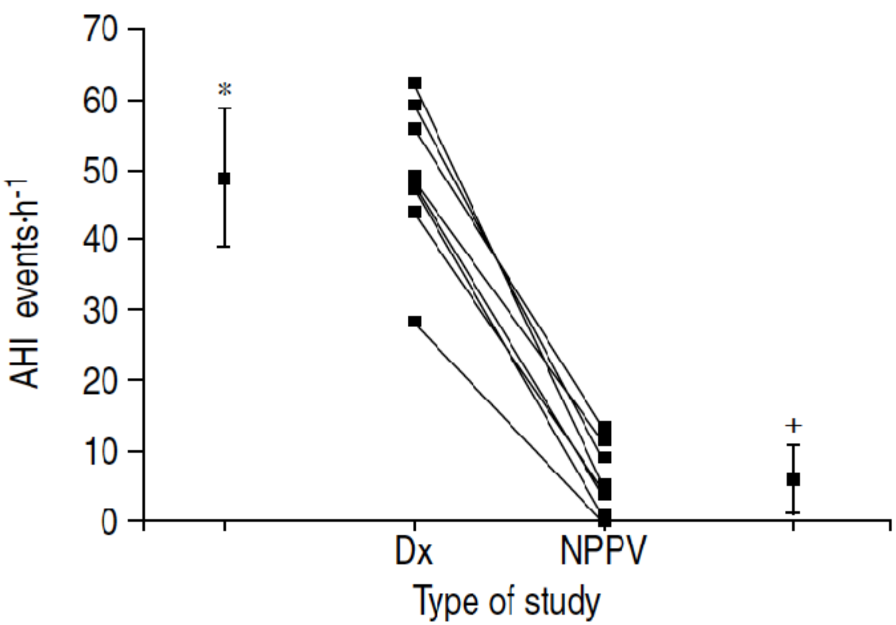
NIV in Patients with CHF

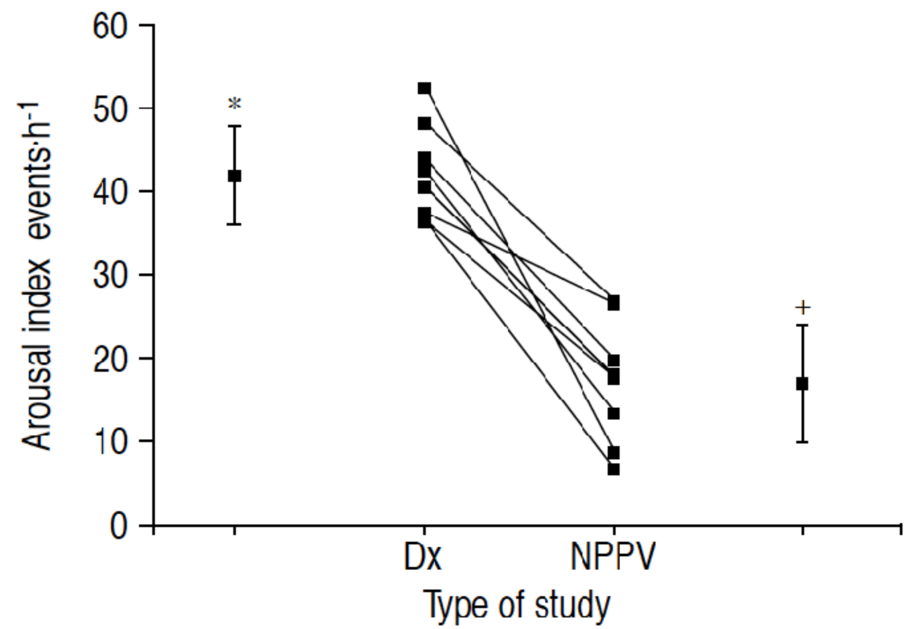
Baseline PSG | Initial NIV Support | Stable NIV Support



Willson GN, *et al. Eur Respir J* 2001; 17: 1250–1257

NIV Improves CSA

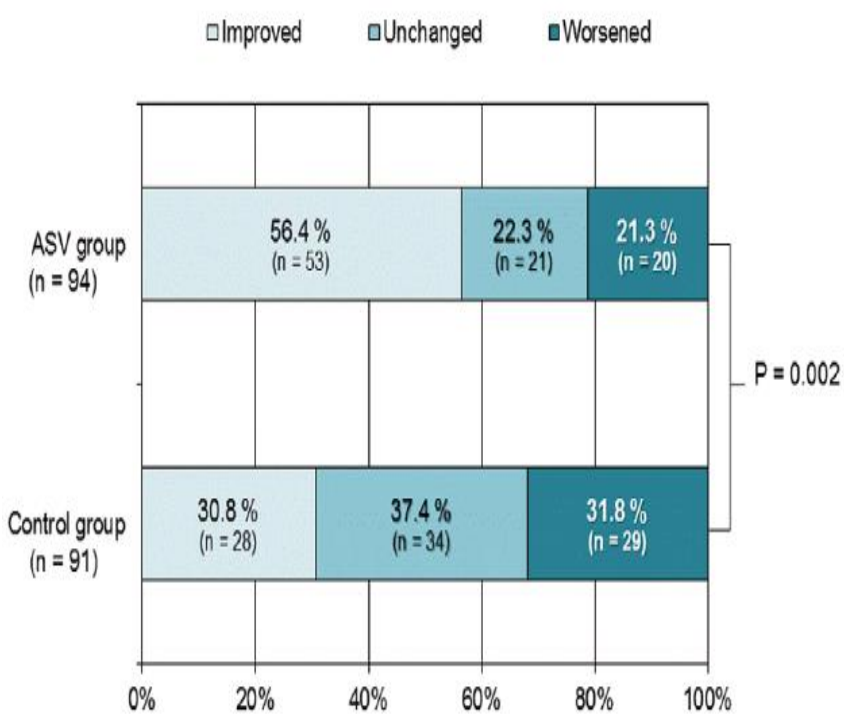




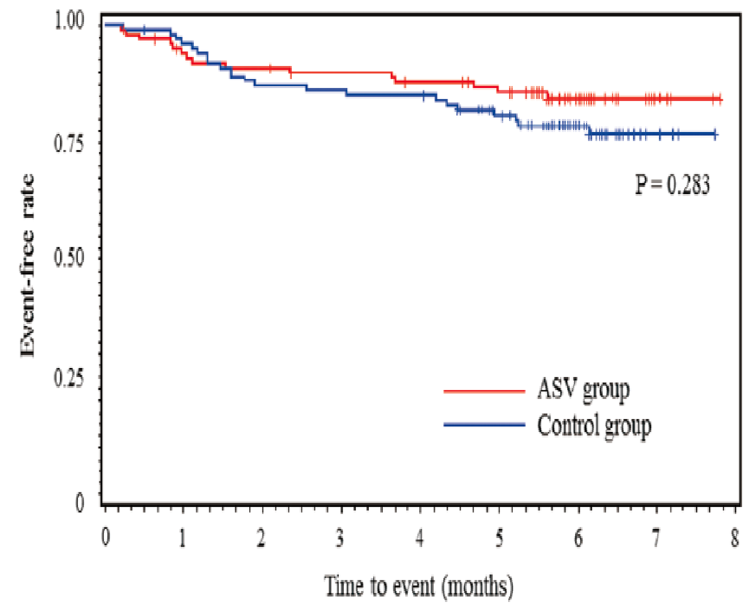
Willson GN, *et al. Eur Respir J* 2001; 17: 1250–1257

ASV in CSA of HF
SAVIOR-C Trial, 24 wk, n=205

Some Clinical Response
(QoL, NYHA Class etc.)



No Survival Benefits



Number at risk

ASV group	102	93	90	84	83	80	40	7	3
Control group	103	98	89	87	85	76	45	9	4

Momomura SI, *et al. Circ J* 2015

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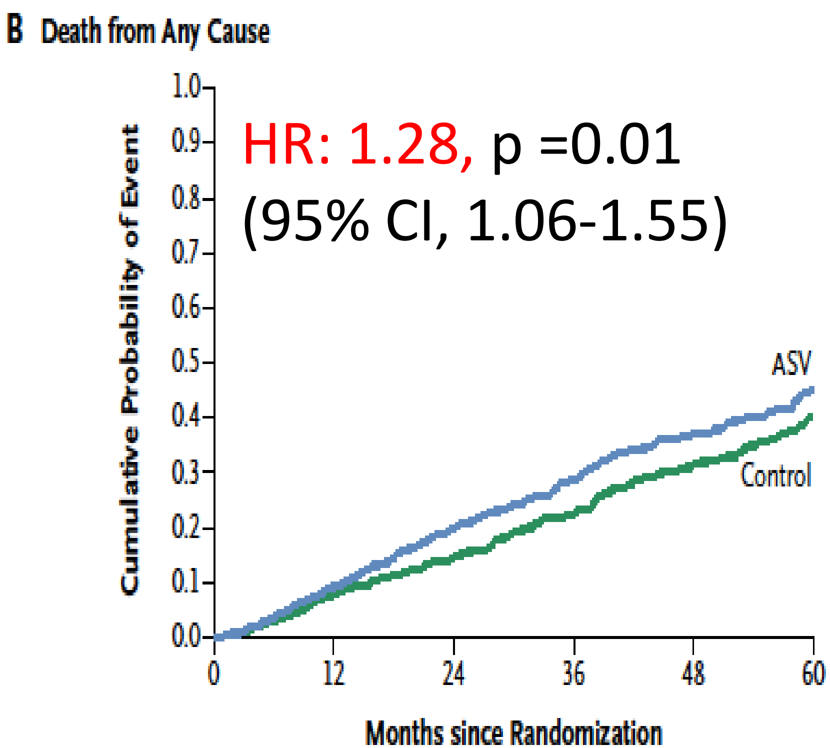
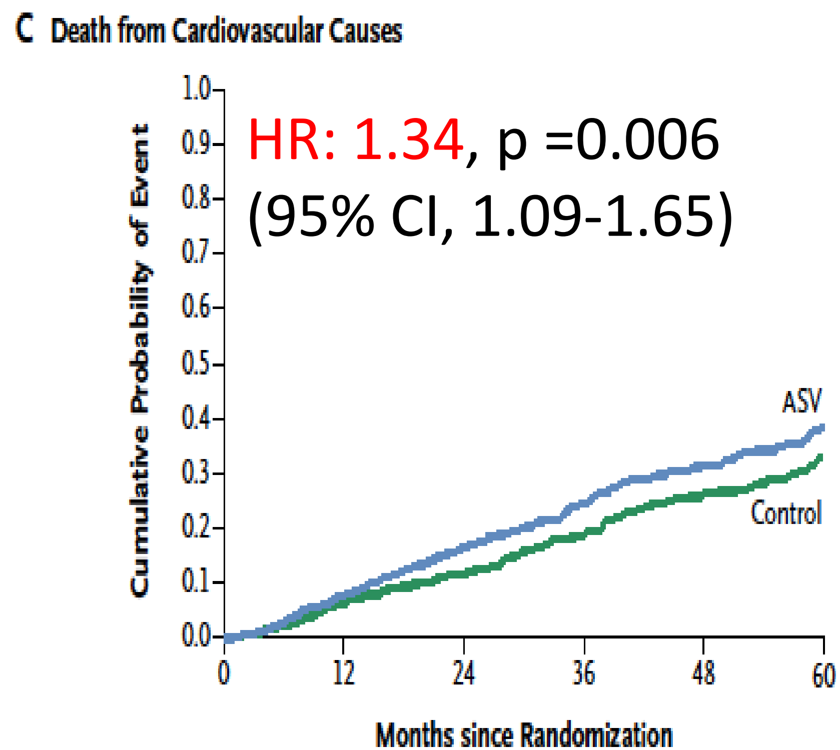
ASV Increased Mortality in CSA

SERVE-HF Trial (0-80 m, Median 31 m), n=1325



No. at Risk						
Control	659	563	493	334	213	117
ASV	666	555	466	304	189	97



No. at Risk						
Control	659	563	493	334	213	117
ASV	666	555	466	304	189	97

Cowie MR, *et al. NEJM* 2015

ASV in HF with Low LVEF
SERVE-HF Trial

	n (%)	Hazard ratio	95% CI	$p_{interaction}$
LVEF >36%	340 (37%)	1·21	0·48–3·08	0·026
LVEF 31–36%	243 (18%)	2·33	0·60–9·03	0·026
LVEF ≤30%	486 (26%)	5·21	2·11–12·89	0·026

LVEF data missed in 19% of patients

Eulenburg C, *et al. Lancet Respir Medicine* 2016

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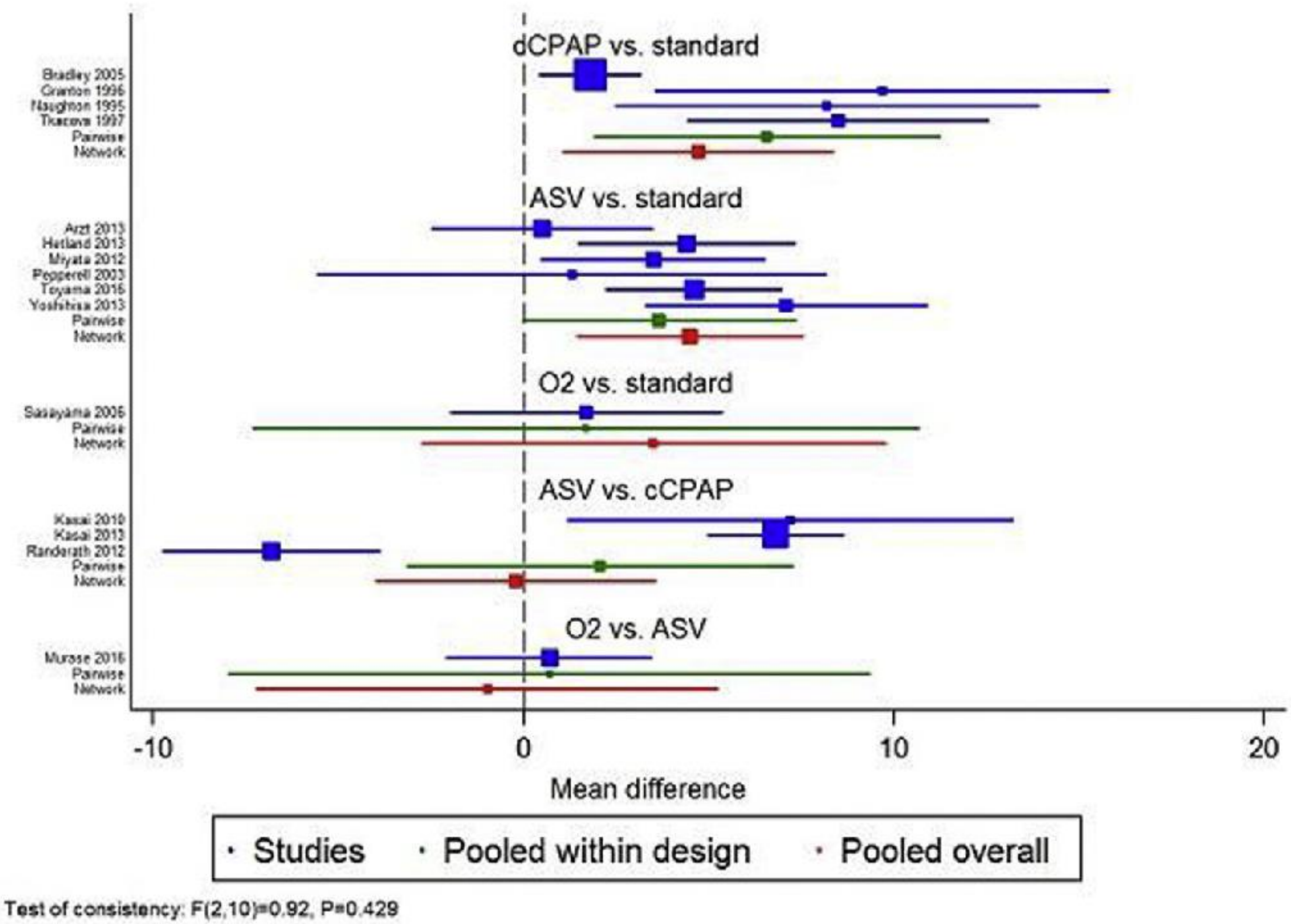
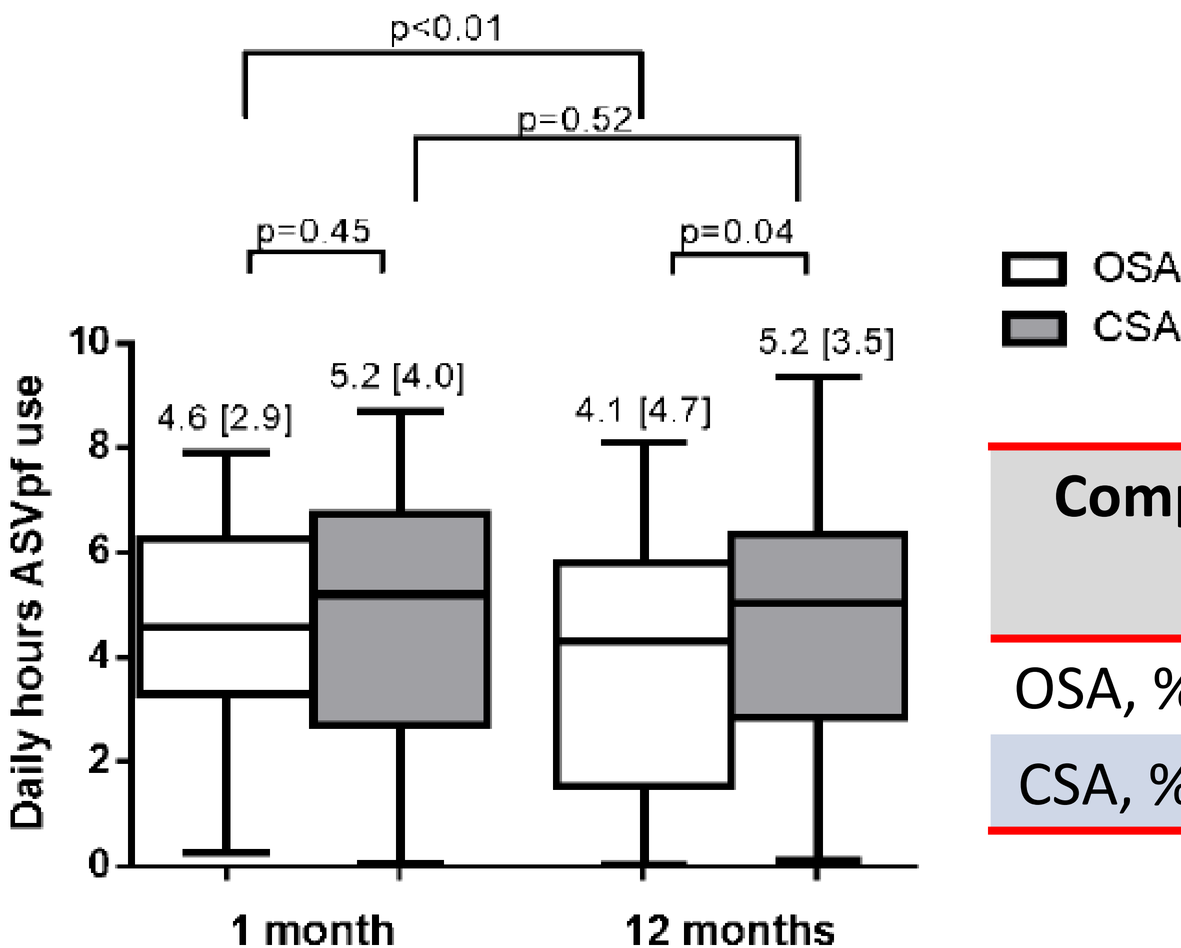
ASV vs CPAP in CSA Treatment
A Network Meta-analysis



Schwarz EI, *et al. Chest* 2017;151(5):A60,

ADVENT-HF Trial (ASVpf)
Preliminary Data on Adherence, 12m, n=177



Compliance on ASVpf		
	1 m	12 m
OSA, %	86	67
CSA, %	87	80

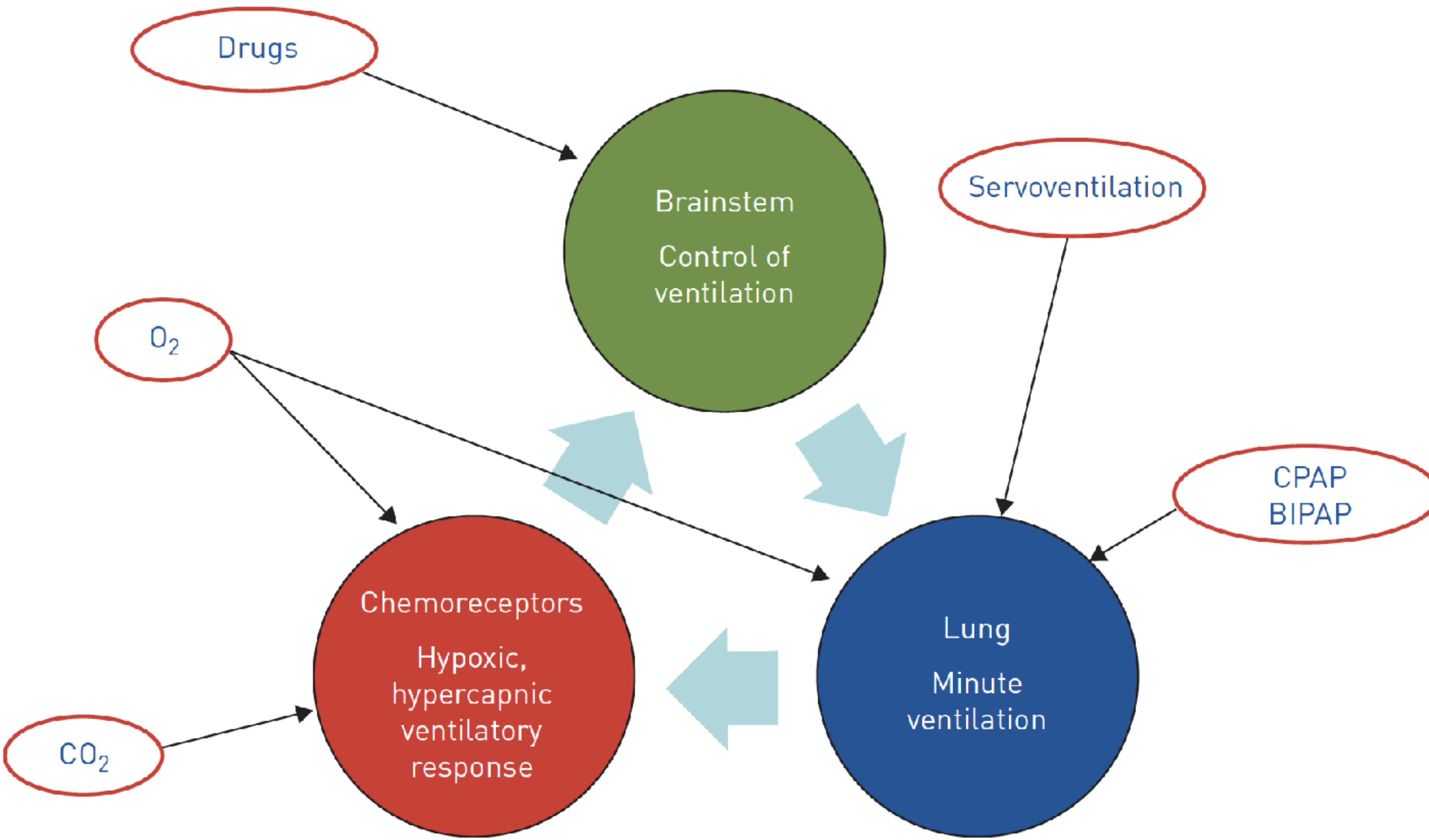
Perger E, *et al. ERJ* 2018

NIV for COPD or
Overlap Syndrome (OSA + COPD)

Sleep in COPD Patients

- Airflow limitation
- Hypoventilation in sleep
  - In health subjects, minute ventilation decreases about 6-16% in sleep, especially in REM sleep. Douglas NJ, Thorax 1982

❾ Leading to significant nocturnal hypoxemia



Randerath W, *et al. Eur Respir Rev* 2019; 28: 190084

SDB in COPD Patients

Symptoms or findings indicative for sleep disordered breathing in patients with COPD
Sleep-related symptoms such as snoring, gasping and choking, as well as nocturia or morning headache
Increased daytime sleepiness
Signs of obesity including BMI >30 $kg \cdot m^{-2}$ in men and >35 $kg \cdot m^{-2}$ in women, neck circumference >43 cm in men and >41 cm in women
Reduced daytime pulse oxygen saturation (<93%) at rest or during exercise
Daytime hypercapnia
Signs of pulmonary hypertension or right heart failure, such as peripheral oedema
Polycythaemia
Patients who use opioids and/or hypnotic medications
Comorbidities such as atrial fibrillation, end-stage renal disease, type 2 diabetes, heart failure, difficult to treat hypertension and stroke

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

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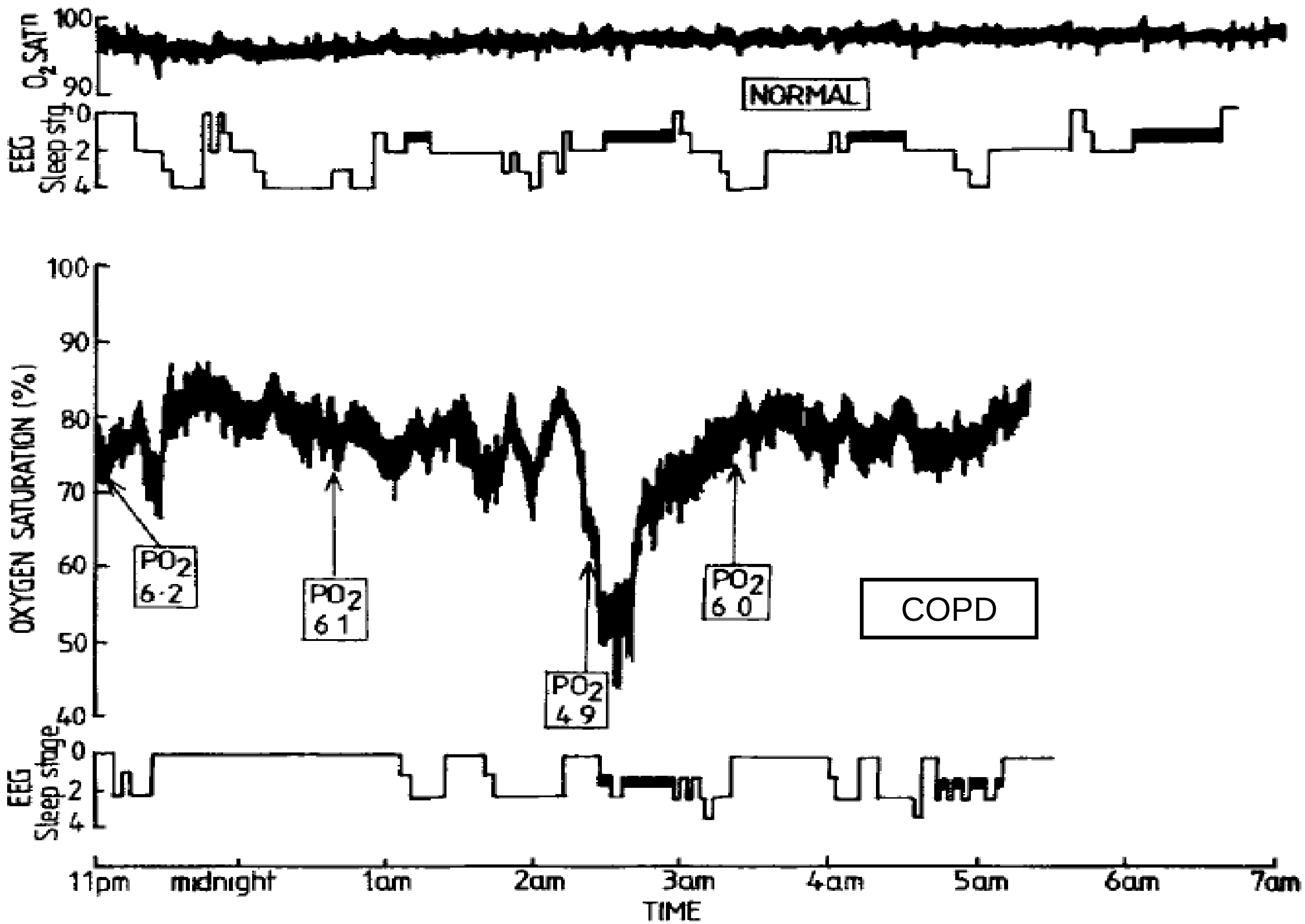
COPD and OSA
The "Overlap Syndrome"

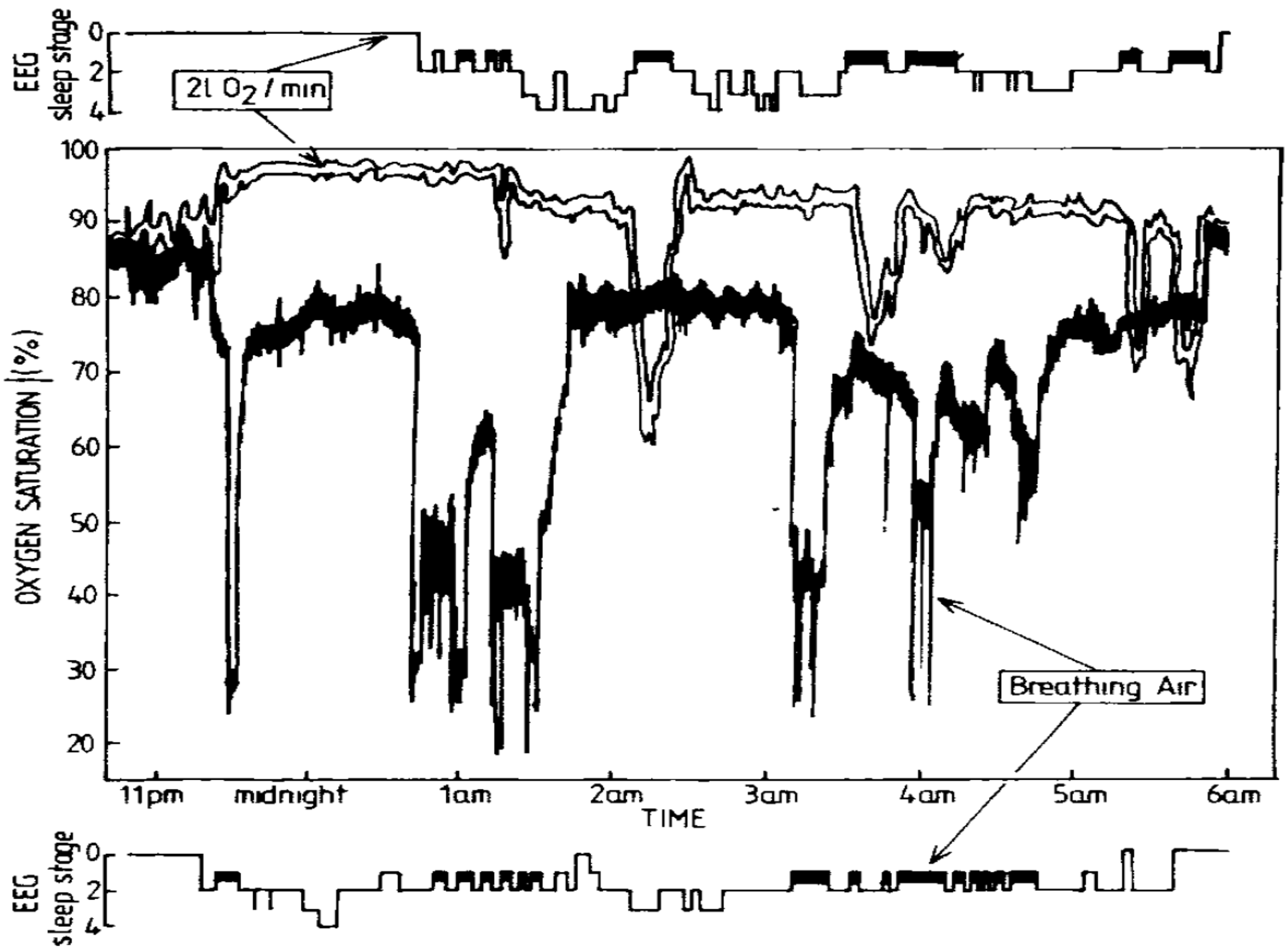
- OSA and COPD are both prevalent
  – (4-9% and 10-20%, respectively)
- OSA and COPD share risk factors
  – male gender, age, cigarette smoking
- Control of breathing defect may predispose to OSA
- 11% of 265 patients with OSA have COPD

Nocturnal Hypoxemia in COPD



Douglas NJ, *et al. Lancet* 1973

Transient Hypoxemia during Sleep



Douglas NJ, *et al. Lancet* 1973

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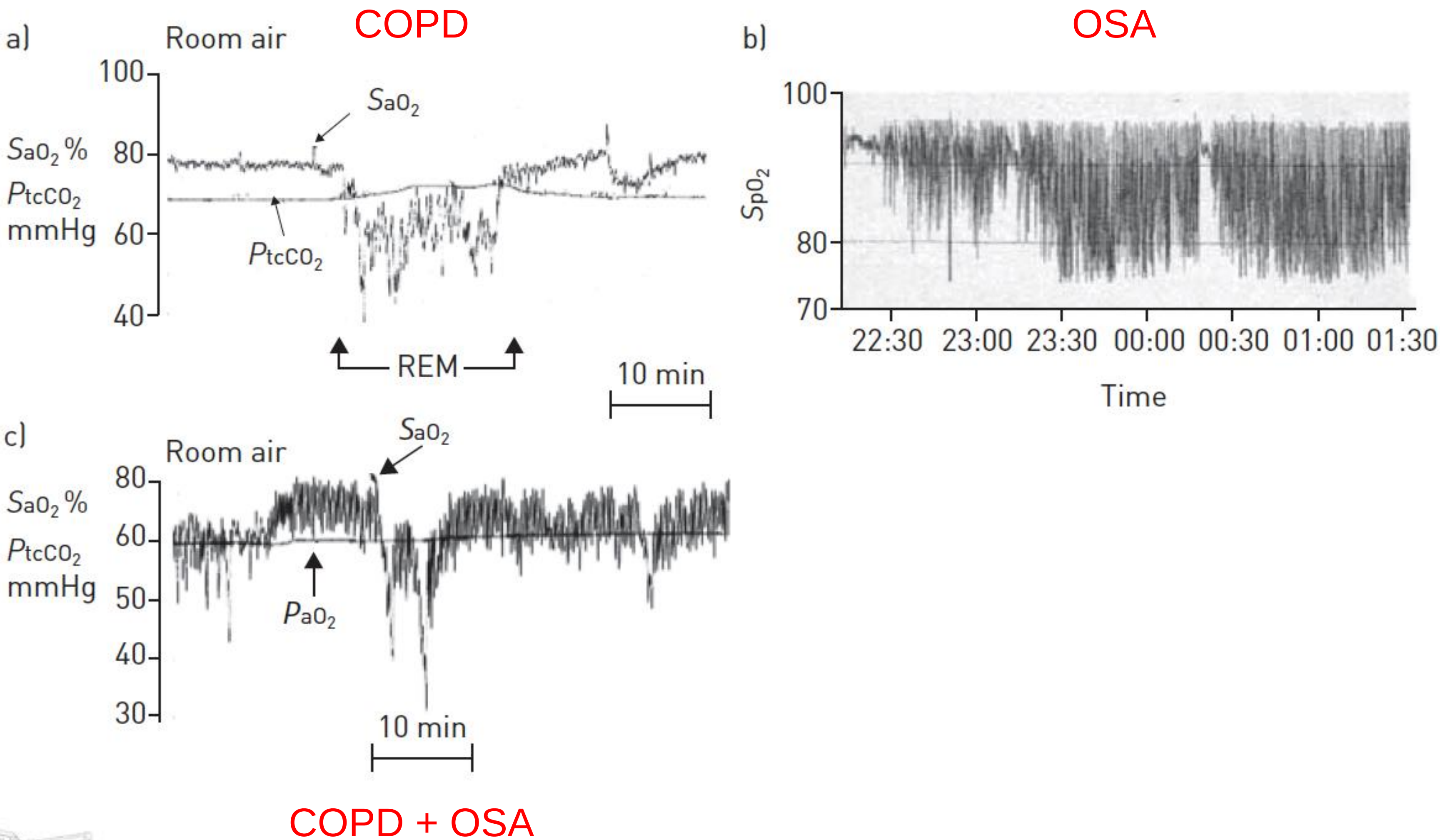
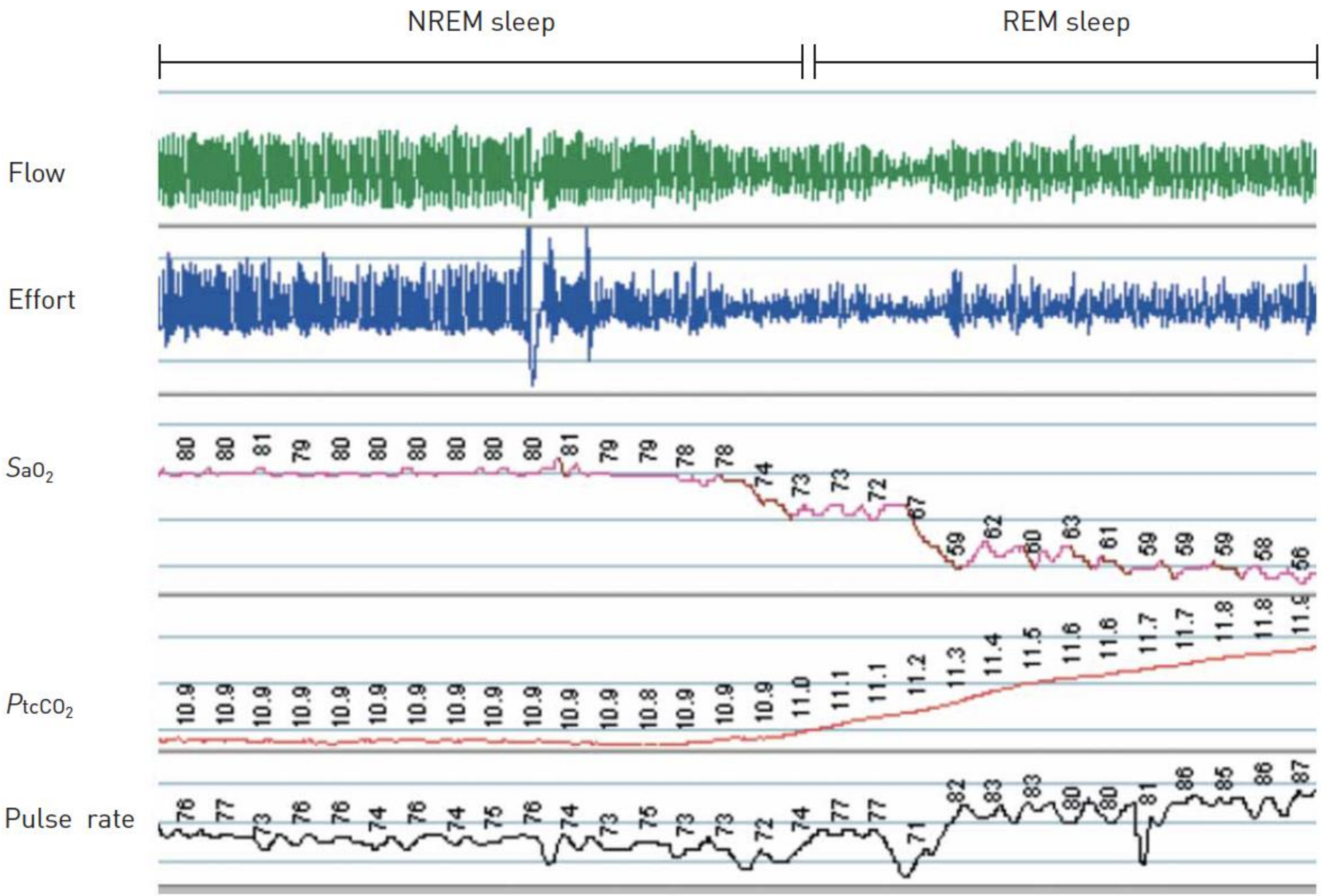
Nocturnal Hypoxemia and Hypercapnia in COPD



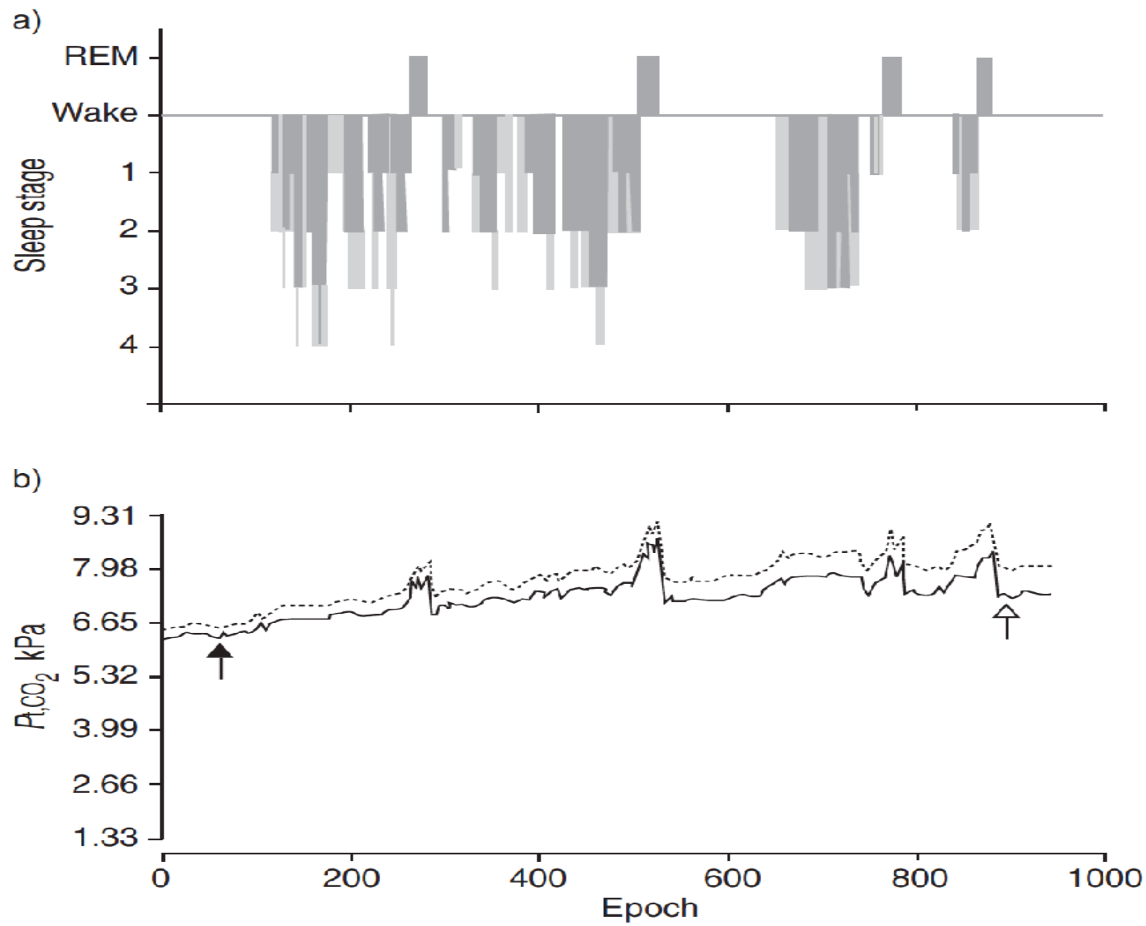
McNicholas WT, *et al. Eur Respir Rev* 2019; 28: 190064



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

Nocturnal Hypercapnia in COPD

43% of daytime hypercapnic COPD patients spent ≥20% of total sleep time with an increase of PtcCO2 > 10 mmHg



O'Donoghue FJ, *et al. Eur Respir J* 2003; 21: 977–984

Factors Correlated with Overnight Sleep Hypoventilation

	20%incr	Maxincr
Age	-0.19 (0.17)	-0.05 (0.72)
Female#	-0.15 (0.27)	-0.10 (0.50)
BMI	0.27 (0.05)	0.37 (0.01)
FEV_1 % pred#	0.19 (0.17)	0.19 (0.19)
FVC % pred	0.05 (0.72)	-0.06 (0.71)
FEV_1/FVC	0.10 (0.46)	0.25 (0.08)
P_{a,O_2}	-0.18 (0.24)	-0.18 (0.26)
P_{a,CO_2}	0.39 (0.009)	0.42 (0.007)
Life alcohol#	-0.29 (0.06)	-0.11 (0.52)
Current alcohol#	-0.31 (0.04)	-0.23 (0.14)
AHI#	0.13 (0.33)	0.22 (0.13)
%SWS	-0.10 (0.46)	-0.05 (0.75)
%REM	0.28 (0.04)	0.32 (0.03)
TST	0.18 (0.19)	0.17 (0.25)
REMflow	0.12 (0.53)	0.17 (0.37)
NREMflow	0.00 (0.98)	0.16 (0.38)

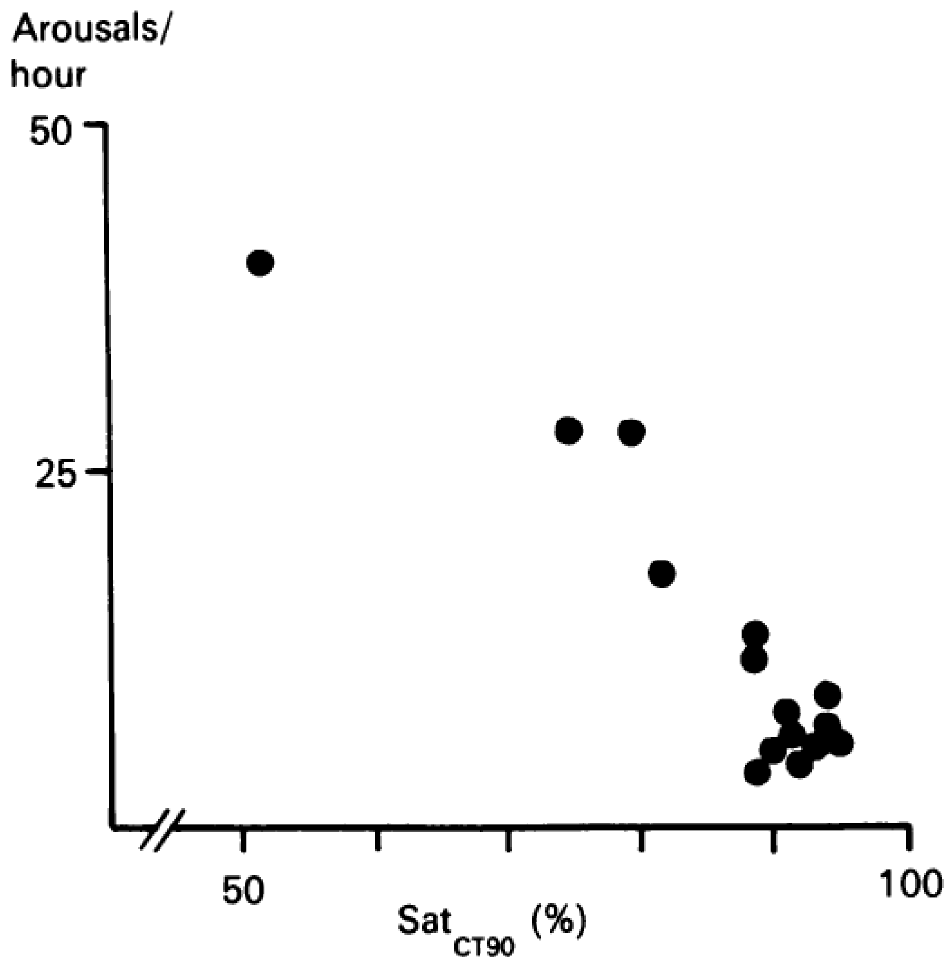
O'Donoghue FJ, *et al. Eur Respir J* 2003; 21: 977–984

Factors Correlated with Hypoventilation in REM Sleep

	ΔNREM–REM
Age	-0.13 (0.29)
Female#	-0.03 (0.78)
BMI	0.09 (0.45)
FEV_1 % pred#	0.04 (0.75)
FVC % pred	-0.29 (0.02)
FEV_1/FVC	0.20 (0.1)
P_{a,O_2}	-0.02 (0.85)
P_{a,CO_2}	0.18 (0.17)
Life alcohol#	0.02 (0.88)
Current alcohol#	-0.08 (0.55)
AHI#	0.25 (0.04)
AHI in REM sleep#	0.24 (0.05)
%REM	-0.12 (0.32)
%SWS	0.32 (0.01)
REM_{flow}	0.31 (0.04)
$NREM_{flow}$	0.05 (0.71)

O'Donoghue FJ, *et al. Eur Respir J* 2003; 21: 977–984

Increased Arousals with Decreased Oxygen Saturation



Cormick W, *et al. Thorax* 1986

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Overlap Syndrome (OSA+COPD)

- Older in age
- More severe in nocturnal oxygen desaturation
- More arousals (due to hypoxemia and OSA)
- More prevalent in pulmonary hypertension

- Outcomes, such as survival, cardiovascular events
  - No data

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Treatment of Overlap Syndrome

- Nasal CPAP
  - Treatment of choice
- Nasal CPAP plus supplemental oxygen
  - For uncorrectable hypoxemia after correction of OSA with CPAP
- Noninvasive positive airway pressure
  - Works for OSA, hypoxemia and hypercapnia

NIV for Restrictive Thoracic Disorders

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Factors Contributing to SDB in Neuromuscular and Chest Wall Disease

- Effects of sleep on breathing in normal individuals
- Loss of wakefulness drive to breathe
- Reduction in nonmetabolic inputs to ventilation
- Decreased chemo-responsiveness to hypoxia and hypercapnia
- REM-related skeletal muscle atonia
- Reduced lung volumes
- Increased upper airway resistance
- Chest wall abnormality

- Superimposed loads in individuals with restrictive thoracic disorders
- Diaphragm weakness
- Weakness of accessory muscles of respiration
- Upper airway muscle weakness
- Obesity
- Macroglossia
- Craniofacial abnormalities
- Associated cardiomyopathy
- Atelectasis
- Further decreased chemoresponsiveness

Hilbert J. *Clin Chest Med* 2018;39:309–324

Major neuromuscular and skeletal disorders provoking sleep hypoventilation

Neuromuscular disorders

- Guillain-Barré syndrome
- Myasthenia gravis
- Poliomyelitis
- Post-polio syndrome
- Amyotrophic lateral sclerosis
- Cervical or thoracic spinal cord injury
- Polymyositis
- Muscular dystrophies

Skeletal chest wall diseases

- Kyphoscoliosis
- Ankylosing spondylitis

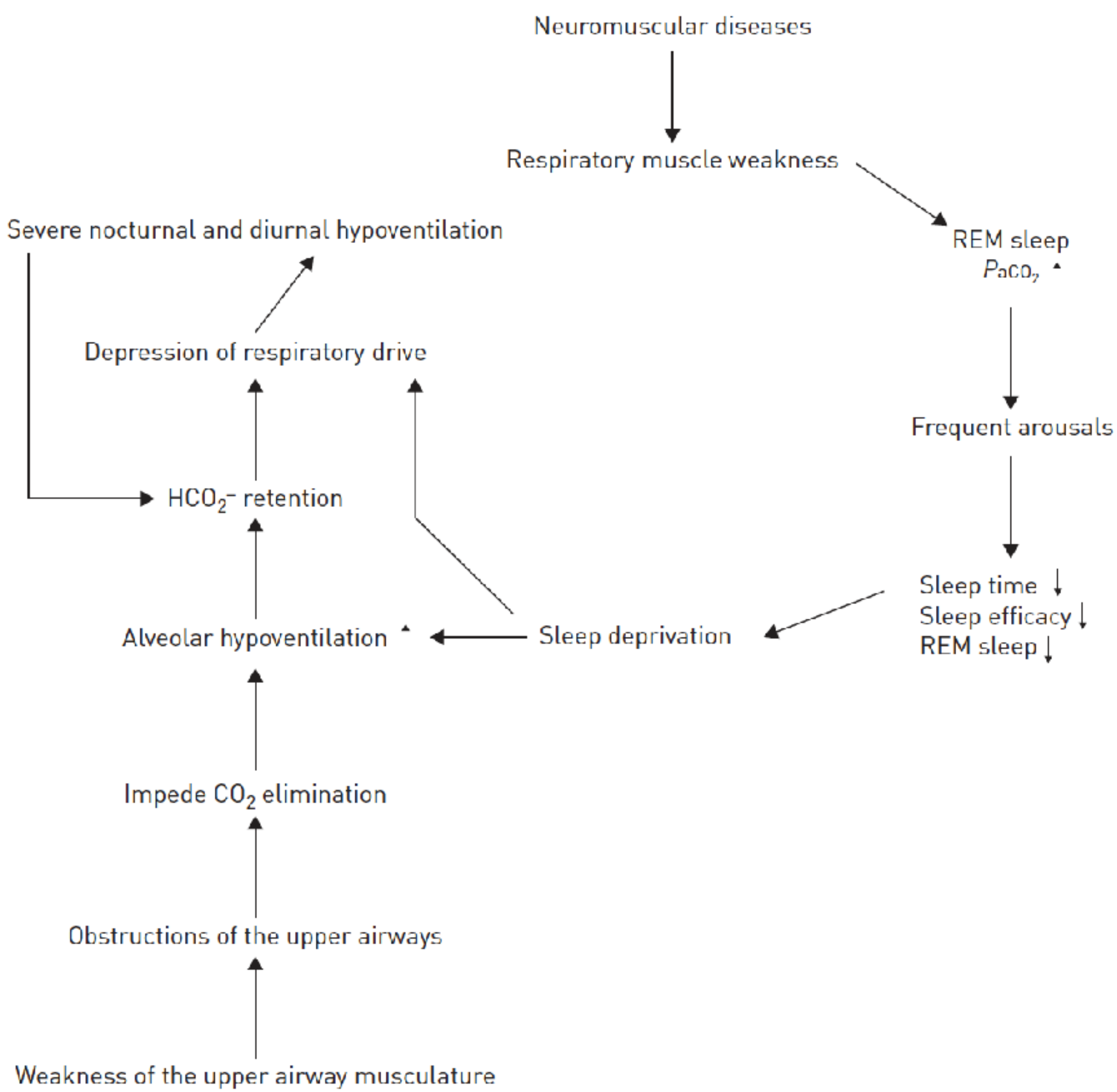
McNicholas WT, *et al. Eur Respir Rev* 2019; 28: 190064

Neuromuscular and Chest Wall Diseases

- Restrictive lung disease
  - Low vital capacity
  - Low function residual lung volume

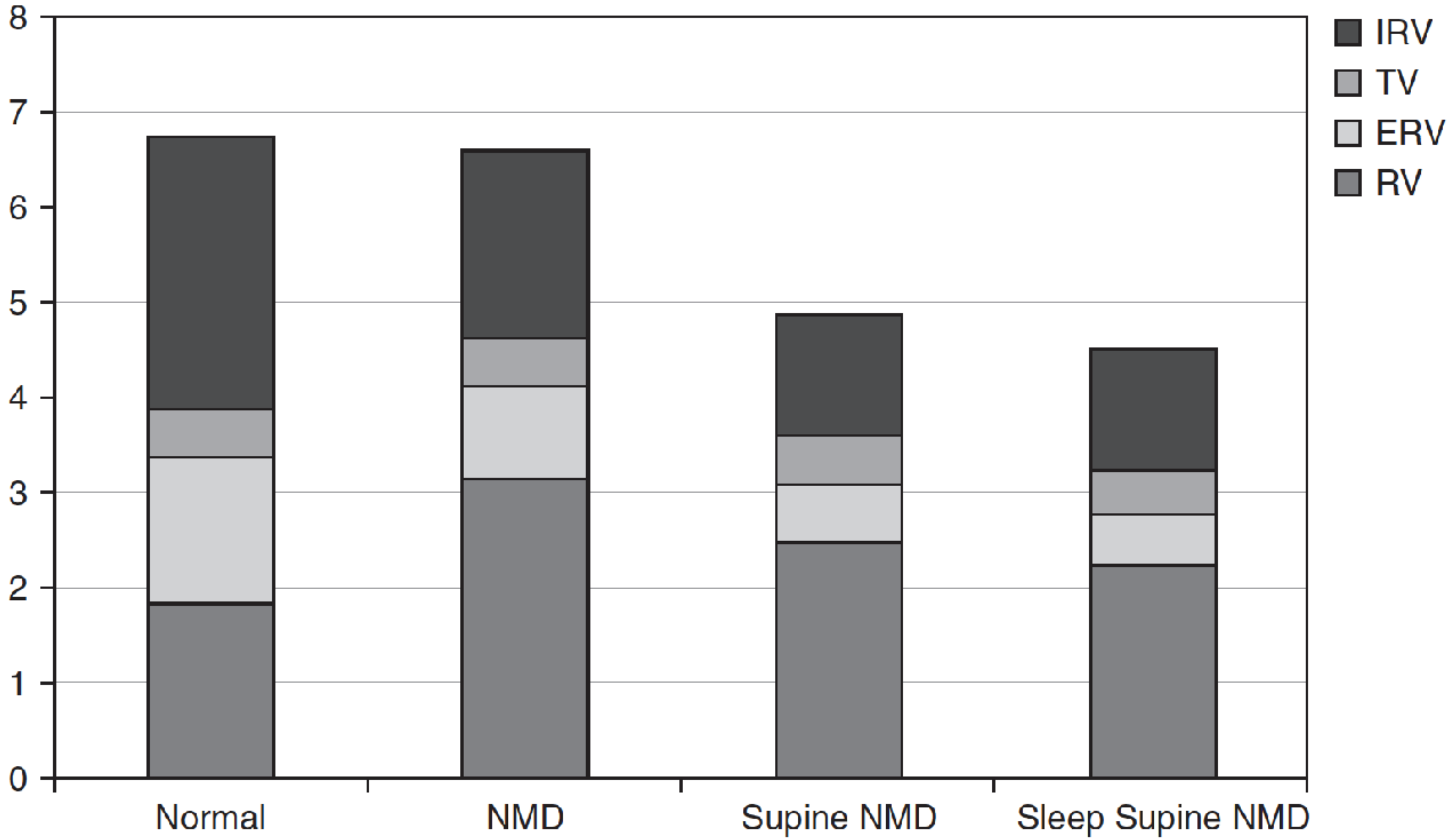
- During sleep
  - Decrease in SaO_2
  - Increase in $PaCO_2$
  - Increased arousals, poor sleep efficiency

Pathophysiology of sleep-related hypoventilation in neuromuscular diseases



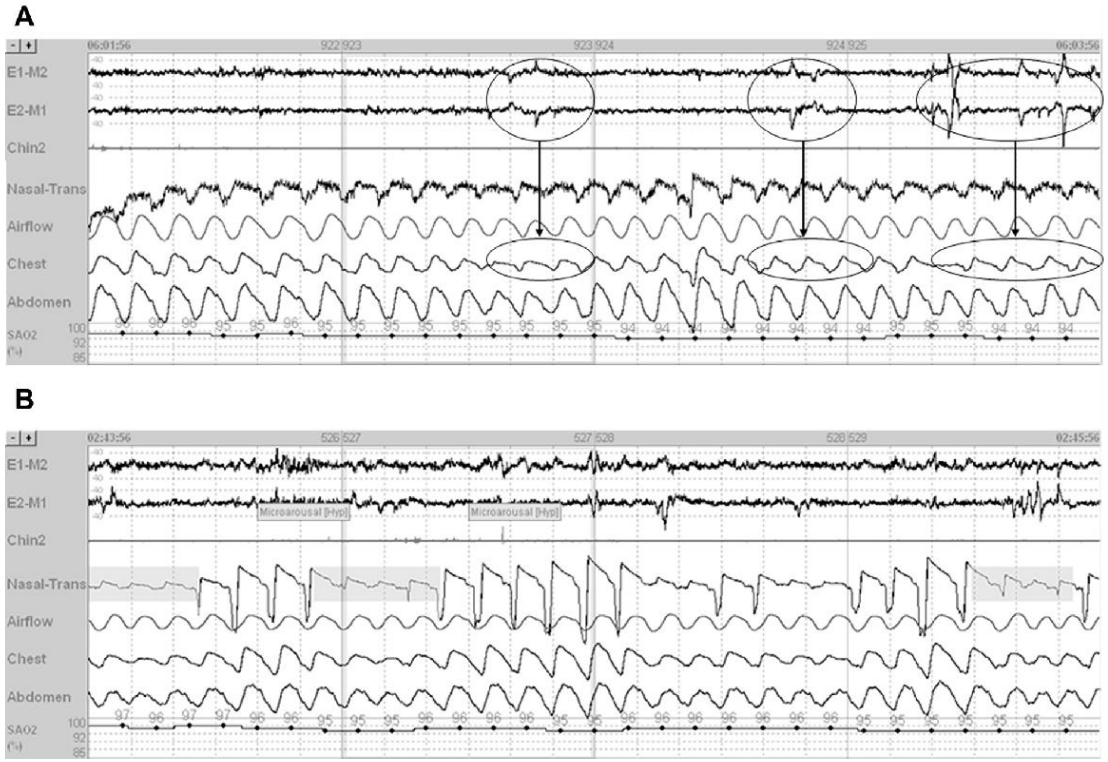
McNicholas WT, *et al. Eur Respir Rev* 2019; 28: 190064

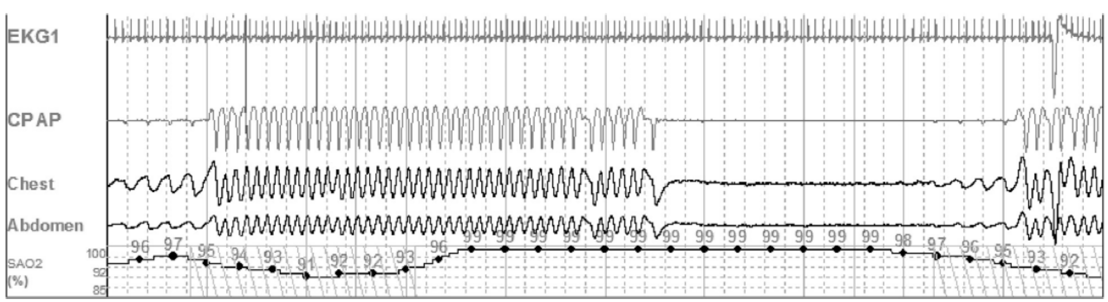
Lung Volume Changes in Sleep in Patients with Neuromuscular Disorder



Aboussouan LS, *AJRCCM* 2015

PSG in NMD





Aboussouan LS, *et al. Chest* 2017; 152(4):880-892

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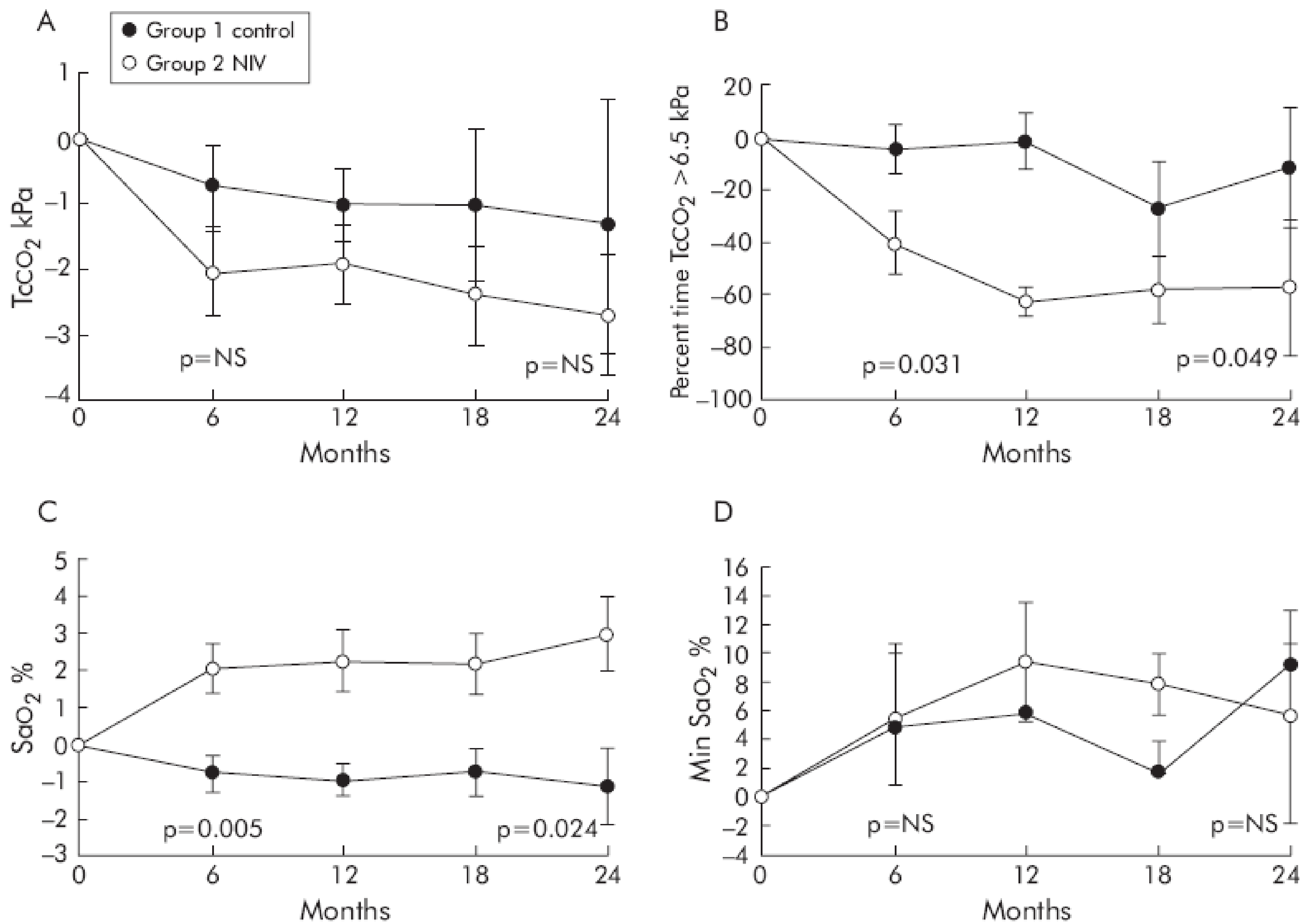
Improvement by NIV in NMD



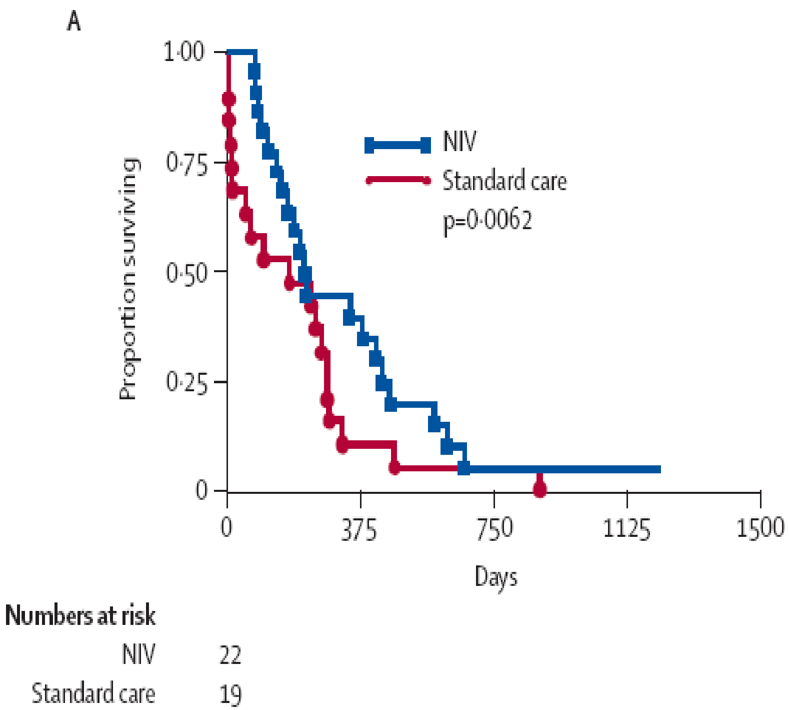
Ward S, et al. Thorax 2005

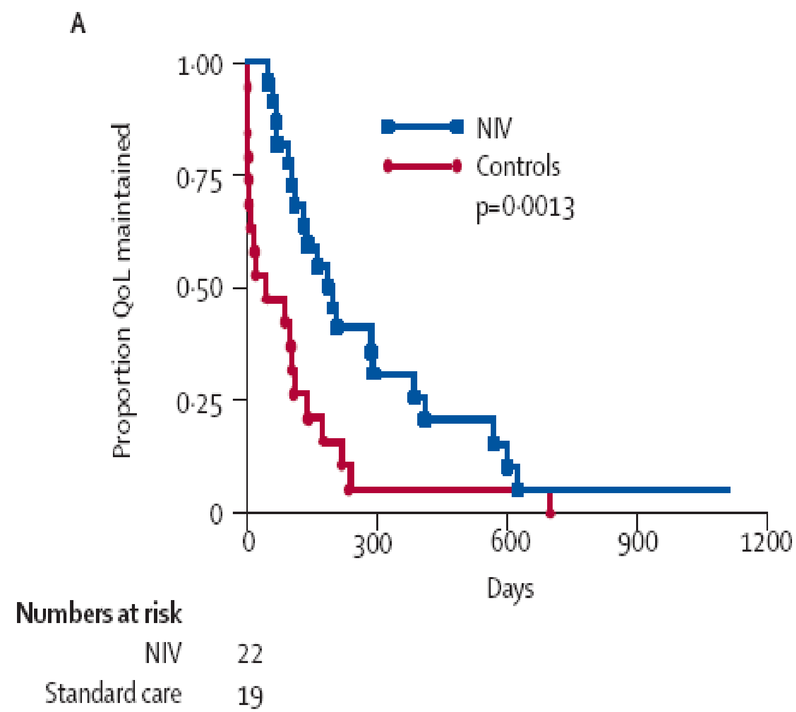
NIV in Patients with ALS

	NIV (n=22)	Standard care (n=19)
Age (years)	63·7 (10·3)	63·0 (8·1)
Sex (male)	14 (64%)	10 (53%)
Disease duration* (years)	1·9 (1·3)	2·0 (1·1)
Riluzole	19 (86%)	17 (89%)
Bulbar score	3·4 (1·7)	3·3 (1·8)
Vital capacity (% predicted)	55·6% (18·7)	48·8% (20·7)
$P_I$max (% predicted)	31·1% (11·0)	31·0% (10·6)
SNIP (% predicted)	22·6% (11·4)	24·4% (10·8)
PaO_2 (kPa)	10·0 (1·8)	10·2 (1·9)
$PaCO_2$ (mm Hg)	6·1 (1·1)	6·4 (1·2)
LEP	0·34 (0·23)	0·36 (0·31)
Body-mass index	21·6 (3·6)	21·5 (3·1)
Mean sleep SaO_2	92·7% (4·0)	91·6% (7·6)
% sleep SaO_2 <90%	27·2% (40·0)	22·9% (36·9)
Total sleep time (min)	201 (114)	273 (116)
REM sleep	5·3% (6·5)	11·9% (9·3)

Bourke SC, *et al. Lancet Neurol* 2006

Improvement in Survival and Quality of Life by NIV in Patients with ALS

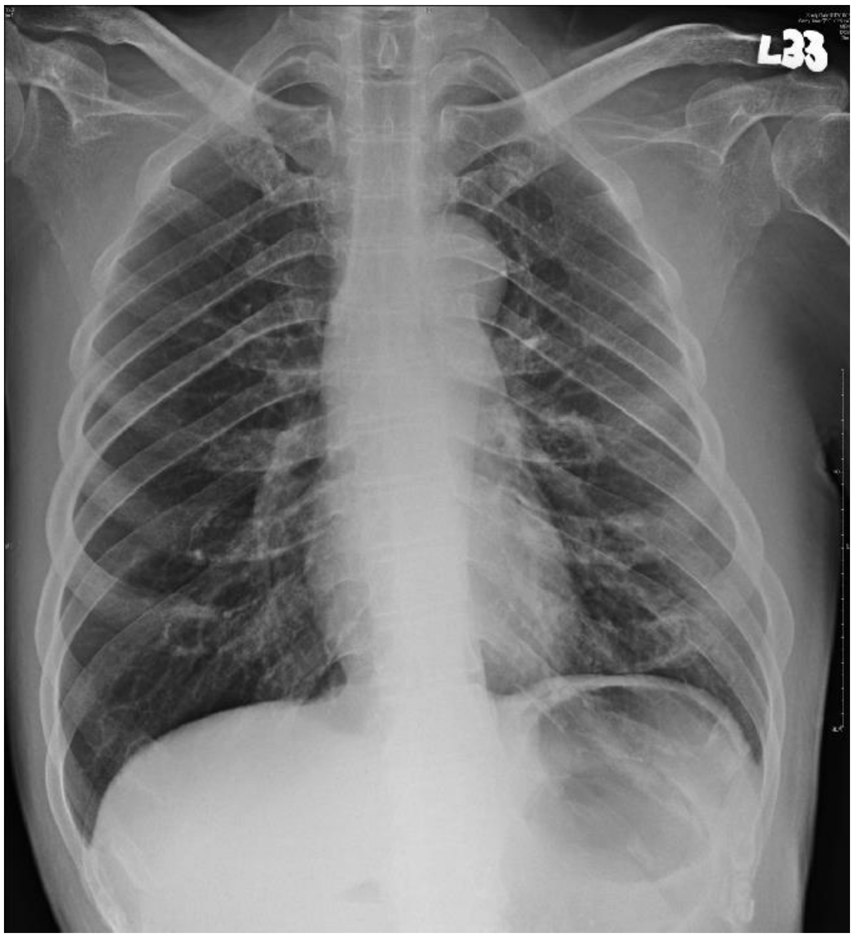


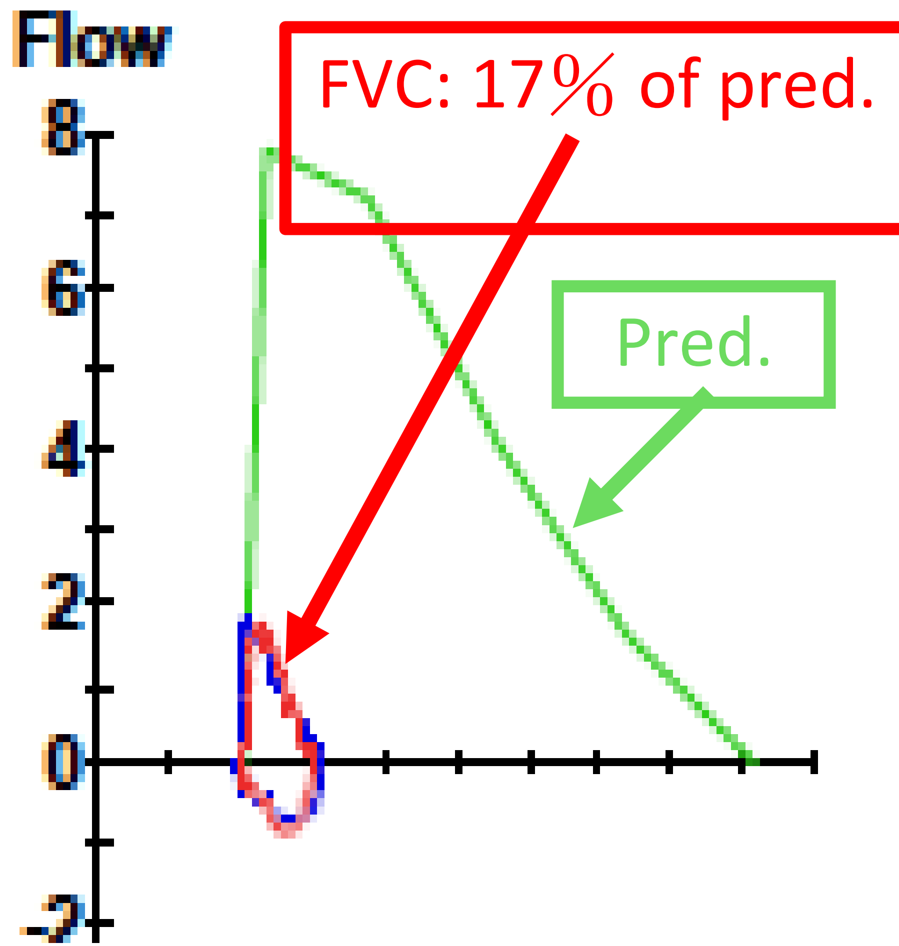


ALS: amyotrophic lateral sclerosis

Bourke SC, et al. Lancet Neurol 2006

38 y/o Male with Baker's Muscular Dystrophy and Nocturnal Dyspnea





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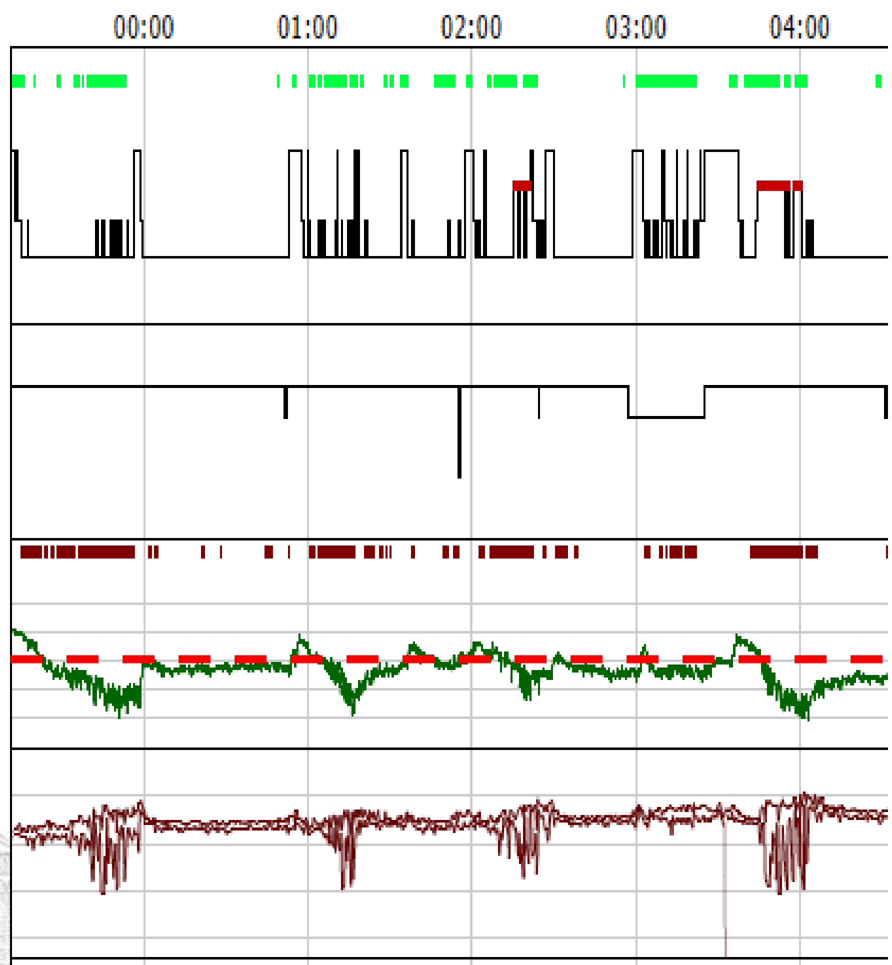
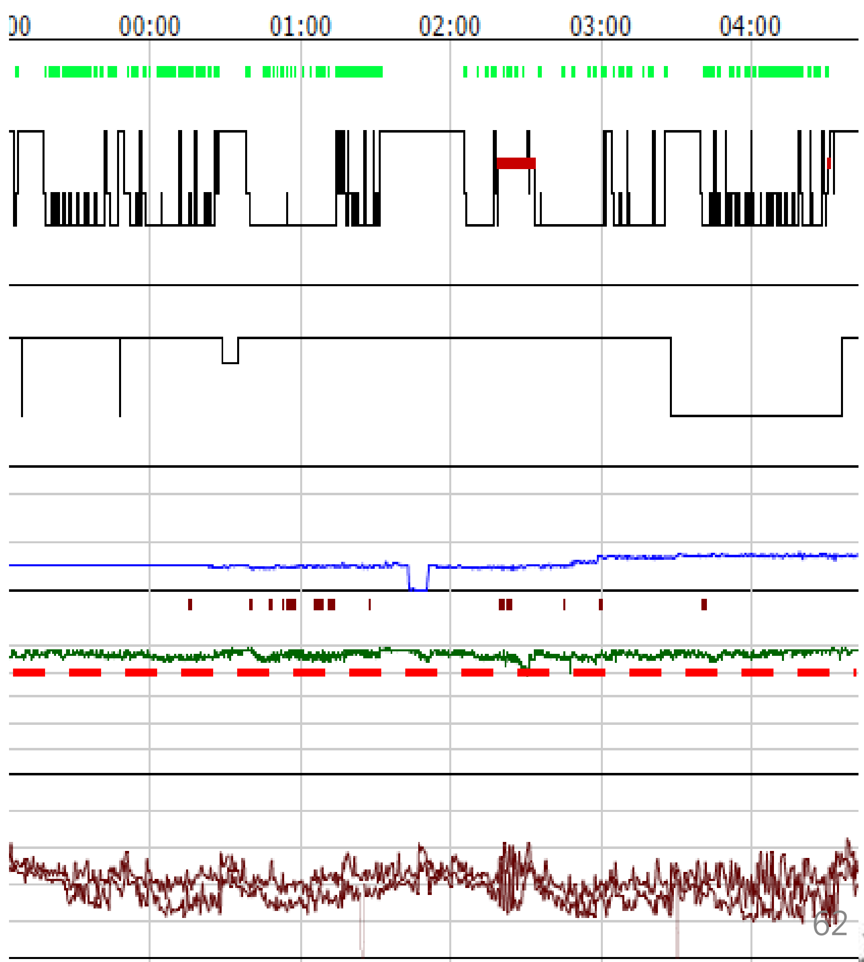
Sleep Studies

Nocturnal Hypoxemia



NIV Support



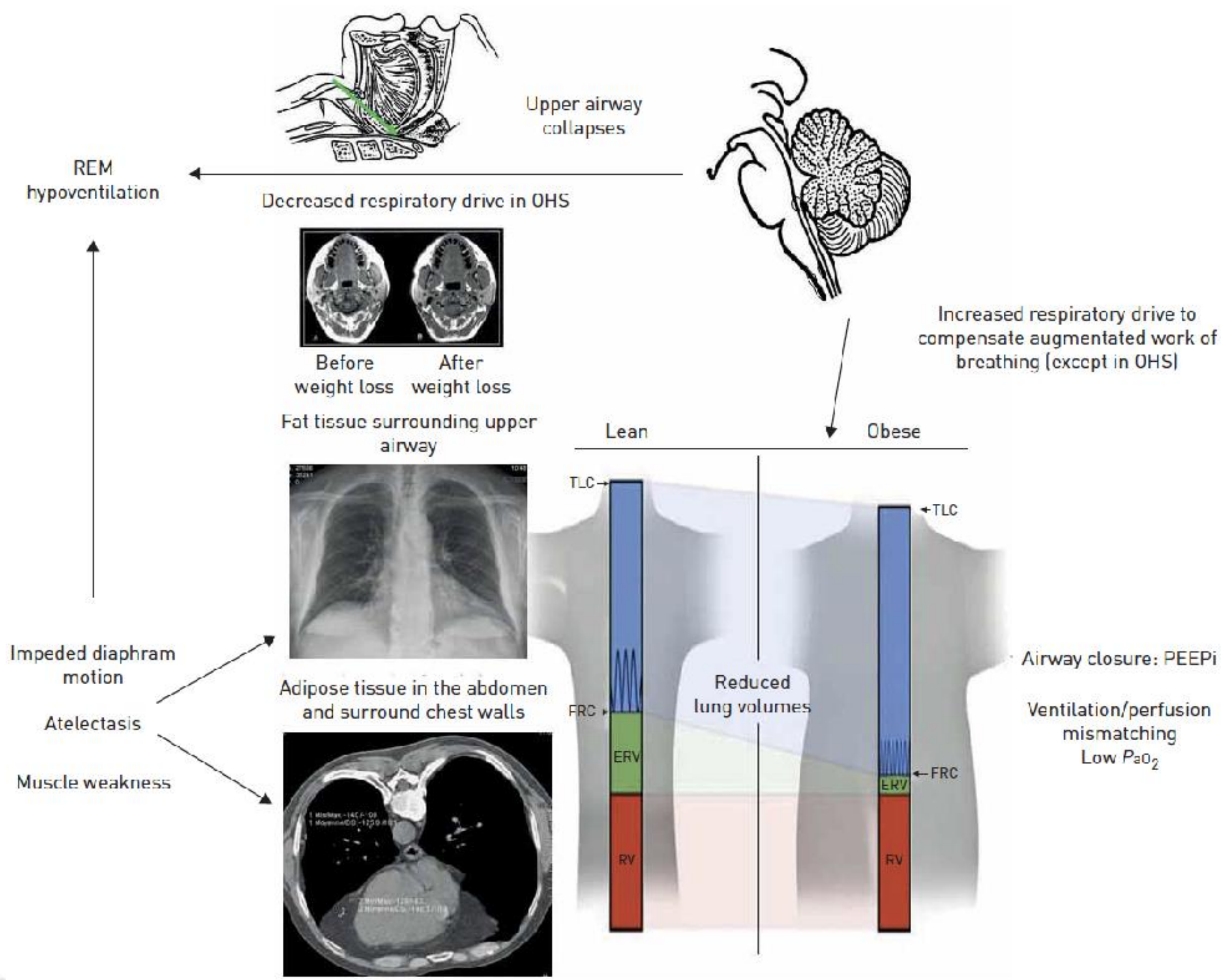
NIPPV in Neuromuscular Disease and Chest Wall disease

- Improving nocturnal and diurnal arterial blood gas

- Prolonging the survival in patients with daytime hypercapnia

NIV for OHS

Pathophysiology of Obesity Hypoventilation Syndrome (OHS)



Masa JF, *et al. Eur Respir Rev* 2019

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Obesity Hypoventilation Syndrome (OHS, = Pickwickian syndrome)

- Definition
  - Obesity: BMI ≥ 30 kg/m^2
  - Chronic hypoventilation: daytime $PaCO_2 \geq$ 45 mmHg
  - Sleep breathing disorder: OSA or sleep hypoventilation
  - Excluding severe obstructive lung disease, kyphoscoliosis, etc..
- Primary features
  - Obesity
  - Hypercapnia during wakefulness
- Possible co-existing features
  - Hypoxemia
  - Pulmonary hypertension
  - Obstructive sleep apnea

Pickwickian Syndrome -- 1956

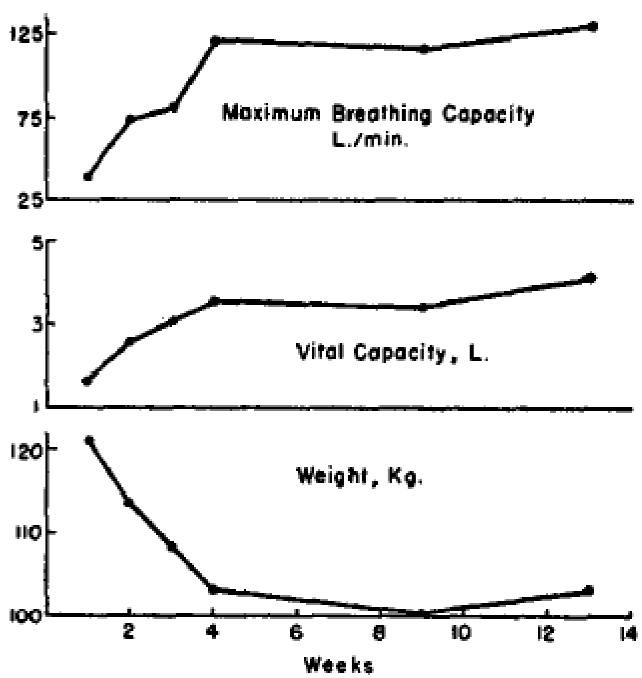
Fat boy in "The Pickwick Papers"

Clinical features

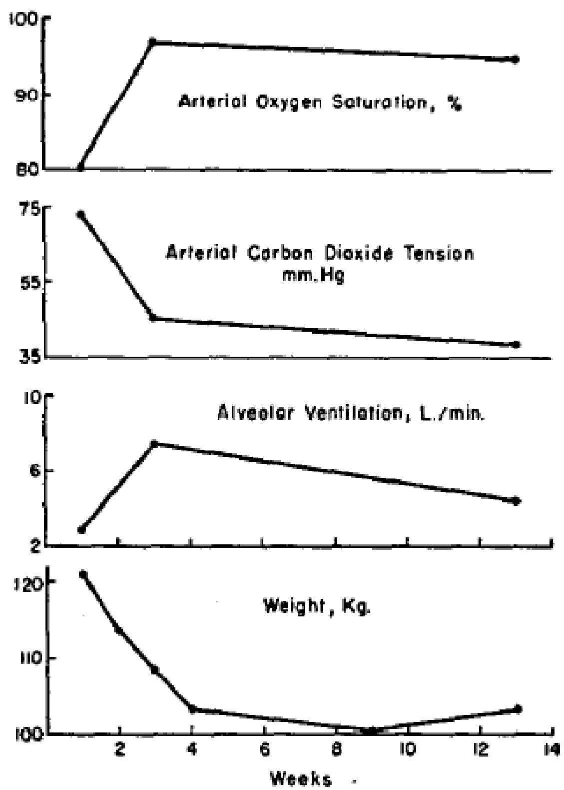
- Marked obesity
- Somnolence
- Twitching
- Cyanosis
- Periodic respiration
- Polycythemia, secondary
- Right ventricular hypertrophy
- Right ventricular failure

Improvement after Weight Loss

Change in Lung Function



Change in Arterial Blood Gas



Comorbidities in OHS

Conditions	Prevalence, %
Hypertension	61-79
Heart failure	21-32
Pulmonary hypertension	59-88
Type 2 DM	30-32
Asthma	18-24
Erythorcytosis	8-15

Mokhlesi B, *et al. Chest* 2007

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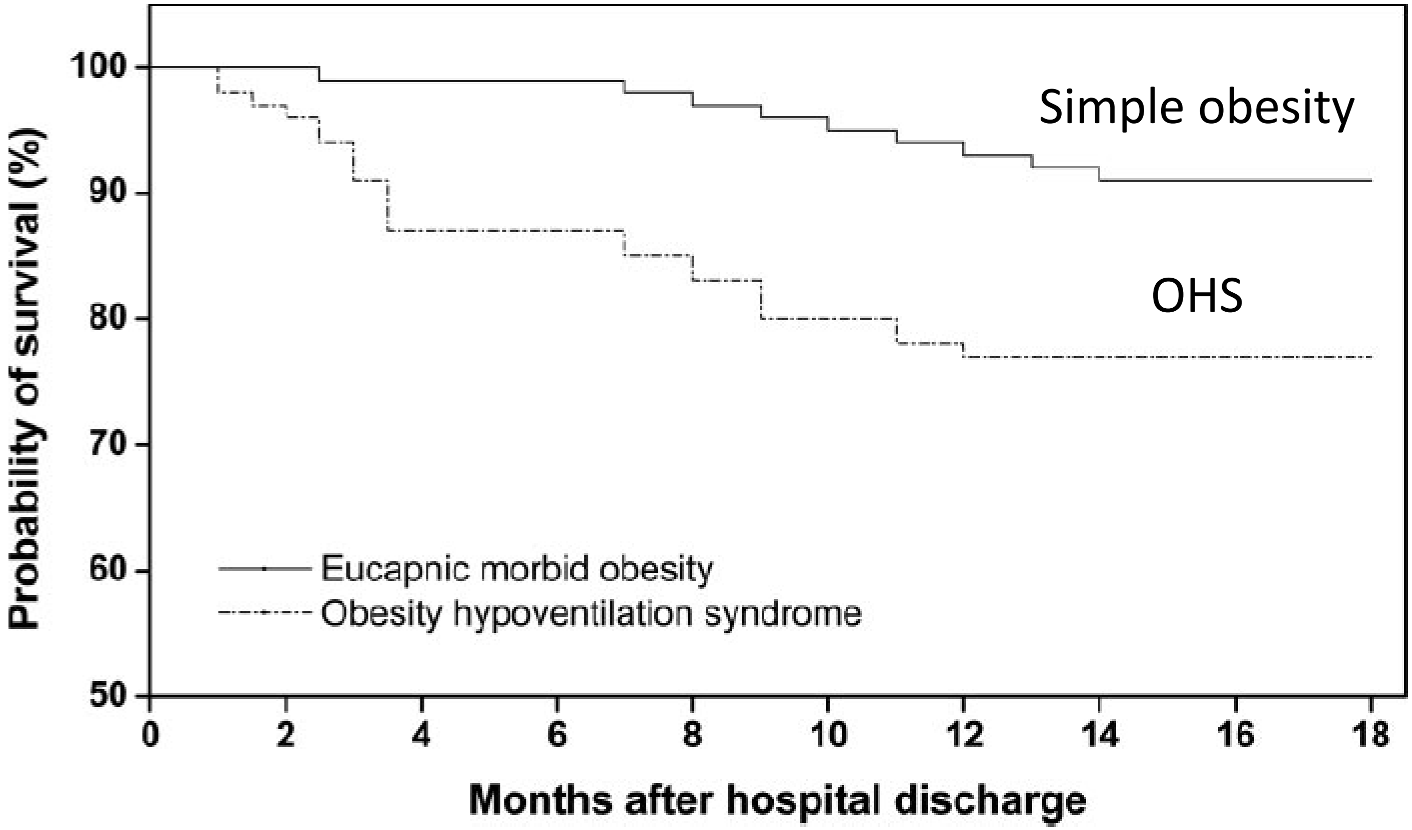
Poor Prognosis of OHS



Nowbar S, *et al. Am J Med* 2004

Treatment of OHA

CPAP for obstructive apneas, hypopneas and flow limitation

Weight loss

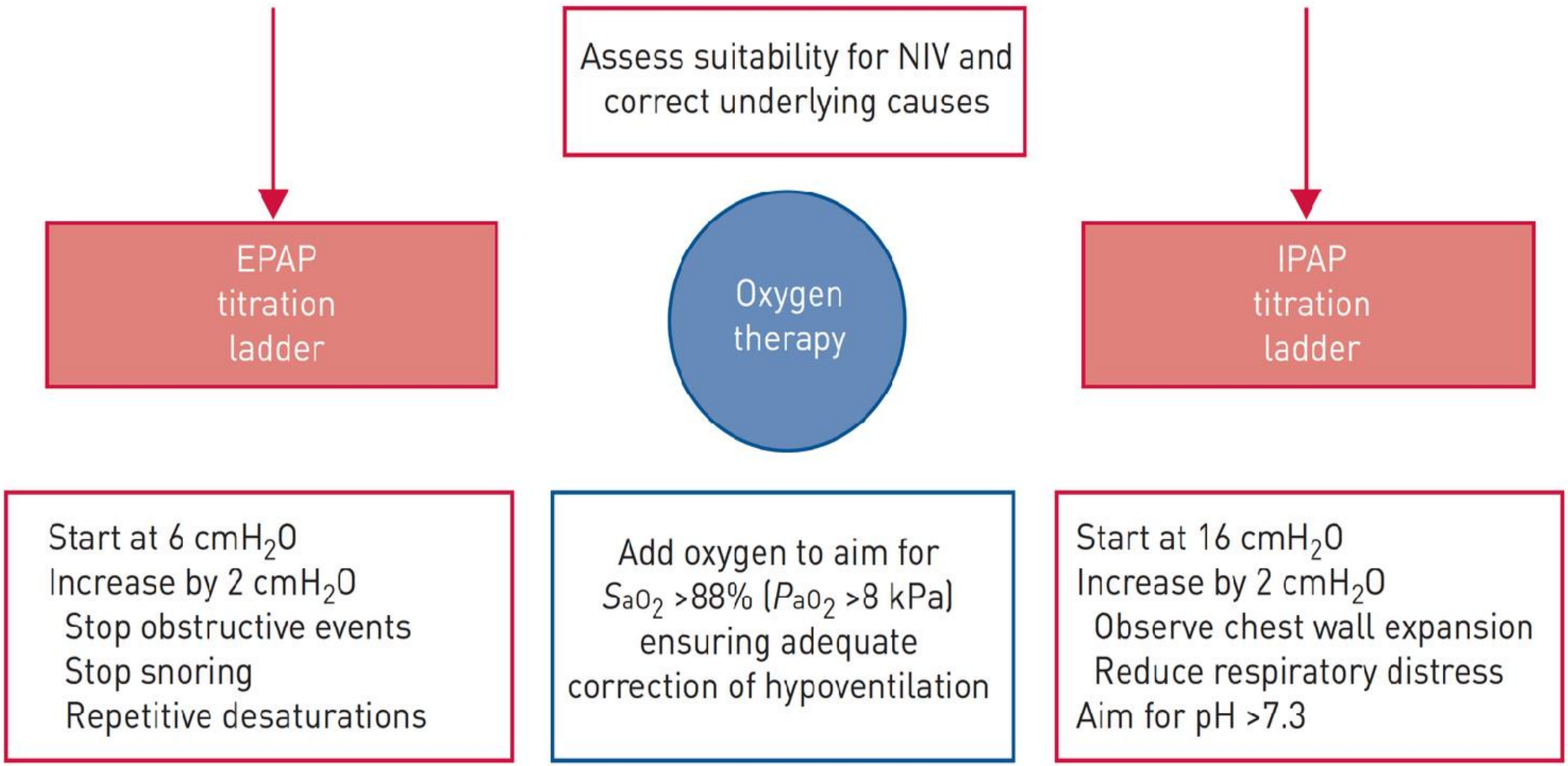
SaO_2 < 90%

Bilevel Positive Airway Pressure (↑IPAP) until SaO2 > 90%

Add Oxygen if SaO2 < 90% when IPAP-EPAP = 8-10 cmH2O

Weight loss surgery, tracheostomy, or mechanical ventilation

PAP for Obesity-related Respiratory Failure



Masa JF, *et al. Eur Respir Rev* 2019

Improvement by NIV

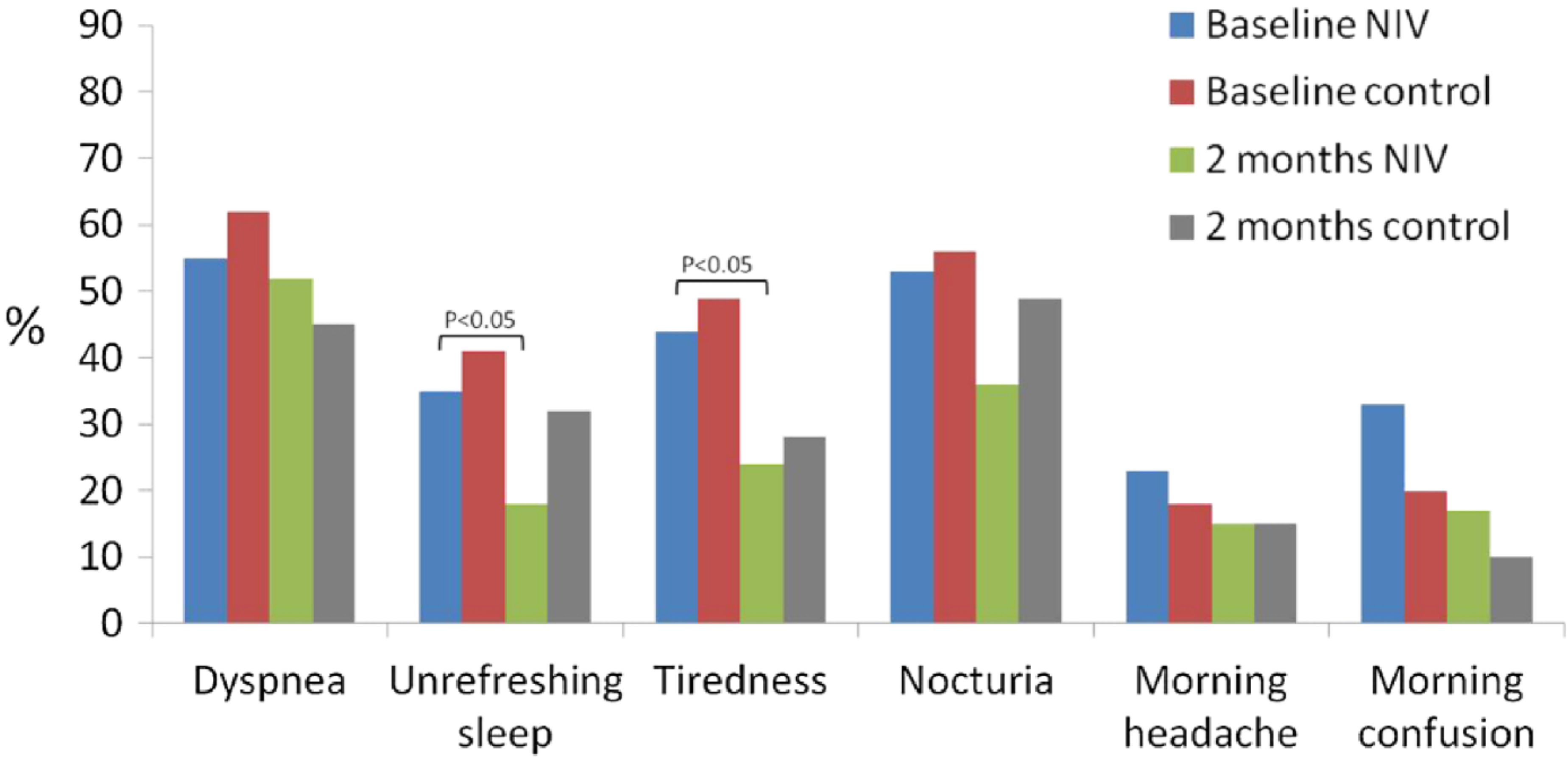
Table 3 Baseline values and changes in the ESS score, health-related quality of life test results and weight

	Baseline, mean (SD)		Intra-group differences, mean (95% CI)		p Value of inter-group differences	
	NIV	Control	NIV	Control	Unadjusted	Adjusted
ESS	7.7 (5.5)	8.5 (4.2)	**−2.9 (−4.1 to −1.7)‡**	**−1.2 (−2.2 to −0.2)***	0.038	0.021
FOSQ	72 (22)	75 (19)	4.4 (−1.7 to 10.5)	−2.7 (−8.1 to 3.1)	NS	–
SF 36-Physical	35 (10)	37 (8)	3.1 (−0.4 to 6.6)	0.9 (−1.3 to 3.2)	NS	–
SF 36-Mental	41 (12)	43 (11)	**4.1 (0 to 8.3)†**	−0.9 (−3.7 to 1.8)	0.038	0.035
VAWS	45 (25)	63 (22)	**18 (8.4 to 27)†**	1.8 (−4.7 to 8.3)	0.006	–
Weight, kg	102 (19)	100 (17)	0.7 (−2.5 to 3.9)	**−1.6 (−3.1 to −0.2)***	NS	–

Bold type indicates statistical significance.
p Values of intra-group differences (2 months − baseline): *p<0.05; †p<0.01; ‡p<0.001.
p Values of inter-group differences unadjusted or adjusted by basic adjustment (baseline values of the variable analysed and age, gender, BMI and AHI).
AHI, apnoea–hypopnoea index; BMI, body mass index; ESS, Epworth sleepiness scale; FOSQ, Functional Outcomes of Sleep Questionnaire; NIV, non-invasive ventilation; SF 36, Medical Outcome Survey Short Form 36; VAWS, visual analogue well-being scale.

Masa JF, *et al. Thorax* 2016;71:899–906.

Improvement by NIV



Masa JF, *et al. Thorax* 2016;71:899–906.

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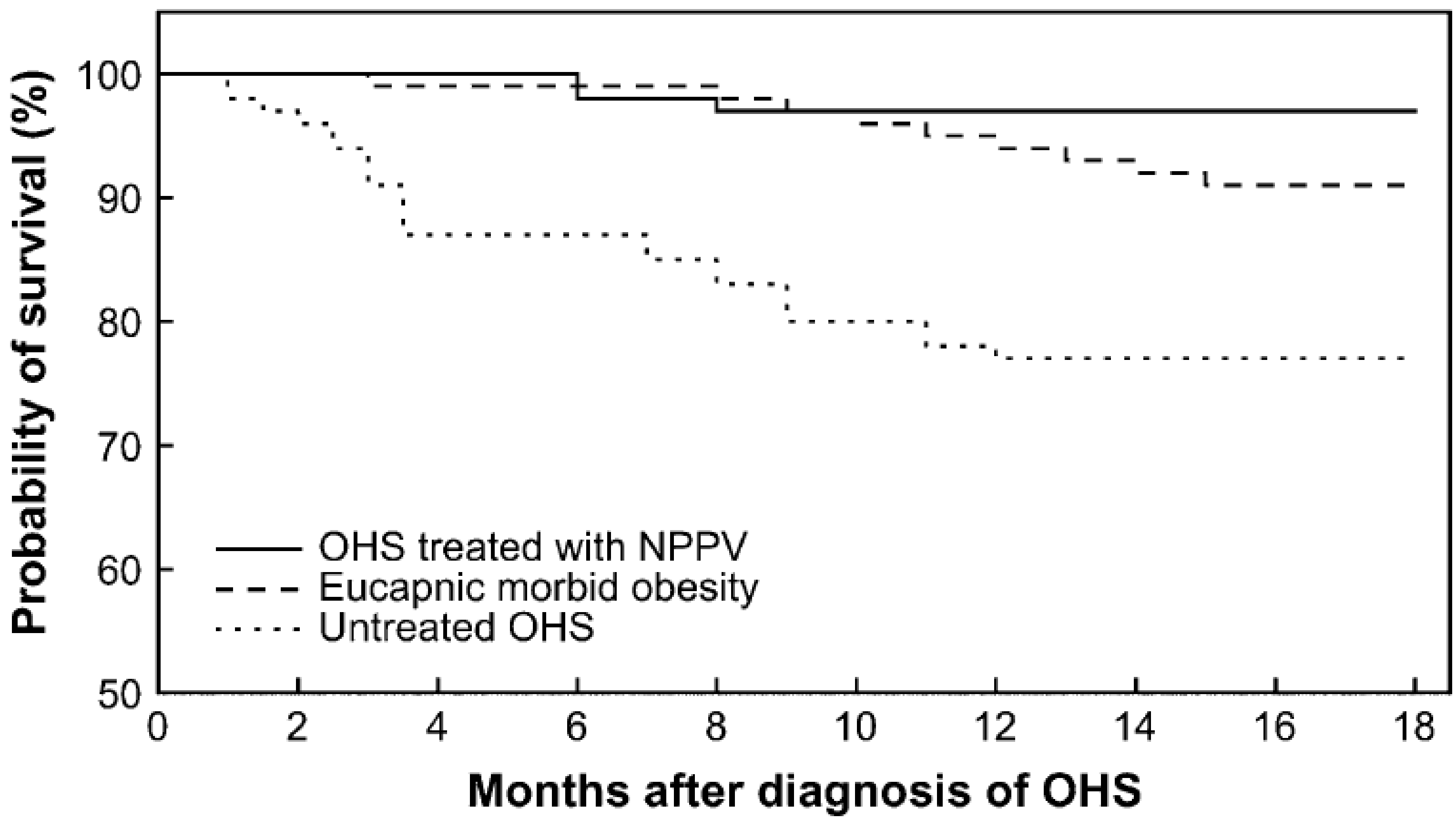
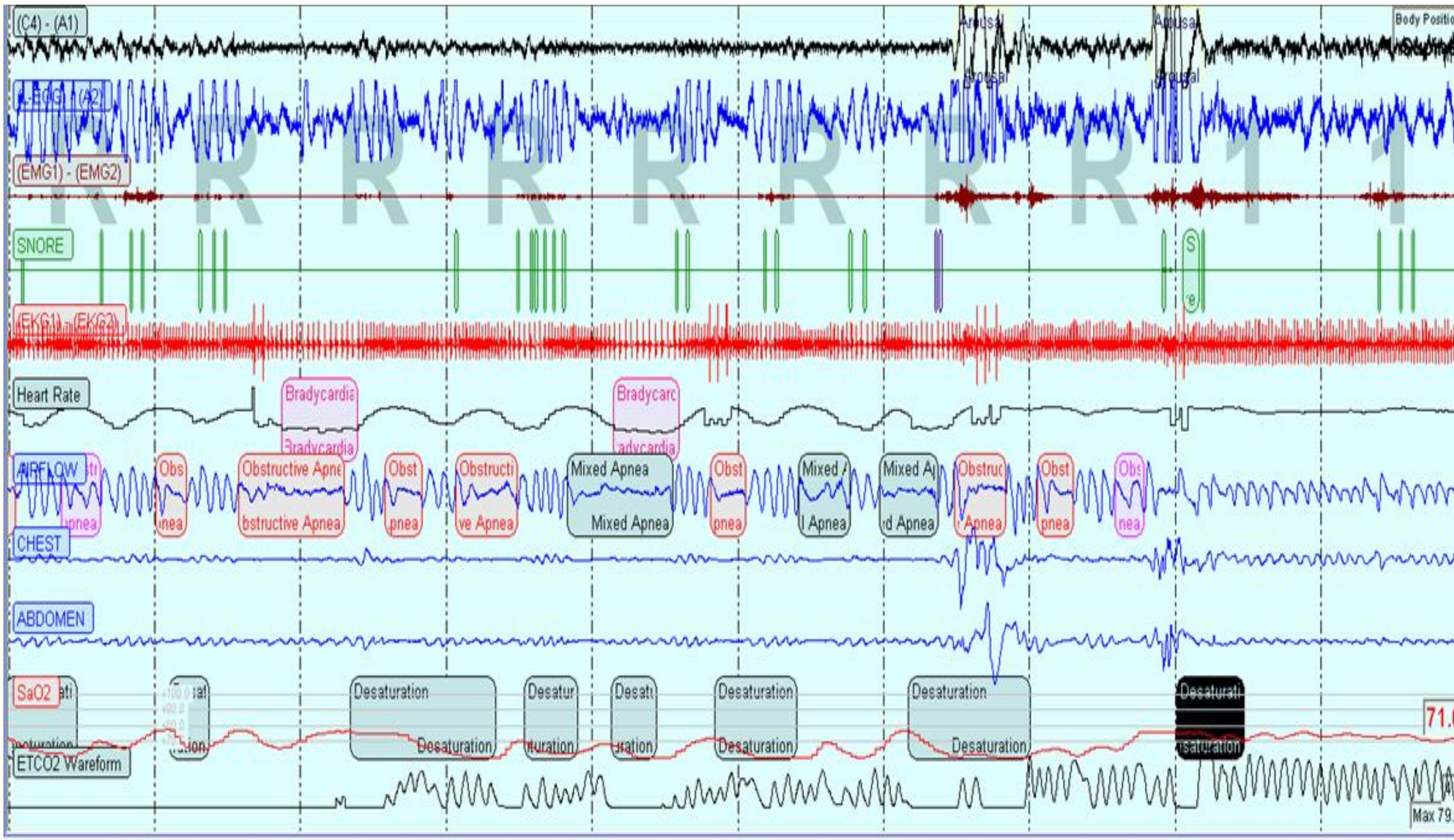
Improvement in Survival by NPPV



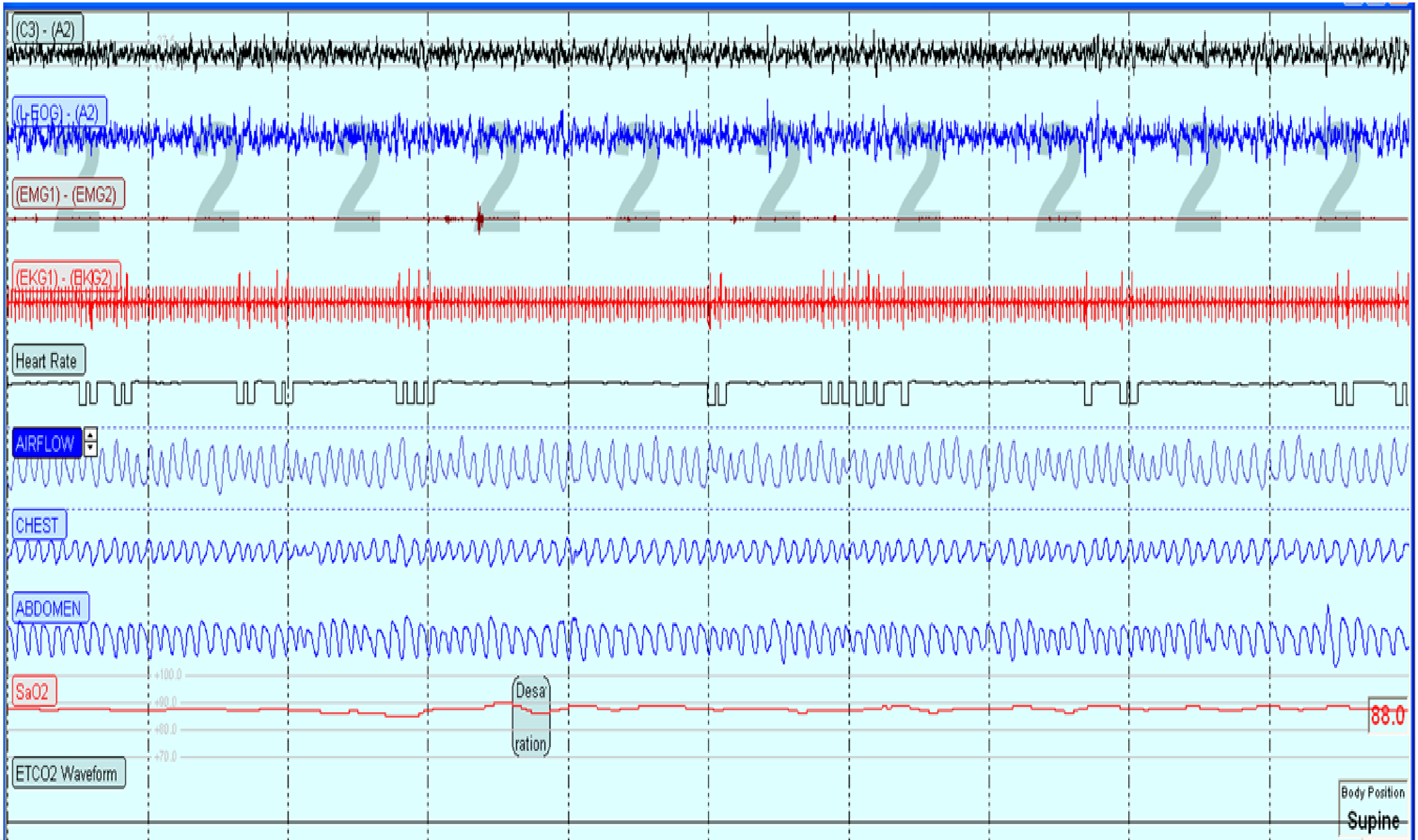
Nowbar S, *et al. Am J Med* 2004

57 y/o F, BMI: 43.7kg/m^2, acute ventilatory failure (pH: 7.23, PaO_2: 42 mmHg, $PaCO_2$: 86mmHg)



Very severe obstructive sleep apnea (AHI: 163/hr), MinSpO2: 54%, % Of time of TST with SpO2<90%: 86%

On NIV Titration



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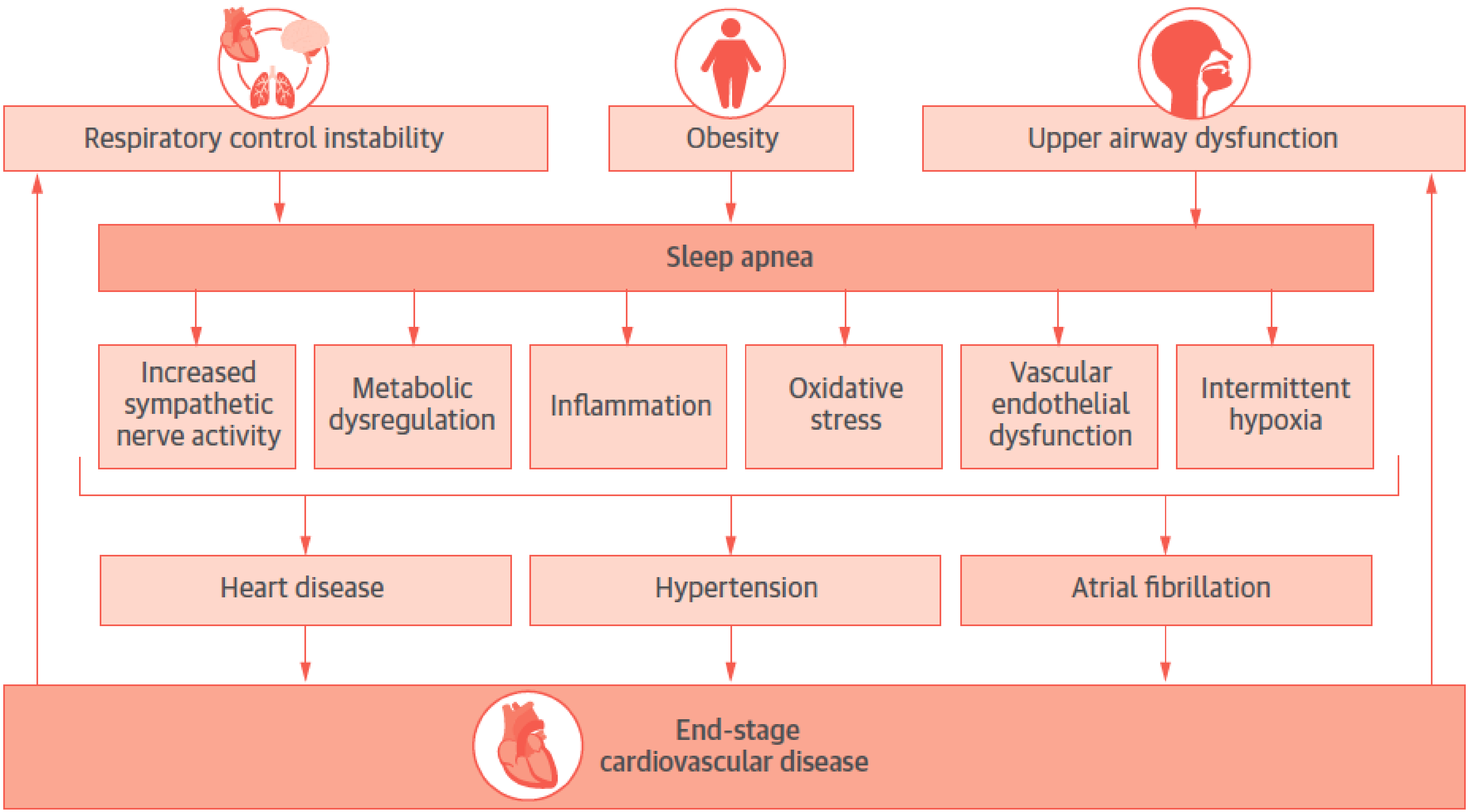
Conclusions

- CPAP is treatment of choice in obstructive sleep apnea
- In patients with HF and CSA, NIV is effective in some patients but no improvement in survival
- NIV is effective in patients with neuromuscular or chest wall diseases and could improve survival
- NIV is effective and improves survival in patients with OHS

Questions and Comments?

Pathophysiology of SDB on Cardiovascular System



Javaheri, S. et al. J Am Coll Cardiol. 2017;69(7):841-58.

Type	Applications	Setup requirements	Advantages	Disadvantages
Continuous positive airway pressure (CPAP)	Obstructive sleep apnea; congestive heart failure with coexisting obstructive sleep apnea; obesity-hypoventilation syndrome with coexisting obstructive sleep apnea	CPAP level	Simple to use; relatively inexpensive	Minimal or no ventilation support; preset pressures may not address variability in obstructive sleep apnea, severity with sleep stages and positional stages
AUTO-CPAP	Obstructive sleep apnea; congestive heart failure with coexisting obstructive sleep apnea; obesity-hypoventilation syndrome with coexisting obstructive sleep apnea	Range of allowable CPAP levels	Reduces number of titration studies; self-adjusting to adapt to variability in obstructive sleep apnea with sleep stages and positional changes; maybe useful for patients with ongoing weight loss such as after bariatric surgery	More expensive than fixed CPAP; may not be effective for patients with cardiopulmonary disorders or other conditions in which desaturation may be unrelated to obstructive events
Adaptive servo-ventilation (ASV)	Congestive heart failure; central sleep apnea; complex sleep apnea syndrome	Maximum and minimum inspiratory pressures; end-expiratory pressure	Adapts pressure to maintain more consistency of respiration over time	More expensive than other modes; may worsen ventilation in disease with chronic ventilator insufficiency such as COPD or restrictive thoracic disorders
Bilevel positive airway pressure (BIPAP) without backup rate	Obstructive sleep apnea with CPAP intolerance; obstructive sleep apnea with central sleep apnea; restrictive thoracic disorders; severe chronic obstructive pulmonary disease; obesity hypoventilation syndrome with coexisting obstructive sleep apnea and residual hypoventilation despite CPAP	Inspiratory and expiratory positive airway pressures	Promotes alveolar ventilation; unloads respiratory muscles; decreases the work of breathing; controls obstructive hypopneas	More expensive than CPAP; may generate central apnea
Bilevel positive airway pressure (BIPAP) with backup rate	Central sleep apnea; complex sleep apnea syndrome; worsening restrictive disorder	Inspiratory and expiratory positive airway pressure; backup rate; ratio of inspiratory time to expiratory time	Provides mandatory respiratory support during central or pseudocentral apneas	More expensive than conventional BIPAP; may generate central apnea
Average volume-assured pressure support (AVAPS)	Obesity-hypoventilation syndrome; neuromuscular disease; chronic obstructive pulmonary disease	Target tidal volume (8 ml/Kg of ideal weight); inspiratory positive airway pressure limits; respiratory rate	Ensures a delivered tidal volume; compensates for diseases progression	More expensive than other modes

Antonello N, *et al., J Gen Pract* 2013, 1:2

Complication and/or side effect	Action
Air Leaks	Prevention of neck flexion
	Semi-recumbent positioning
	Use of chin rest
	Use of cervical collar
	Switch to controlled pressure mode
	Decrease peak inspiratory pressure and increase volume
	Optimize the interfaces(using oro-nasal mask)
Nasal Dryness,Congestion	Cold pass over
	Heated humidifier
Aerofagia,Eructation,Flatulence,	
Abdominal Discomfort	Decrease peak inspiratory pressure below 25 cmH_2O

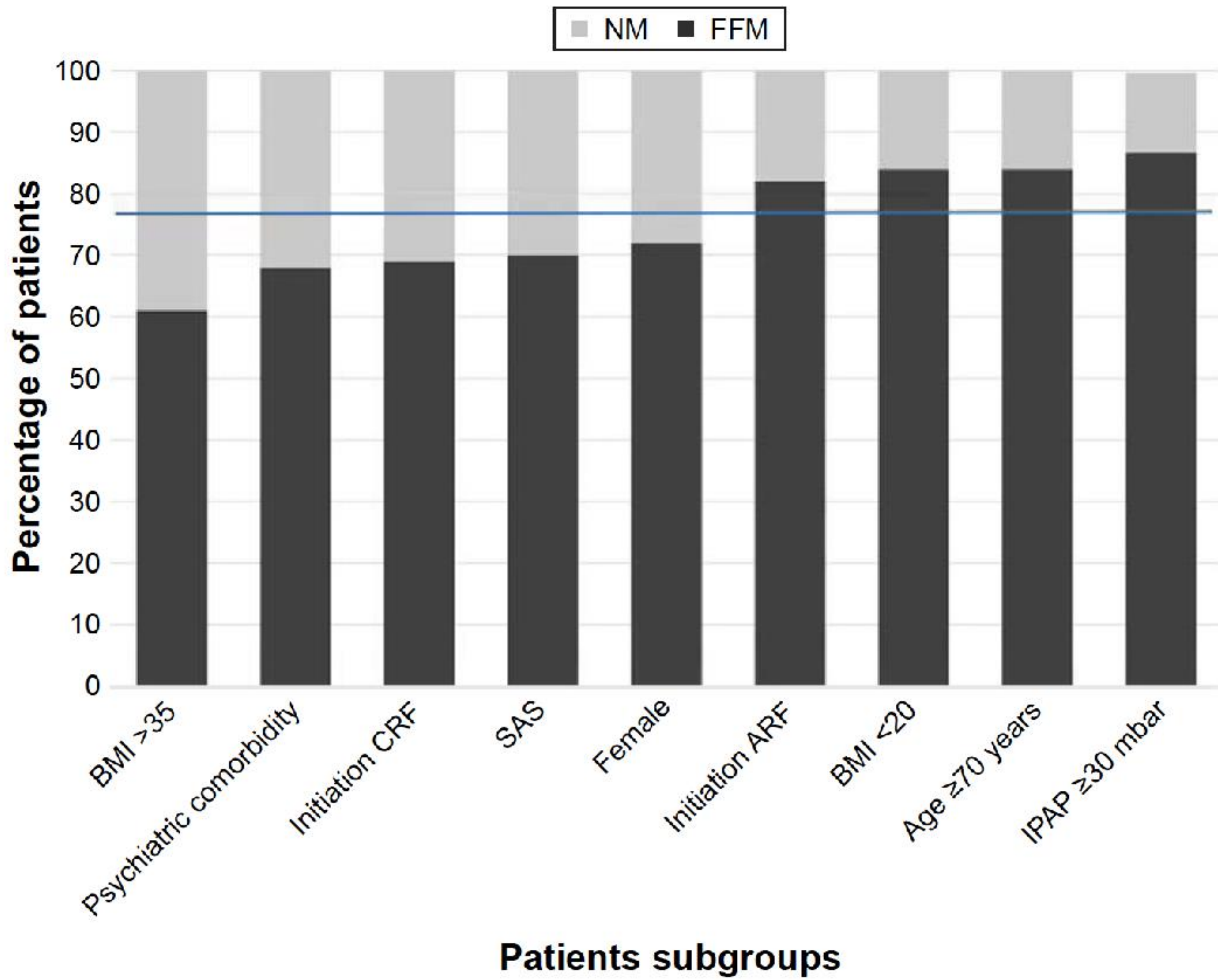
Antonello N, *et al., J Gen Pract* 2013, 1:2

NIV Settings

Pathophysiology/ Device Settings	Chronic OHS (Compensated)	Chronic COPD (Compensated)	Chronic NMD (Compensated)
Respiratory mechanics	↑ Muscle load (↑ UA resistance, 90% OHS) Increased resistance from chest and abdominal wall ↓ FRC due to obesity (expiratory flow limitation, airway closure, V/Q mismatch) ↓ Respiratory drive (leptin resistance, 10% OHS)	↑ Muscle load (↑ Lower airway resistance in COPD) ↓ Muscle capacity (diaphragm atrophy, mechanical disadvantage)	↓ Muscle capacity ↑ Chest wall resistance
Target volume (cc)	Target tidal volume 8 cc/kg ideal body weight	Target tidal volume 8 cc/kg ideal body weight	Target tidal volume 8 cc/kg ideal body weight
	To adjust PS (BPAP-ST), expiratory tidal volume (AVAPS), or Va (iVAPS) based on ABG (pH, Pa_{CO_2}), $TcCO_2$, or a combination		
IPAP (cm H_2O)	High IPAP BPAP-ST: adjust IPAP to a PS for goal tidal volume (average PS, 8-10 cm H_2O) VAPS: allow a large IPAP max/IPAP min difference to reach target expiratory tidal volume or Va	High IPAP (or best tolerated) BPAP: adjust IPAP to a PS for goal tidal volume (or best tolerated) Allow large IPAP max/IPAP min difference to reach target expiratory tidal volume or Va as tolerated	Intermediate IPAP (or best tolerated) Adjust IPAP to a PS for tidal volume goal in BPAP-ST. (average PS, 6 cm H_2O) Allow IPAP min at a higher baseline
EPAP (cm H_2O)	High EPAP in OHS/OSA Adjust to eliminate obstructive apneas (average 8-12 cm H_2O) or snoring	Adjust to eliminate obstructive apneas if present If ineffective trigger, increase EPAP to overcome high iPEEP (first-line therapy)	Low EPAP to reduce work of breathing and improve triggering
Respiration rate (bpm)	To adjust to goal minute ventilation based on ABGs or $TcCO_2$, or both		
Trigger sensitivity[a]	Respironics: Auto-Trak or flow trigger 2-3 L/min ResMed: trigger from medium to low	Respironics: Auto-Trak or flow trigger 4-5 L/min ResMed: trigger medium	High trigger sensitivity to support a weak respiratory muscular effort Respironics: flow trigger at 1-3 L/min ResMed: trigger high or very high
Rise time (ms)	Default or slow rise time Respironics: 3 (300 ms)-6 (600 ms) ResMed: 500-900 ms	Fast rise time	Default or slow rise time Respironics: 3 (300 ms)-6 (600 ms) ResMed: 500-900 ms
Ti (ms)	Long Ti or long Ti min to maximize tidal volume and gas exchange by (↑ I:E) Ti/Ttot 50%	Short Ti or short Ti max to increase expiratory time and minimize iPEEP (↓ I:E) Ti/Ttot 25% in patients with BMI > 30	Long Ti or long Ti min to maximize tidal volume and gas exchange (↑I:E) Ti/Ttot 50%
Cycle Sensitivity[a]	Default or low cycle sensitivity Respironics: Auto-Trak or manual at 10%-15% of peak flow ResMed: Cycle medium to low	Default or high cycle sensitivity (early cycle) to provide a longer exhalation time (↓ I:E) Respironics: Auto-Trak or manual at 30%-50% of peak flow ResMed: Cycle sensitivity medium to high	Default or low cycle sensitivity (late cycle) to provide a longer inhalation time (maximize tidal volume and gas exchange by high I:E) Respironics: Auto-Trak or manual at 10%-15% of peak flow ResMed: Cycle low

Selim BJ, *et al. Chest* 2017

NIV for COPD



Storre JH, *et al. JCOPD* 2018

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Scoring Criteria for Sleep-related Hypoventilation -- AASM

- Adult criteria
  - 10 min of sleep with $PaCO_2$ (or surrogate) >55 mm Hg OR
  - 10 mm Hg increase in $PaCO_2$ (or surrogate) during sleep (in comparison to an awake supine value) to a value exceeding 50 mm Hg for 10 min

- Pediatric criteria
  - Greater than 25% of the total sleep time as measured by either the arterial PCO_2 or surrogate is spent with a $PaCO_2$ greater than 50 mm Hg

Berry RB, *et al. J Clin SleepMed* 2012;8(5):597–619.