SLEEP DISORDERED BREATHING IN NEUROMUSCULAR DISEASE

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University of Texas Southwestern Medical Center
Associate Professor

Saturday, January 19, 2019 – 1:10 p.m. – 1:40 p.m.

Won Lee, MD, is an associate professor in pulmonary, critical care and sleep medicine at the University of Texas Southwestern Medical Center in Dallas, Texas. He serves as medical director of the Sleep and Breathing Disorders Center. His primary clinical interests include sleep disordered breathing and neuromuscular pulmonary disorders.

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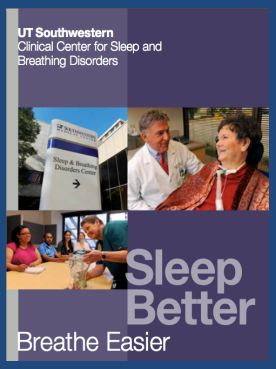
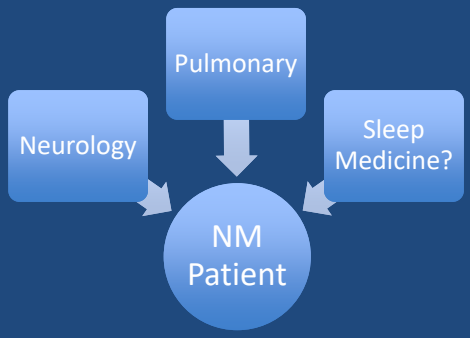


UT Southwestern Medical Center

I have no financial disclosures to declare.

Traditional Management of Patients with Neuromuscular Diseases



- Sleep medicine specialists
  - have expertise to IMPROVE quality of life
  - can also make mistakes to WORSEN quality of life

Neuromuscular Disorders (NMD)	• Overview of neuromuscular diseases • Physiologic testing • Restrictive physiology and impaired forces
Noninvasive Ventilation (NIV)	• How to qualify for a respiratory assist device? • The Polysomnogram – Friend or Foe? • The double edged sword
Longitudinal Management	• Practical pearls and lessons learned • "With great power, comes great responsibility"

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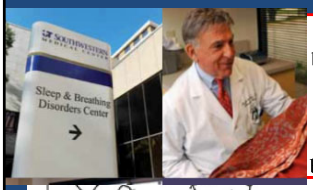
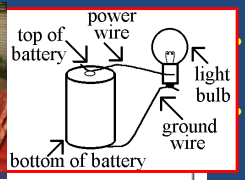
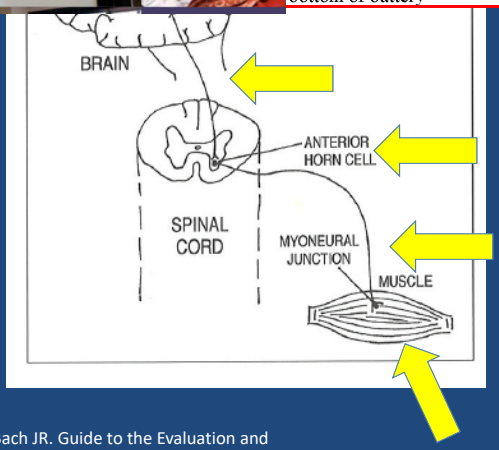
Pathophysiology

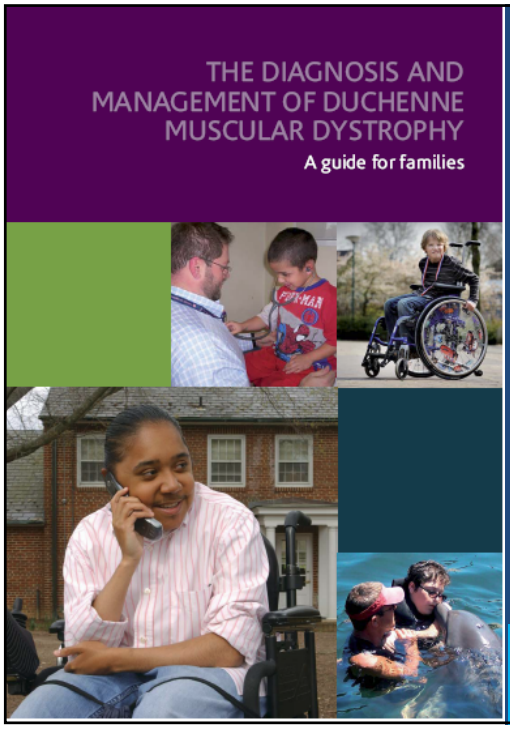






- Motor dysfunction
- Neuropathies
  - Guillain-Barre syndrome
    - Acute inflammatory demyelinating polyneuropathy
    - Molecular mimicry/autoimmune
    - Injury/loss of myelin sheath
      - Myelin → coils around nerve
- Anterior horn cell
  - Poliomyelitis (infection)
  - Acute flacid myelitis (AFM)
- Myoneural junction
  - Myasthenia gravis (antibodies)
- Myopathies
  - Muscular dystrophy

Bach JR. Guide to the Evaluation and Management of Neuromuscular Disease. 1999.

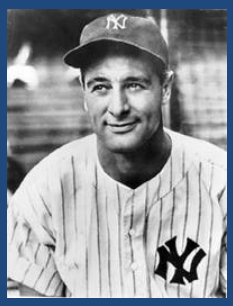


Muscular Dystrophy

- Duchenne muscular dystrophy
  - X-linked.
  - Absence of dystrophin protein
- Proximal muscle weakness
  - Age 5 → initial symptoms
  - Age 13 → most require wheelchair before their teenage years
  - Late teens/early 20's → chronic respiratory failure
  - Cardiomyopathies

Bushby K et al. Lancet Neurol 2009; published online Nov 30. DOI:10.1016/S1474-4422(09)70271-6.
http://www.cdc.gov/ncbddd/musculardystrophy/

Amyotrophic Lateral Sclerosis (ALS) Lou Gehrig's Disease

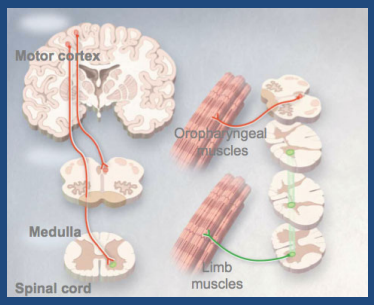


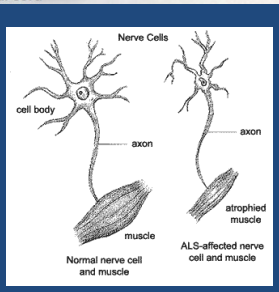
- NY Yankees
  - 17 seasons
    - 2130 consecutive games
    - 1938/1939 season
      - Decreased coordination, lack of power, batting average decline
- Diagnosed with ALS
  - Mayo Clinic in 1939
- Died in 1941, at age 37

Brennan F. Am J Hosp Palliat Care. 2012: 29(7): 512-4

Amyotrophic Lateral Sclerosis

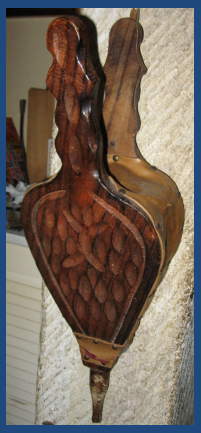
- Relentless, progressive, and incurable
  - Median survival of 3 to 5 years
- All races, age 40-75, Men > women
  - 90% sporadic
  - 10% familial
- Idiopathic degeneration of cells/pathologic inclusions
  - motor cortex
  - anterior horn
  - corticospinal tracts
  - corticobulbar tracts
    - Dysarthria, dysphagia, sialorrhea





Why pulmonologists need to know…

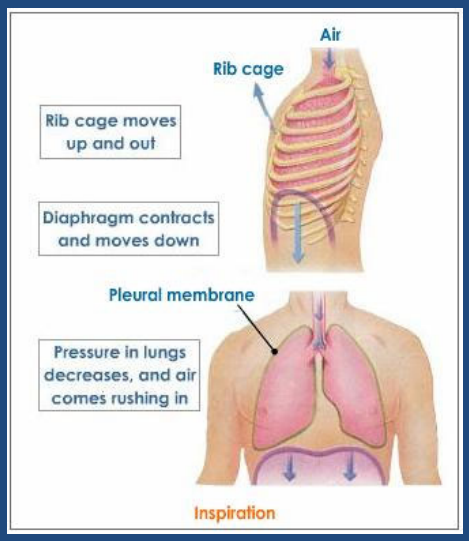
- Severe restrictive physiology
  - Progressive dyspnea
- Need for ventilatory support
  - Acute Guillain Barre Syndrome
    - 20-30 %
  - Myasthenia gravis
    - 15-28 %
  - ALS
    - most will die from progressive respiratory failure



Sharshar T et al. Crit Care Med. 2003:31:278.
Mehta S. Respir Care. 2006;51:1016.
Durand MC et al. Lancet Neurol. 2006;5:1012.

NMD → Respiratory Muscles

- Muscles
  - Diaphragm, external intercostels, scalene, sternocleidomastoid, trapezii
- Dyspnea, orthopnea, rapid shallow breathing
- Use of accessory muscles
- Hypercarbia, hypoxemia
- Nocturnal hypoventilation



West JB. Respiratory physiology: the essentials. 5th Ed. Williams & Wilkins, 1995.

ALS and Respiratory System

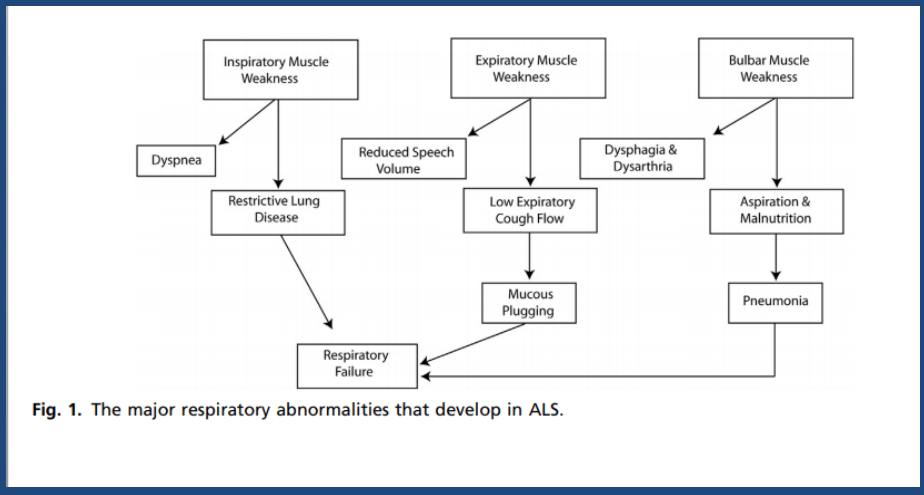
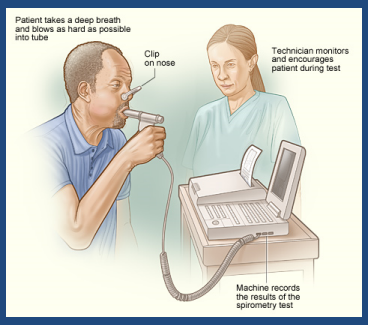


Fig. 1. The major respiratory abnormalities that develop in ALS.

Braun AT, Caballero-Eraso C, Lechtzin N. Clin Chest Med 39 (2018) 391-400.

Physiologic Evaluation is Important

- Reason:
  1. Quantify respiratory muscle weakness
  2. Evaluate cough effectiveness
  3. Identify those who need ventilatory support



- Tools
  - FVC and MIP
  - MEP or Peak Cough Flow

ATS/ERS Statement on Respiratory Muscle Testing. 2002

Why restrictive physiology on PFTs?

- IRV is reduced → due to weak inspiratory muscles
- ERV is reduced → due to weak expiratory muscles

- FVC in the supine position is ~ 10% lower than upright
  - Can drop between 12 and 65% in NM disease patients.

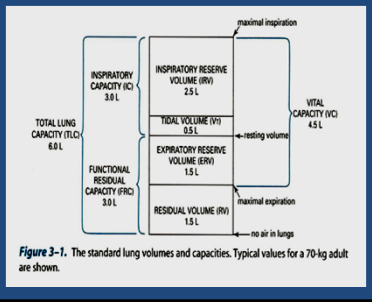
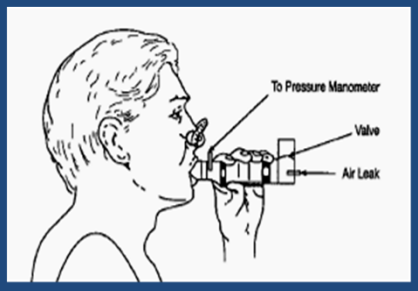


Figure 3–1. The standard lung volumes and capacities. Typical values for a 70-kg adult are shown.

MIP / MEP



- Mechanical pressure gauge connected to a mouthpiece
- Electronic devices available

- Should have a small hole (1mm diameter and 20-30 mm in length) which allows an air leak.
  - Prevents patient from generating pressure by using cheek muscles

ATS/ERS Statement on Respiratory Muscle Testing. 2002

Normal MIPs and MEPs

- Men:

  MIP: – 100
  MEP: + 100

- Women:

  MIP: - 80
  MEP: + 80

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) reference ranges derived from population-based studies with good reference equations

	MIP*	MEP*
Children (ages 7 to 13)[1]	Male: 77 to 114	99 to 161
	Female: 71 to 108	74 to 126
Adolescents (ages 13 to 35)[2]	Male: 114 to 121	131 to 161
	Female: 65 to 85	92 to 95
Adults (ages 18 to 65)[3]	Male: 92 to 121	140•
	Female: 68 to 79	95•
Older adults (ages 65 to 85)[4]	Male: 65 to 90	140 to 190
	Female: 45 to 60	90 to 130

UpToDate

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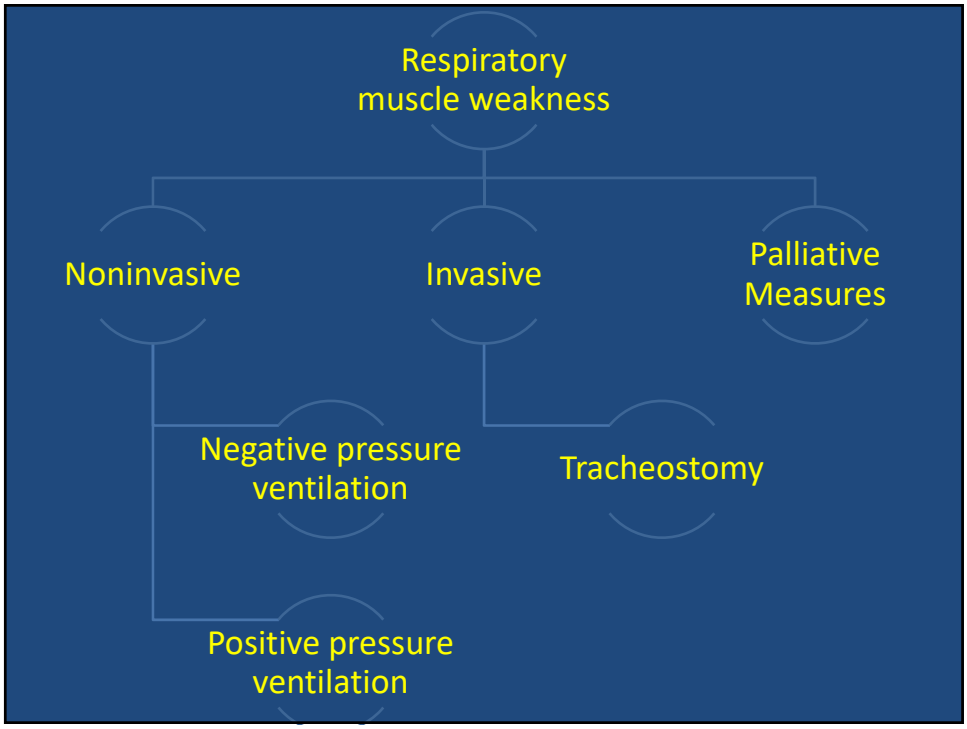
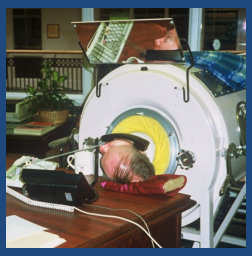
Longitudinal Management	• Practical pearls and lessons learned • "With great power, comes great responsibility"



Negative Pressure Ventilation (NPV)
The Iron Lung

- Augments normal spontaneous breathing
  - Negative pressure
    - Rotary pumps causes thoracic expansion, pressure gradient

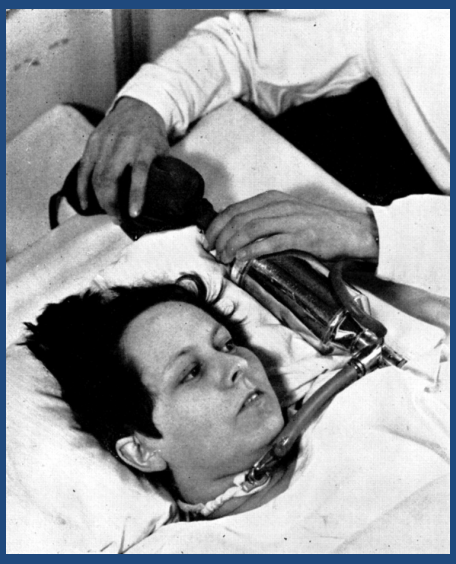


- Poliomyelitis epidemic
  - Copenhagen in 1952
  - 31 patients, 27 died
    - Within 3 days *despite negative pressure ventilation*.

West JB. J Appl Physiol 2005;99:424-432

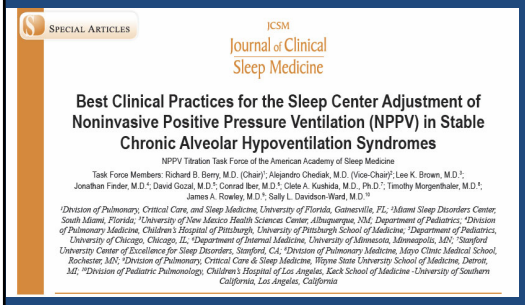
Positive Pressure Ventilation

- **Patient 32 (12 year girl)**
  - Dr. Bjorn Ibsen
    - tracheostomy
    - positive pressure ventilation
    - manual pressure from a rubber bag
- **Up to 1500 medical and dental students**
    - 6-8 hour shifts around the clock to deliver positive pressure ventilation



West JB. J Appl Physiol 2005;99:424-432

Best Clinical Practices


SPECIAL ARTICLES

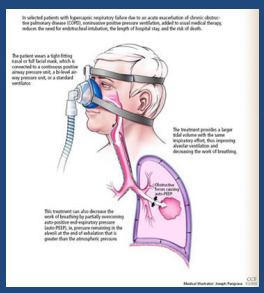
JCSM
Journal of Clinical Sleep Medicine

Best Clinical Practices for the Sleep Center Adjustment of Noninvasive Positive Pressure Ventilation (NPPV) in Stable Chronic Alveolar Hypoventilation Syndromes

NPPV Titration Task Force of the American Academy of Sleep Medicine

Task Force Members: Richard B. Berry, M.D. (Chair)[1]; Alejandro Chediak, M.D. (Vice-Chair)[2]; Lee K. Brown, M.D.[3]; Jonathan Finder, M.D.[4]; David Gozal, M.D.[5]; Conrad Iber, M.D.[6]; Clete A. Kushida, M.D., Ph.D.[7]; Timothy Morgenthaler, M.D.[8]; James A. Rowley, M.D.[9]; Sally L. Davidson-Ward, M.D.[10]

[1]Division of Pulmonary, Critical Care, and Sleep Medicine, University of Florida, Gainesville, FL; [2]Miami Sleep Disorders Center, South Miami, Florida; [3]University of New Mexico Health Sciences Center ,Albuquerque, NM; Department of Pediatrics, [4]Division of Pulmonary Medicine, Children's Hospital of Pittsburgh, University of Pittsburgh School of Medicine; [5]Department of Pediatrics, University of Chicago, Chicago, IL, [6]Department of Internal Medicine, University of Minnesota, Minneapolis, MN; [7]Stanford University Center of Excellence for Sleep Disorders, Stanford, CA; [8]Division of Pulmonary Medicine, Mayo Clinic Medical School, Rochester, MN; [9]Division of Pulmonary, Critical Care & Sleep Medicine, Wayne State University School of Medicine, Detroit, MI; [10]Division of Pediatric Pulmonology, Children's Hospital of Los Angeles, Keck School of Medicine -University of Southern California, Los Angeles, California



- Task Force → evidence and consensus-based standardized NIV titration guidelines
- Chronic Alveolar Hypoventilation syndromes secondary :
  - central respiratory control disturbances (CRCD)
  - restrictive thoracic cage disorders (RTCD) → scoliosis
  - neuromuscular diseases (NMD)
  - obesity hypoventilation syndrome (OHS)

Berry, RB et al. J Clin Sleep Med 2010;6(5):491-509.

Survival Benefit for use of NIV in ALS

Table 1. Studies demonstrating survival benefit for ALS patients using NIV.

Author, year	Study design	NIV device	NIV started	Participants & treatments	Findings
Pinto, 1995	NCT	Bi-level PAP	Daytime hypercapnia or hypoxia	10 NIV 10 standard	3-year survival higher with NIV (87.5% vs 22.2%, $P < .004$)
Aboussouan, 1997	Obs	BiPAP®; ST mode or PLV-100	Daytime orthopnea, hypercapnia or both	21 NIV ≥4h nocturnal 18 intolerant	Median survival 2 months in those NIV intolerant, 15 months NIV tolerant ($P < 0.001$)
Kleopa, 1999	Obs	Bi-level PAP	Respiratory symptoms, FVC <50% predicted, or FVC drop >15% in 3 months	38 NIV>4h/d 32 NIV<4h/d 52 refused NIV	Mean survival 14.2 mo >4h/d(p<0.001), 7.0 mo <4 h/d ($P = 0.038$), 4.6 mo refused NIV
Gruis, 2006	Obs	Bi-level PAP; S mode	Respiratory symptoms and FVC <50% or MIF <−60 cm water	18 NIV ≥4 h/nocturnal 19 intolerant	NIV tolerant decreased risk of death (HR 0.23) 95% CI (0.10,0.54)
Bourke, 2006	RCT	VPAP® STIl; ST mode	Orthopnea & MIP <60% or hypercapnia	22 NIV 19 standard	Median survival benefit 205 days with NIV ($P = .006$).

NCT, nonrandomized controlled clinical trial; Obs, observational study; RCT, randomized controlled clinical trial; NIV, noninvasive positive-pressure ventilation; PAP, positive airway pressure; FVC, forced vital capacity; MIP, maximum inspiratory pressure; MIF, maximum inspiratory force (MIP, MIF, or negative inspiratory force are often used interchangeably); PLV-100, volume-controlled portable ventilator in assist-control mode (Life Care Products, Lafayette, CO); BiPAP® (Respironics, Inc., Murrysville, PA); VPAP® STIl (ResMed, UK Ltd, Abingdon, UK); ST, spontaneous timed mode; S, spontaneous mode; HR, hazard ratio; CI, confidence interval; cm, centimeters; h, hours; mo, months.

Muscle Nerve. 2012; 46: 313–331.

NIV improves ALS survival in those with preserved bulbar function

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

- ALS patients
  - Randomized
    - NIV (22 patients) vs. no ventilation (19)
  - Orthopnea, MIP < - 60, or symptomatic hypercapnia
  - NIV improved quality of life, sleep quality, and survival mostly in ALS patients without bulbar disease
    - Increased survival by 205 days
  - Good bulbar function → 9.3 hours per day
  - Poor bulbar function → 3.8 hours per day
  - Settings
    - Average IPAP of 15 cm H2O
    - Average EPAP of 4 cm H2O

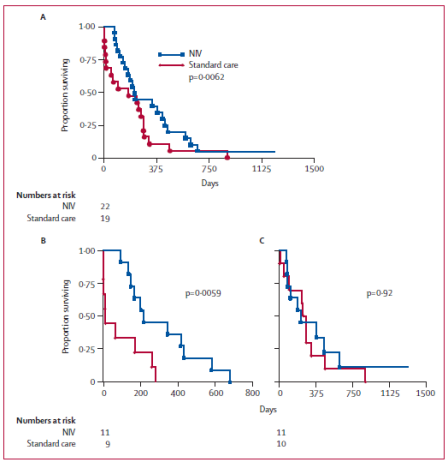


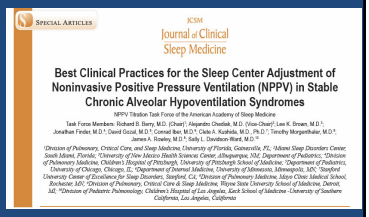
Figure 2: **Survival from randomisation**
A: all patients; B: patients with normal or moderately impaired bulbar function; C: patients with severe bulbar impairment.

Bourke SC et al. Lancet Neurol. 2006;5:140-7.

Why does optimal NIV settings/titration matter?

4.1.8 Attended NPPV titration with polysomnography allows definitive identification of an adequate level of ventilatory support for patients with NMD in whom NPPV treatment is planned. (Level A - Consensus)

- Preserve quality of life
  - Maintain ability to communicate
  - Improve sleep quality
- Reduce morbidity
  - Decrease carbon dioxide
  - Avoids morbidity involved with tracheostomy
- Reduce mortality
  - Extend duration of life



Berry, RB et al. J Clin Sleep Med 2010;6(5):491-509.

Do we need a DIAGNOSTIC sleep study to facilitate initiating a RAD for NMD?

- Common phone call
  - "I have a patient with a diagnosis of a NMD (ALS, muscular dystrophy, etc…) and hypercapnic respiratory failure."
  - "The patient has done GREAT on bilevel PAP in the hospital."
  - "I am told that the patient needs a diagnostic attended polysomnogram to get his bilevel PAP device."
  - True or **False**?

Bilevel PAP Devices

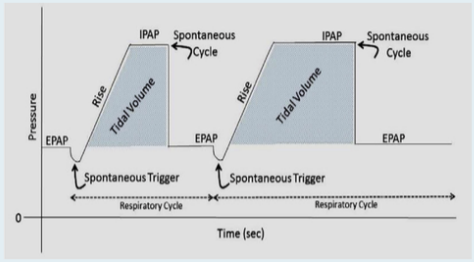
Coding

- **E0470** – Respiratory Assist Device, Bi-Level Pressure, Without Backup Rate Feature
  - Delivers adjustable, variable levels of positive air (during single respiratory cycle) and supplements volume of air into the lungs
- **E0471** – Respiratory Assist Device, Bi-Level Pressure, With Backup Rate Feature
  - Has the same features as E0470, with the addition of timed backup feature to deliver air when insufficient inspiratory efforts fail

www.medicare.gov

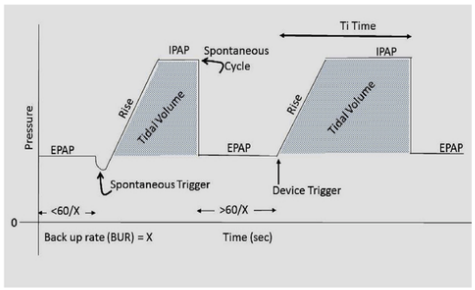
S Mode (spontaneous)

E0470



ST mode (spontaneous/timed)
BIPAP-ST (Respironics)
VPAP-ST (ResMed)

E0471



Selim B, Wolfe L, Coleman J, and Dewan N
Chest 2018: 153 (1): 251-265

Why is a sleep study NOT needed to initiate NIV?

Initial Coverage Criteria

- **Restrictive Thoracic Disorders**

A	**Documentation of progressive neuromuscular disease, or severe thoracic cage abnormality**
B	**1. Arterial blood gas (while awake) ≥ 45 mm Hg or** **2. O2 saturation ≤ 88% for at least 5 continuous minutes** **3. For progressive neuromuscular disease (only) maximal inspiratory pressure is < 60 cm H2O or Forced vital capacity is %50 predicted and**
C	**Chronic Obstructive pulmonary disease does not contribute significantly to beneficiary's pulmonary limitations**

- **If criteria A-C are met, either E0470 or E0471 will be covered for the first three months.**

www.medicare.gov

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Muscle Nerve. 2012; 46: 313–331.

Eur Respir J 2002; 19: 1194–1201
DOI: 10.1183/09031936.02.01302001a
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European Respiratory Journal
ISSN 0903-1936

REVIEW

Sleep and breathing in neuromuscular disease

S.C. Bourke, G.J. Gibson

NORMAL SUBJECTS

Decrease in minute ventilation
Decrease in tidal volume
Increase in respiratory rate

- NREM
- REM
- Tonic REM
- Phasic Rem

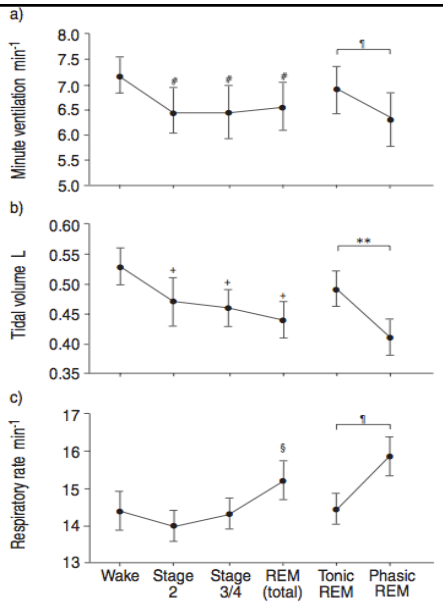

Fig. 1.–a) Minute ventilation, b) tidal volume and c) respiratory rate during wakefulness and sleep in 10 normal adult subjects. Data are presented as mean±SEM. #: Ventilation lower during sleep compared to wake p<0.02; ": p=0.01; ¶: tidal volume lower during sleep compared to wake p<0.05; **: p<0.01; §: respiratory rate higher in rapid eye movement (REM) compared to nonrapid eye movement sleep (NREM) or wake p<0.05. Data from GOULD *et al.* [26].

Eur Respir J 2002; 19: 1194–1201
DOI: 10.1183/09031936.02.01302001a
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European Respiratory Journal
ISSN 0903-1936

REVIEW

Sleep and breathing in neuromuscular disease

S.C. Bourke, G.J. Gibson

Screening sleep studies have been recommended in patients with neuromuscular disease, often guided by serial daytime respiratory function tests (typically spirometry plus/minus blood gases) [9, 10, 39, 40]. However in comparison to daytime lung function, nocturnal measurements, including oxygen saturation, are surprisingly weak predictors of survival [4, 44]. In amyotrophic lateral sclerosis orthopnoea (due to respiratory muscle weakness) is a more sensitive predictor of benefit from noninvasive ventilation than either nocturnal desaturation or daytime hypercapnia and the apnoea/hypopnoea index is unhelpful [45]. The studies available cast doubt on the need for routine polysomnography or nocturnal oximetry in assessing such patients for noninvasive ventilation, although polysomnography may identify the occasional patient with coexistent obstructive sleep apnoea. There is a need for further studies evaluating the optimal criteria for and timing of initiating noninvasive ventilation in patients with neuromuscular disease. Currently there is no evidence that sleep studies improve the selection of subjects for noninvasive ventilation over and above evaluation of symptoms and daytime respiratory function.

Is a sleep study needed?

- "…daytime respiratory function has greater prognostic value than nocturnal measurements."
- In comparison to daytime lung function [and symptoms],
  - nocturnal measurements are surprisingly WEAK predictors of survival.
- There is NO evidence that sleep studies improve the selection of subjects for NIV over and above symptoms and daytime respiratory function.

A diagnostic sleep study is NOT needed to initiate NIV therapy

– "…daytime respiratory function has greater prognostic value than nocturnal measurements."

Bourke SC and Gibson, GJ. Eur Respir J. 2002; 19:1194-1201.

– Confirmed NMD Diagnosis AND one of the following…
  - PaCO2 > 45 mm Hg
  - FVC < 50%
  - MIP < - 60
  - SpO2 < 88% for 5 consecutive minutes (min 2 hour recording)

- These patients can EITHER:
  – DIRECTLY obtain a respiratory assist device
  – Go DIRECTLY to the sleep laboratory or hospital for optimal titration

[Contemporary Reviews in Sleep Medicine]

CHEST

Sleep-Disordered Breathing in Neuromuscular Disease

Diagnostic and Therapeutic Challenges

Loutfi S. Aboussouan, MD, FCCP; and Eduardo Mireles-Cabodevila, MD

Normal sleep-related rapid eye movement sleep atonia, reduced lung volumes, reduced chemosensitivity, and impaired airway dilator activity become significant vulnerabilities in the setting of neuromuscular disease. In that context, the compounding effects of respiratory muscle weakness and disease-specific features that promote upper airway collapse or cause dilated cardiomyopathy contribute to various sleep-disordered breathing events. The reduction in lung volumes with neuromuscular disease is further compromised by sleep and the supine position, exaggerating the tendency for upper airway collapse and desaturation with sleep-disordered breathing events. The most commonly identified events are diaphragmatic/pseudo-central, due to a decrease in the rib cage contribution to the tidal volume during phasic rapid eye movement sleep. Obstructive and central sleep apneas are also common. Noninvasive ventilation can improve survival and quality of sleep but should be used with caution in the context of dilated cardiomyopathy or significant bulbar symptoms. Noninvasive ventilation can also trigger sleep-disordered breathing events, including ineffective triggering, autotriggering, central sleep apnea, and glottic closure, which compromise the potential benefits of the intervention by increasing arousals, reducing adherence, and impairing sleep architecture. Polysomnography plays an important diagnostic and therapeutic role by correctly categorizing sleep-disordered events, identifying sleep-disordered breathing triggered by noninvasive ventilation, and improving noninvasive ventilation settings. Optimal management may require dedicated hypoventilation protocols and a technical staff well versed in the identification and troubleshooting of respiratory events. CHEST 2017; 152(4):880-892

KEY WORDS: neuromuscular disease; noninvasive ventilation; sleep-disordered breathing

Clinical Case #1

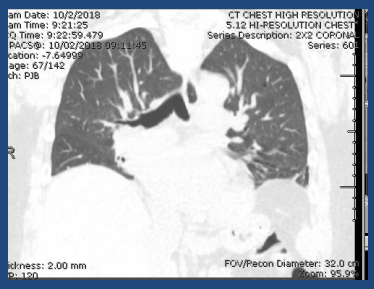
- 37 F with limb girdle muscular dystrophy.
  - Wheelchair limited. Marked dyspnea.
  - FVC 19% and MIP – 17
- Qualifies for NIV?
- Evaluated by a pulmonary/sleep specialist
  - Diagnosed with mild sleep apnea (AHI 5.1)
  - Titrated, then retitrated to CPAP 19 cm H2O
    - Choking, suffocating, dyspnea is markedly worse.
- We switched her from CPAP to NIV during nighttime and daytime mode ventilation
  - Marked improvement in quality of life

Clinical Case #2

- 35 F, diagnosed with bulbar ALS early this year and referred to discuss ventilation options.
  - She is getting more dyspneic and rapidly weakening.
- Spirometry and forces
  - FVC 45%
  - MIP -20
- ABG
  - pH 7.32, PaCO2 55mm Hg, and PaO2 of 62 mm Hg
- Qualifies for NIV?
- She had a diagnostic sleep study 8/1/17
  - "poor sleep efficiency, AHI of 1.5, no sleep related breathing disorder" so unfortunately it wasn't super helpful.
- Can you help?

Clinical Case #3

- 51 year old female
- Shrinking lung syndrome, SLE
- Gradual dyspnea
  - FVC 27%
  - MIPs -42
  - 2 diagnostic PSGs
    - Both showed an AHI < 5



- Which of the following is the next appropriate step?
  - A. Repeat a 3rd diagnostic sleep study
  - B. Order oxygen, she is not a candidate for noninvasive ventilation (NIV)
  - C. Order a bilevel PAP with back up rate at settings of 8/4 cm H2O with a rate of 10 and gradually increase as tolerated
  - D. Order a bilevel PAP in AVAPS mode
  - E. Perform a titration sleep study using bilevel PAP with back up rate to meet patients' respiratory needs

NMD and Sleep Medicine

- Strengths
  - Expertise in noninvasive ventilation
    - Synchrony to optimize sleep quality, ventilation, and oxygenation
  - Expertise in mask interfaces
  - Compliance monitoring
- Pitfalls of sleep medicine
  - The current state of sleep medicine training, does not focus on NMD patient population
    - Excess focus on OSA
  - Complexities of respiratory physiology

Lessons Learned

Protocols and equipment to accommodate for NM patients in the sleep lab

- Hospital bed
  - 2 of our beds
- Hoyer lift
- Suction
- Supplemental O2
- Call system
- Accommodations for a care giver
- Technical expertise
  - RRT and RPSGT
  - 1:1 if needed

Goals of NIV

1. Decrease work of breathing
2. Optimize ventilation and oxygenation
3. Tolerance to NIV
   - Minimize mask leakage
   - Good sleep quality

4.9.4.3 The respiratory function of patients on chronic NPPV treatment should be assessed with measures of oxygenation and ventilation (arterial blood gas, end-tidal CO_2, transcutaneous PCO_2) on a regular follow-up basis or if signs of clinical deterioration are present. (Level A - Consensus)

4.9.1.1 The NPPV device settings used for treatment should ideally reflect the following treatment goals: control of airway obstruction as defined by a respiratory disturbance index (RDI) < 5/hour, absence of snoring, a minimum SPO_2 > 90% at sea level, normalization/improvement of ventilation with a PCO_2 (if measured) no greater than 10 mm Hg above the treatment goal, reduction in excessive respiratory muscle activity, and a mask leak within acceptable parameters for the selected pressures and mask interface. In this work RDI refers to the number of apneas + hypopneas + RERAs and the hours of sleep. (Level A - Consensus)

4.9.1.2 An optimal titration meets the above treatment goals at the selected NPPV settings for at least a 15-minute period that includes REM sleep in the supine position (unless this position is contraindicated) that is not continually interrupted by arousals. (Level A - Consensus)

4.9.1.3 A good titration meets the above treatment goals at the selected NPPV settings for at least a 15-minute period that includes NREM sleep in the supine position (unless this position is contraindicated) and REM sleep in any position at the selected settings. (Consensus B)

4.9.1.4 An adequate titration meets the above treatment goals, except that the RDI must be less than 10/hour at the selected NPPV settings for at least a 15-minute period that includes NREM sleep in the supine position (unless this position is contraindicated) and REM sleep in any position at the selected settings. (Level A - Consensus)

Berry, RB et al. J Clin Sleep Med 2010;6(5):491-509.

Start Slow

- Start 8/4 cm H2O with back up rate
- Increase IPAP to augment tidal volume
  - Goal tidal volume of 8-10 mL/kg
    - Ideal body weight
- Increase back up rate to match needs
- Example
  - 15/5 cm H2O
  - TV ~600 mL

4.3 Recommendations for Initial and Maximum Pressures during NPPV Titration

4.3.1. The recommended minimum starting IPAP and EPAP should be 8 cm H_2O and 4 cm H_2O, respectively. (Level A - Consensus).

4.4.2 Recommendations for adjusting pressure support for low tidal volume or hypoventilation during sleep

4.4.2.1 The PS should be increased every 5 minutes if the tidal volume is below the acceptable goal. An acceptable tidal volume goal for most patients ranges from 6 to 8 mL/kg using ideal body weight (**FIGURE 3**). (Level A - Consensus).

4.3.5 The minimum and maximum incremental changes in PS during NPPV titration should be 1 and 2 cm H_2O, respectively. (Level A - Consensus).

4.3.4 The recommended maximum IPAP should be 20 cm H_2O for patients < 12 years and 30 cm H_2O for patients ≥ 12 years. (Level A - Consensus)

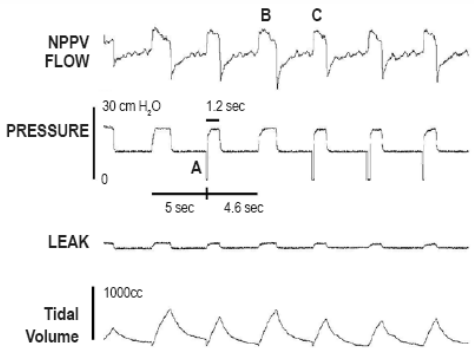
Berry, RB et al. J Clin Sleep Med 2010;6(5):491-509.

BPAP ST Mode

- BPAP ST
  - NPPV in the spontaneous-timed (ST) mode provides a backup rate to ensure a minimum respiratory rate
  - For example, if the back-up rate is 10 bpm, the time window following the previous breath is 6 seconds.
  - If a spontaneous breath does not occur, the device provides a machine triggered breath.

NPPV Titration Task Force

Figure 1—Tracing of NPPV flow, pressure, leak, and tidal volume in a patient receiving BPAP in the ST mode

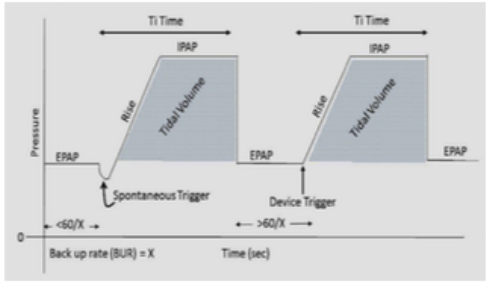


The backup rate is 12, and as the patient did not trigger a breath for 5 seconds, a machine triggered breath was provided (A). Note that spontaneous and machine triggered breaths have similar peak flows (B, C) but different durations and different tidal volumes. The negative pressure spike (A) is an artifact generated by the NPPV device to denote a machine triggered breath.

Berry, RB et al. J Clin Sleep Med 2010;6(5):491-509.

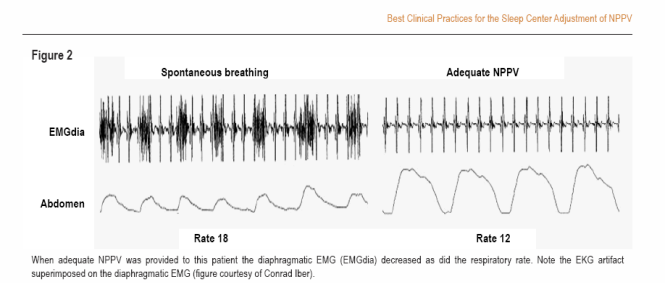
Pressure Control Fixed Inspiratory Time

PC mode (pressure control)



Selim B, Wolfe L, Coleman J, and Dewan N
Chest 2018: 153 (1): 251-265.

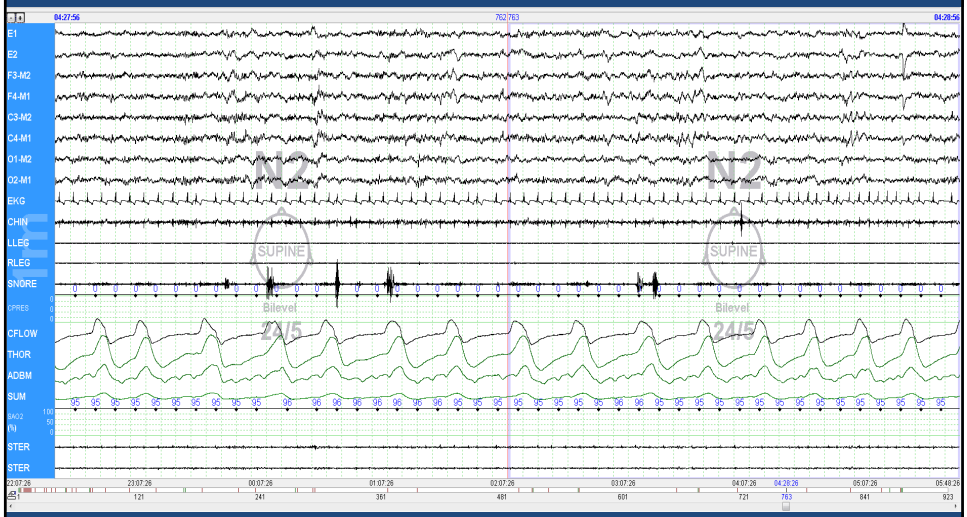
Achieve Muscle Rest



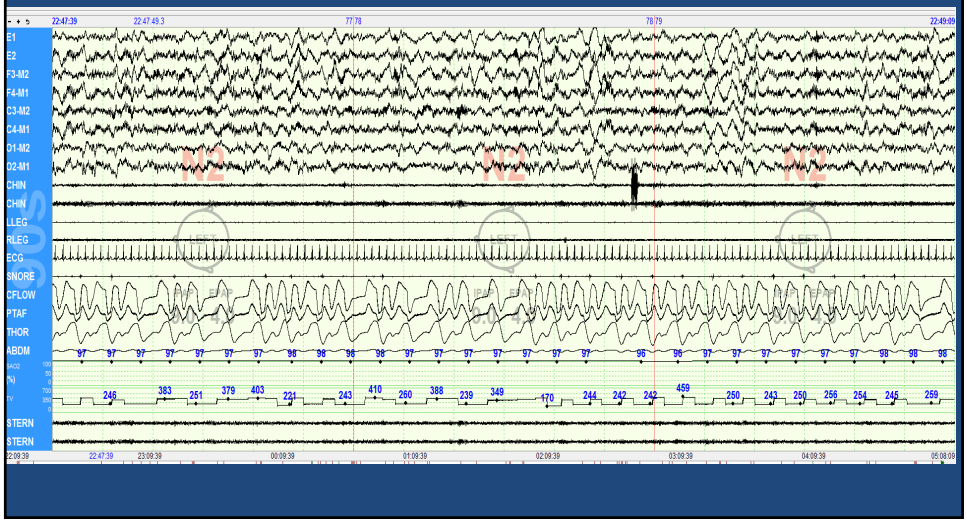
- Bipolar electrodes
  - Surface diaphragm electrodes
    - 2 electrodes, 2 cm apart horizontally in 7-8th intercostal spaces in right anterior axillary line (reduce EKG artifact)
  - Sternocleidomastoid muscles
  - Right parasternal intercostal muscles
    - 2nd and 3rd intercostal spaces in mid-clavicular line

Initial settings
Bilevel PAP 8/4 cm H2O with rate 16

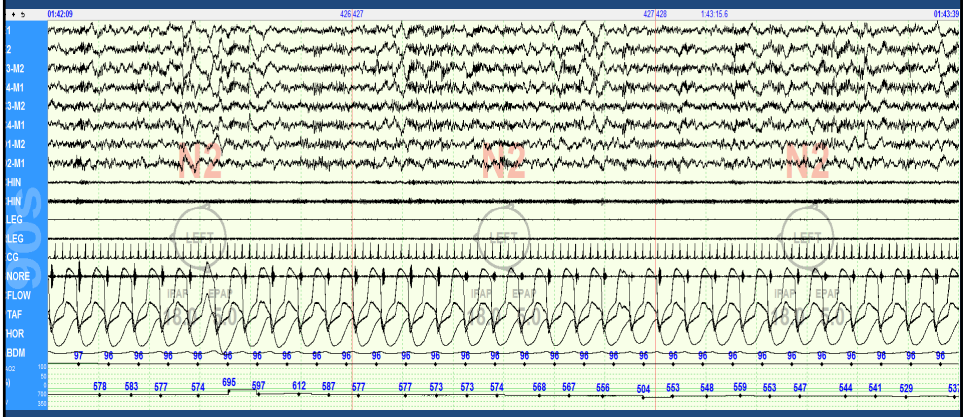
Better settings
Reduction in accessory muscle use



Suboptimal – Bilevel 8/4 with rate 10
Irregular breathing, low tidal volumes (250's mL)…



Optimal – Bilevel 16/5 rate 20 Regular breathing and better tidal volumes (550 mL)…



[Contemporary Reviews in Sleep Medicine]

CHEST

Initiation of Noninvasive Ventilation for Sleep Related Hypoventilation Disorders

Advanced Modes and Devices

Bernardo J. Selim, MD, FCCP; Lisa Wolfe, MD, FCCP; John M. Coleman III, MD, FCCP; and Naresh A. Dewan, MD, FCCP

Although noninvasive ventilation (NIV) has been used since the 1950s in the polio epidemic, the development of modern bilevel positive airway pressure (BPAP) devices did not become a reality until the 1990s. Over the past 25 years, BPAP technology options have increased exponentially. The number of patients receiving this treatment both in the acute setting and at home is growing steadily. However, a knowledge gap exists in the way the settings on these devices are adjusted to achieve synchrony and match the patient's unique physiology of respiratory failure. This issue is further complicated by differences in pressure and flow dynamic settings among different types of NIV devices available for inpatient and home care.

CHEST 2018; 153(1):251-265

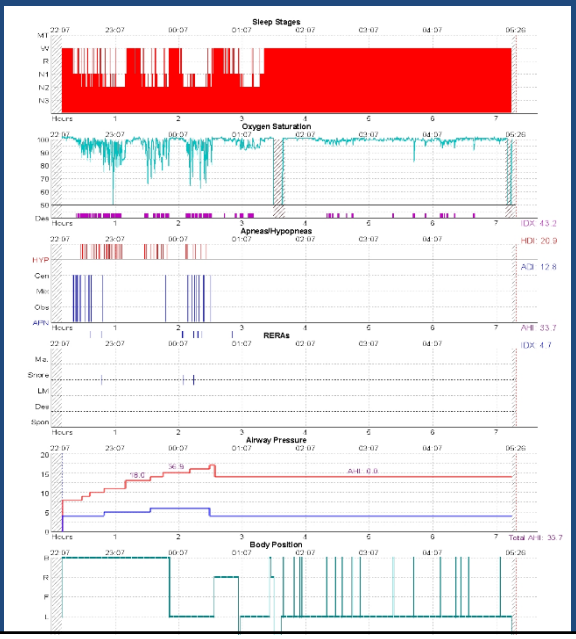
Setting	Recommendation	Reason
Trigger	Sensitive	Weak inspiratory muscles
Inspiratory time	Make it longer	Recruit alveoli and avoid atelectasis
Tidal volumes	More is better	8-10 ml/kg

Pearl
Not all NMD can tolerate NIV

- **Bulbar disease**
  - May trigger vocal cord spasm
  - Sialorrhea (drooling)
    - medications (Robinul, Levsin, Scopolamine, atropine, BoTox)
  - Suboptimal mask fit, poor seal
- **Claustrophobia**
  - Myotonic dystrophy
  - Weakened upper extremity strength, inability to remove mask

Benditt JO. Semin Respir Crit Care Med 2002;23:239-47.

Clinical Case



- 32 year man
- Myotonic dystrophy
- FVC 82%
- MIP - 54

- Poorly tolerated bilevel PAP
  - Poor sleep efficiency
  - Severe desaturations
  - No REM

Pearl

NM patients may require several interfaces

- Sleep clinics/labs have access to a wide variety of interfaces
  - "creativity"
- Interface needs
  - Daytime
  - Nighttime
  - Chin straps may be necessary

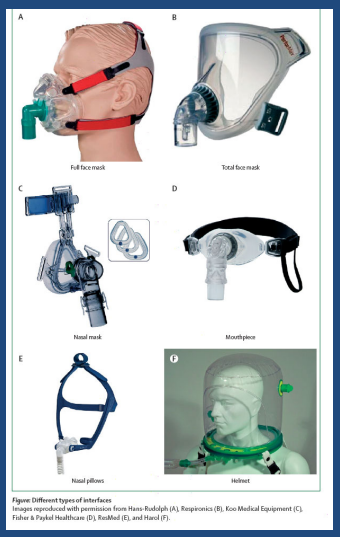
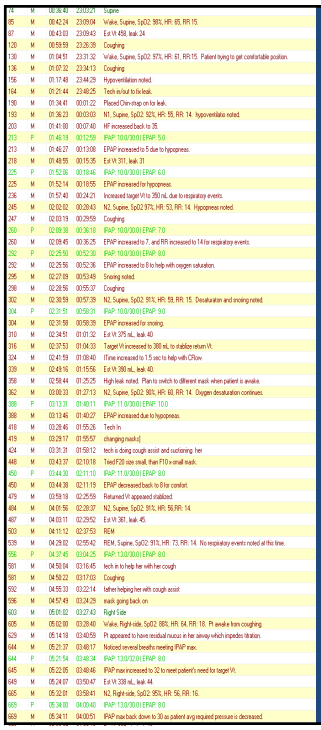


Figure: Different types of interfaces
Images reproduced with permission from Hans-Rudolph (A), Respironics (B), Koo Medical Equipment (C), Fisher & Paykel Healthcare (D), ResMed (E), and Harol (F).

Nava S and Hill N. Lancet. 2009;374:250-259



Tough Case

Technical comments

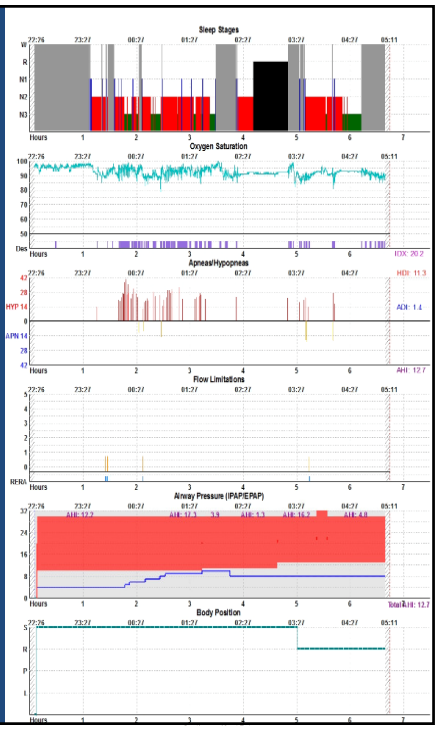
Mask adjustments

Tidal volumes 360 mL

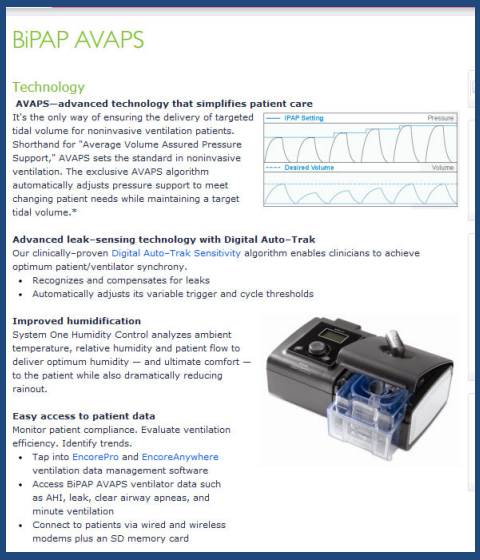
Mask switch

Adjustment in Back up rate

Hypopneas Higher EPAP



Volume Assured Pressure Support (VAPS)



BiPAP AVAPS

Technology

AVAPS—advanced technology that simplifies patient care

It's the only way of ensuring the delivery of targeted tidal volume for noninvasive ventilation patients. Shorthand for "Average Volume Assured Pressure Support," AVAPS sets the standard in noninvasive ventilation. The exclusive AVAPS algorithm automatically adjusts pressure support to meet changing patient needs while maintaining a target tidal volume.*

IPAP Setting — Pressure — Desired Volume — Volume

Advanced leak-sensing technology with Digital Auto-Trak

Our clinically-proven Digital Auto-Trak Sensitivity algorithm enables clinicians to achieve optimum patient/ventilator synchrony.

- Recognizes and compensates for leaks
- Automatically adjusts its variable trigger and cycle thresholds

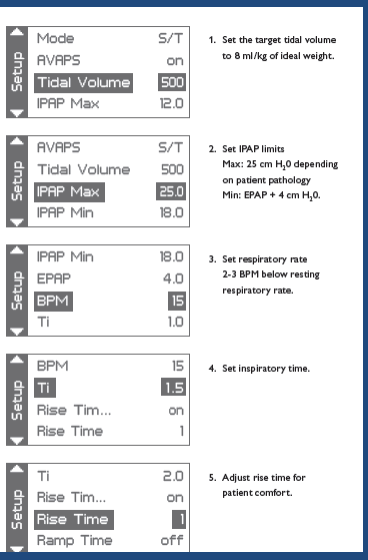
Improved humidification

System One Humidity Control analyzes ambient temperature, relative humidity and patient flow to deliver optimum humidity — and ultimate comfort — to the patient while also dramatically reducing rainout.

Easy access to patient data

Monitor patient compliance. Evaluate ventilation efficiency. Identify trends.

- Tap into EncorePro and EncoreAnywhere ventilation data management software
- Access BiPAP AVAPS ventilator data such as AHI, leak, clear airway apneas, and minute ventilation
- Connect to patients via wired and wireless modems plus an SD memory card



Setup		
	Mode	S/T
	AVAPS	on
	Tidal Volume	500
	IPAP Max	12.0

1. Set the target tidal volume to 8 ml/kg of ideal weight.

Setup		
	AVAPS	S/T
	Tidal Volume	500
	IPAP Max	25.0
	IPAP Min	18.0

2. Set IPAP limits
Max: 25 cm H_2O depending on patient pathology
Min: EPAP + 4 cm H_2O.

Setup		
	IPAP Min	18.0
	EPAP	4.0
	BPM	15
	Ti	1.0

3. Set respiratory rate 2-3 BPM below resting respiratory rate.

Setup		
	BPM	15
	Ti	1.5
	Rise Tim...	on
	Rise Time	1

4. Set inspiratory time.

Setup		
	Ti	2.0
	Rise Tim...	on
	Rise Time	1
	Ramp Time	off

5. Adjust rise time for patient comfort.

http://www.healthcare.philips.com/main/homehealth/respiratory_care/bipapavaps/default.wpd

Volume Assured Pressure Support (VAPS)

S9 VPAP ST-A clinical settings — iVAPS mode

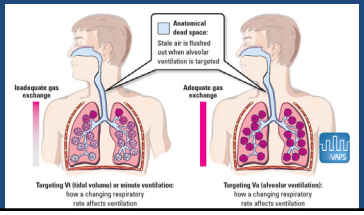
Primary Settings

PARAMETER	DEFAULTS	DESCRIPTION
Target Va	5.2 L	Target alveolar ventilation (Va) is the main parameter that iVAPS uses to determine the amount of pressure support required.
EPAP	4 cm H_2O	EPAP is the pressure delivered when the device is cycled into expiration.
Height	70 in	The patient's height or arm span is needed to determine dead space.
Target Patient Rate	15 bpm	Target patient rate is the reference point that iVAPS uses to determine the range for the backup rate. This should be set the same as the patient's actual respiratory rate (RR).

Synchronization Settings

PARAMETER	DEFAULTS	DESCRIPTION
Ti Max	2.0 seconds	Sets the maximum limit on the time the device spends in IPAP.
Ti Min	0.3 seconds	Sets the minimum limit on the time the device spends in IPAP.
Min PS	4 cm H_2O	Minimum pressure support in iVAPS mode.
Max PS	20 cm H_2O	Maximum pressure support in iVAPS mode.

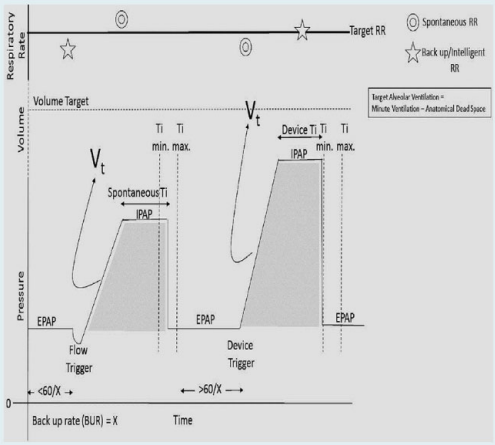
- Adjustment of Ti min and Ti max



http://www.resmedstellar.com/stellar/en/ivaps.html

Volume Assured Pressure Support (VAPS)

Volume-assured pressure support modes (VAPS)
AVAPS (assured volume assured pressure support; ResMed) targets expiratory tidal volume
iVAPS (intelligent volume assured pressure support ResMed) targets alveolar ventilation (minute ventilation minus death space ventilation)



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Chest 2018: 153 (1): 251-265.

Neuromuscular Disorders (NMD)	• Overview of neuromuscular diseases • Physiologic testing • Restrictive physiology and impaired forces
Noninvasive Ventilation (NIV)	• How to qualify for a respiratory assist device? • The Polysomnogram – Friend or Foe? • The double edged sword
Longitudinal Management	• Practical pearls and lessons learned • "With great power, comes great responsibility"

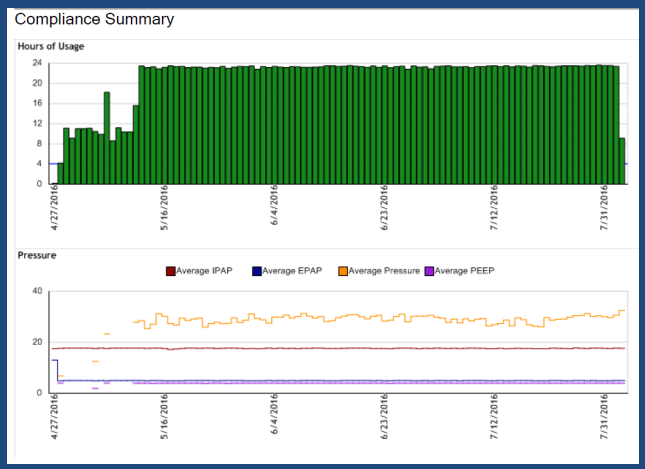
Sleep clinics have expertise obtaining download data

		1/1/2018	2/1/2018	3/1/2018	4/1/2018	5/1/2018	6/1/2018	7/1/2018	8/1/2018	9/1/2018
AHI	Min	0.4	0.4	0.2	0.2	0.2	1.2	1.2	0.9	1.6
	Max	9.8	11.9	8.5	7.7	10.9	11	9.9	11.4	9
	Avg	4.9	3.8	3	2.9	3.9	6	4.7	4.2	4.9
Attained EPAP Pressure	Min	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	3.9
	Max	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	Avg	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.4
Attained IPAP/CPAP Pressure	Min	14.5	14.6	14.6	14.6	14.5	14.5	14.6	14.6	11.5
	Max	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
	Avg	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	13.1
Breath Rate	Min	16.9	16.8	16.7	16.7	16.6	16.7	16.7	16.8	16.8
	Max	18.9	20.5	22.8	24.1	20.1	21.6	22.4	19.9	21.9
	Avg	17.8	17.8	18.4	18.8	18	18.3	18.3	18	19.5
Exhaled Tidal Volume	Min	436.5	433.9	465.2	479.3	458.4	450.7	461.6	457.4	381.6
	Max	491.1	508.5	589.9	540	531.5	528.6	545	533.3	497.2
	Avg	462.5	470.6	500.8	505.3	492.2	484	494.2	489.1	434.7
Leak	Min	25.6	25.5	25.3	23.4	24.8	24.4	26.6	27.2	26.5
	Max	30.1	29.3	33.9	44.1	32.4	39	36.9	36.3	38.9
	Avg	27.3	27.3	28.8	28.6	28.2	30.8	31.4	31.3	31.1
Percent Patient Triggered Breaths	Min	26.3	15.5	11.4	14	13.2	14.3	11.9	15.3	20.3
	Max	61	64.3	78.1	62.7	60.3	75	63.9	69	100
	Avg	44.8	37.5	30.9	36	37.2	31.6	30.7	39.1	73.4
Peak Inspiratory Flow	Min	42.8	44.2	52.1	50.2	51	52.2	53	50.4	44
	Max	55.2	61.8	65	68.4	65.4	63.6	62.9	61.6	54.4
	Avg	48.5	51.2	58.5	59.5	57.8	57.1	57.7	55.6	48.4
Minute Vent	Min	7.1	7.1	7.7	7.8	7.7	7.6	7.6	7.7	7.1
	Max	8.5	9.6	10.6	11.4	9.4	9.5	10.4	9.4	8.7
	Avg	7.9	8	8.8	9	8.5	8.4	8.7	8.4	8

1. Minute ventilation
   - Exhaled tidal volumes
   - Respiratory rate
1. Percent patient trigger
1. Hours of usage

Lessons Learned

Assessment of compliance data is important



Associative Increases in Amyotrophic Lateral Sclerosis Survival Duration With Non-invasive Ventilation Initiation and Usage Protocols

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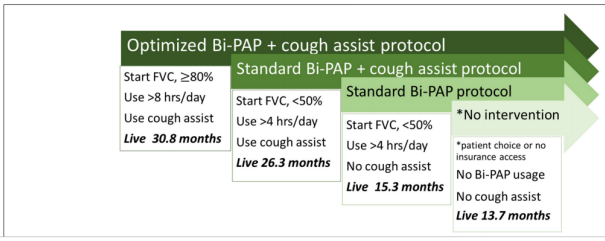
Is an FVC < 50% too low?

TABLE 4 | Comparing Bi-PAP usage protocol parameter combinations.

Bi-PAP user sub-group	*N*	Median ALSFRS-R at Bi-PAP initiation Score, (IQR)	Median survival months, (IQR)
≥80 %predict, >8 h/day, cough assist (+)	6	37 (3)	30.8 (22.38)
≥80 %predict, >0 h/day, cough assist (+)	22	37 (12)	24.17 (19.50)
≥80 %predict, >0 h/day, cough assist (–)	30	31 (10)	21.12 (22.46)
≥60 %predict, >8 h/day, cough assist (+)	26	33 (11)	25.85 (32.78)
≥60 %predict, >8 h/day, cough assist (+)	72	33 (10)	25.55 (22.92)
≥60 %predict, >0 h/day, cough assist (–)	69	29 (10)	19.53 (23.50)
<50 %predict, >8 h/day, cough assist (+)	22	20 (8)	29.77 (17.20)
<50 %predict, >0 h/day, cough assist (+)	73	25 (10)	26.03 (15.20)
<50 %predict, >0 h/day, cough assist (–)	116	19 (13)	14.03 (18.34)



How good are we in providing NIV for NM patients?

Missed opportunities?

The #1 Way to treat ARDS: Low tidal volume ventilation

- Multicenter RCT
- 861 patients with ARDS (P:F ≤ 300)
- Randomized to 6-8 vs. 10-12 ml/kg TV
- Target plateau pressure < 30

	Low Tidal Volume	Traditional Tidal Volume	P-value
Death before discharge	31.0	39.8	.007
Ventilator free days	12	10	.007
Organ-failure free days	15	12	.006

NEJM. 2000,342, 1301-1308

How good are we at implementing low tidal volume ventilation?: Lung Safe study in JAMA, 2016

Ventilator strategy in LUNG SAFE:

- 1/3 of patients never recognized to have ARDS
- P_{plat} measured in 40%
- Less than 2/3 received TV ≤ 8 mg/kg

JAMA. 2016,315, 788-800

Angela Rogers, MD – CTS 2019

Summary Slide

1. Neuromuscular disorders benefit from NIV
   - Quality of life
   - Morbidity
   - Mortality

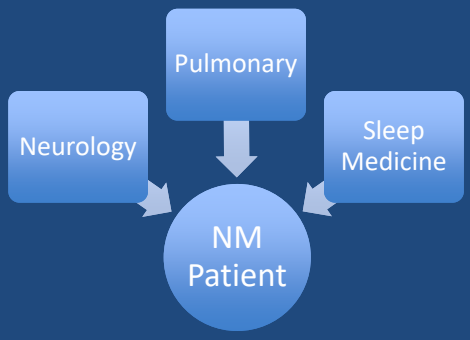
1. Pulmonary physiology determines obtaining a NIV
   - PaCO2 > 45
   - FVC < 50%
   - MIP < -60
   - PaO2 < 88% for 5 minutes

3. An FVC of < 50% may be "too late," but…
   - Make sure to check supine FVC
   - Make sure to get an MIP

4. A diagnostic sleep study is unnecessary to obtain a NIV
   - However a TITRATION sleep study can be very helpful

5. Sleep trained clinicians can make an important and beneficial impact on NM patients

Traditional Management of Patients with Neuromuscular Diseases



- Sleep medicine specialists
  - have expertise to IMPROVE quality of life.

Sleep Disordered Breathing in Neuromuscular Disease

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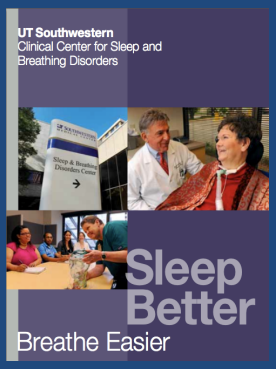

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