Chronic Respiratory Failure in SMA and Initiation of Mechanical Ventilation

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Progression of Respiratory Involvement in NMD

- Recurrent infection
- Atelectasis

Nocturnal Respiratory Dysfunction

- Frequent arousals
- Sleep fragmentation

Daytime Hypercapnia
Signs and Symptoms of Respiratory Failure

- Infants with SMA 1
  - Weak cough
  - Tachycardia
  - Diaphoresis
  - Cyanosis
  - Hypoxemia (pulse oximetry)

Signs and Symptoms of Respiratory Failure

- SMA 2 (and 3)  
  (In addition to prior signs and symptoms)
  - Morning headache
  - Daytime fatigue
  - Lung function abnormalities
    - FVC, IVC, CPF
    - Polysomnogram
NEUROMUSCULAR WEAKNESS

Severe Nocturnal and Diurnal Hypoventilation

Depression of Respiratory Drive

HCO₃⁻ Retention

Alveolar Hypoventilation ↑

Periods of REM Sleep ↑

Sleep Deprivation

Sleep Deprivation

Daytime Hypersomnolence and Fatigue

REM Sleep

PaO₂ ↓

PaCO₂ ↑

Frequent Arousals

Sleep time ↓

Sleep efficiency ↓
# Signs and Symptoms of SDB

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Signs</th>
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<tbody>
<tr>
<td>Morning lethargy, daytime hypersomnolence</td>
<td>Adenotonsillar hypertrophy</td>
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<tr>
<td>Fatigue</td>
<td>Mouth breathing</td>
</tr>
<tr>
<td>Insomnia, poor sleep quality</td>
<td>Macroglossia</td>
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<tr>
<td>Morning headache</td>
<td>Hyponasal speech</td>
</tr>
<tr>
<td>Orthopnea, dyspnea</td>
<td>Facial and lingual myopathy</td>
</tr>
<tr>
<td>Anorexia, poor growth, failure to thrive</td>
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<tr>
<td>Snoring</td>
<td>Hypertension</td>
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<tr>
<td>Restless legs</td>
<td>Cor pulmonale</td>
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<td>Poor school performance, attention deficit</td>
<td>Heart failure</td>
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<tr>
<td>Mood changes</td>
<td>Digital clubbing</td>
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<tr>
<td>Night sweats</td>
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<tr>
<td>Hypoxic seizures</td>
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</tbody>
</table>
Predictors of SDB

IVC, PaCO$_2$

Mellies U et al. Neuromuscul Disord 13:123; 2003
Nocturnal Hypoventilation in Children with NMD

- 46 children with progressive NMD
- NH in 15% (7/46)
- Symptoms rare
- Predictors
  - FVC <70%
    - Sens 71.4, spec 64.1
  - FEV-1 <65%
    - Sens 71.4, spec 79.5
  - Scoliosis

Katz SL et al. Arch Dis Child 95:998; 2010
## Diagnosis of SDB

<table>
<thead>
<tr>
<th>Test</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PSG</strong></td>
<td>C-R function and sleep</td>
<td>Expensive, labor intensive, not widely available, disruptive</td>
</tr>
<tr>
<td>Home audio/video taping</td>
<td>Readily available</td>
<td>Not sensitive or specific</td>
</tr>
<tr>
<td>Nap study</td>
<td>Less intrusive</td>
<td>No REM</td>
</tr>
<tr>
<td>Oximetry study</td>
<td>Readily available</td>
<td>Cannot distinguish OSA from NH, artifacts, arousals</td>
</tr>
<tr>
<td>Oximetry + capnography</td>
<td>May be more sensitive</td>
<td>Accuracy of CO2 readings</td>
</tr>
</tbody>
</table>
Mechanical Ventilatory Support

When to Begin?

- Evaluate when daytime PaCO$_2$ > 45 torr$^{1,2}$
- Acute respiratory illness and failure to wean
- Abnormal polysomnography
- Preventative treatment?
- Preservation / promotion of lung growth?

$^1$Rutgers M et al. Neuromuscul Disord 6:431; 1996
RCT for Those with Nocturnal Hypoventilation

- ↑ daytime PaCO$_2$ (n = 5)
- Symptomatic relief (n = 2)
- FTT, acute pneumonia (n = 1)
- ↑ TcCO$_2$, ↓ in PFTs (n = 1)

Ward S et al. Thorax 60:1019; 2005
Goals of Mechanical Ventilation in SMA

- Palliate dyspnea
- Support during acute illnesses
- Reverse hypoventilation
- Improve sleep quality
- Facilitate home care/reduce hospitalizations
- Remodel thorax, ?promote lung growth
Chest Wall Compliance in Children with NMD

Simonds AK. In Non-Invasive Respiratory Support, Simonds AK, ed. pp 181-2; 2001

Cw (ml/cm H2O /kg)

Age, mos

4 yrs after NIPPV

How Should We Target Ventilator Support?

Clinical Assessment

- Increase Vt
- Decrease trigger effort
- Optimize synchrony
  - Patient - ventilator
  - Chest - abdomen
- Normoxemia
- Normocapnia

Polysomnography

- Improve sleep architecture
- Reverse thoraco-abdominal paradox
- Normocapnia
- Normoxemia
- Resolution of SDB
Thoraco-abdominal Asynchrony and “Wasted” Respiratory Effort

Sleep Disordered Breathing in SMA

- 7 with SDB/NIV; 5 without SDB
- PSG and symptom questionnaire
- Bedside NIV adjustment
- SDB: recurrent hypopneas w/ arousals, mild hypoxemia

Mellies U et al. Neuromusc Disord 14:797; 2004
Summary

- Respiratory compromise follows a predictable course
- Better predictors still required
- Timing of ventilatory support determined by patient status and goals
- Selection of settings can be determined clinically or by PSG
A Couple of Questions

• “High span” BLPAP
  - How much (little) is required?
  - Does it result in enhanced lung growth?
  - Does it change outcome?

• How frequently to test for SDB?

• Choosing BLPAP settings
  - Which is better, PSG or clinical assessment?
Prevalence of SDB in NMDs

• True prevalence unknown
  - As high as 70% in select populations
  - OSA may be 10X higher than normal
  - Patient age and natural hx of underlying disease
  • Type of SDB reflects distribution of respiratory muscles
  • Bimodal disease in DMD\textsuperscript{1}

\textsuperscript{1}Suresh S et al. J Paediatr Child Health 41:500; 2005
## Types of Sleep Problems

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Sleep abnormality</th>
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<tbody>
<tr>
<td>Duchenne muscular dystrophy</td>
<td>Obstructive sleep apnoea (younger patients)</td>
</tr>
<tr>
<td></td>
<td>Hypoventilation (older patients)</td>
</tr>
<tr>
<td>Spinal muscular atrophy</td>
<td>Hypoventilation</td>
</tr>
<tr>
<td></td>
<td>Apnoea/hypopnea</td>
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<tr>
<td>Myotonic dystrophy</td>
<td>Hypoventilation</td>
</tr>
<tr>
<td></td>
<td>Apnoea/hypopnea</td>
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<td></td>
<td>Periodic limb movements</td>
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<td></td>
<td>Excessive daytime sleepiness</td>
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<tr>
<td>Peripheral neuropathies (eg, Charcot-Marie-Tooth disease)</td>
<td>Hypoventilation</td>
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<tr>
<td></td>
<td>Frequent arousals</td>
</tr>
</tbody>
</table>

*Hull J et al. Thorax 67:i1; 2012*
Introduction of Chronic Ventilation

# of Patients


Elective HMV  Non-elective HMV  PSG