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ORIGINAL ARTICLE

Home-Based Overnight Transcutaneous Capnography/Pulse Oximetry for Diagnosing Nocturnal Hypoventilation Associated With Neuromuscular Disorders

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Abstract

Objective: To determine the utility of home-based, unsupervised transcutaneous partial pressure of carbon dioxide (tc-Pco_2) monitoring/oxygen saturation by pulse oximetry (Spo_2) for detecting nocturnal hypoventilation (NH) in individuals with neuromuscular disorders.

Design: Retrospective case series analyzed consecutively.

Setting: Multidisciplinary neuromuscular respiratory failure (NMRF) clinic at an academic institution.

Participants: Subjects (N=35, 68.6% men; mean age, 46.9y) with spinal cord injury (45.7%) or other neuromuscular disorders underwent overnight tests with tc-Pco_2/Spo_2 monitoring. Fifteen (42.9%) were using nocturnal ventilatory support, either bilevel positive airway pressure (BiPAP) or tracheostomy ventilation (TV).

Interventions: A respiratory therapist brought a calibrated tc-Pco_2/Spo_2 monitor to the patient's home and provided instructions for data collection during the subject's normal sleep period. Forced vital capacity (FVC), body mass index (BMI), and exhaled end-tidal Pco_2 (ET-Pco_2) were recorded at a clinic visit before monitoring.

Main Outcome Measures: Detection of NH (tc-Pco_2 $\geq$50mmHg for $\geq$5% of monitoring time). Data were also analyzed to determine whether nocturnal oxygen desaturation (Spo_2 $\leq$88% for $\geq$5% of monitoring time), FVC, BMI, or daytime ET-Pco_2 could predict the presence of NH.

Results: NH was detected in 18 subjects (51.4%), including 53.3% of those using BiPAP or TV. NH was detected in 43.8% of ventilator-independent subjects with normal daytime ET-Pco_2 (present for 49.4%$\pm$31.5% [mean $\pm$ SD] of the study period), and in 75% of subjects with an elevated daytime ET-Pco_2 (present for 92.3%$\pm$8.7% of the study period). Oxygen desaturation, BMI, and FVC were poor predictors of NH. Only 3 attempted monitoring studies failed to produce acceptable results.

Conclusions: Home-based, unsupervised monitoring with tc-Pco_2/Spo_2 is a useful method for diagnosing NH in NMRF.

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Neuromuscular respiratory failure (NMRF) is often managed with noninvasive ventilation (NIV) to forestall progression of hypercapnia and to relieve dyspnea. Because nocturnal hypoventilation (NH) generally precedes daytime hypercapnia, the first indication for NIV may be transient rises in the partial pressure of carbon dioxide (Pco_2) during sleep, even in the absence of obstructive sleep apnea (OSA).[1-3] Recognizing NH early may have particular value, because any nocturnal Pco_2 reaching $\geq$50mmHg marks a high probability of requiring NIV within 2 years.[4] Additionally, initiating NIV based on symptomatic daytime hypercapnia results in improved mortality and quality of life in amyotrophic lateral sclerosis (ALS).[5] A practical, cost-effective method for early recognition of NH has yet to emerge. Currently available

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approaches include correlating NH with lung function parameters,[1,6,7] polysomnograms (PSGs) with exhaled P_{CO_2} monitoring,[8] and arterial blood gas monitoring.

Current methods are limited in their ability to predict or detect NH, and to determine the proper timing for initiating NIV. Pulmonary function parameters such as forced vital capacity (FVC) can predict the need for NIV in certain neuromuscular conditions, but they do not reliably predict hypercapnia.[1,6,7] Nocturnal P_{CO_2} monitoring, either by arterial blood gas or end-tidal P_{CO_2} (ET-P_{CO_2}) measurements, generally requires an inpatient study or an overnight stay in a sleep laboratory. It is problematic to assess outpatients with neuromuscular disorders for NH, as sleep laboratories often are ill-equipped to accommodate their special needs. Barriers to access and the inability to accommodate skilled caregivers impose daunting obstacles that, in our experience, often cause patients to refuse overnight stays in sleep laboratories. Likewise, once nocturnal NIV is initiated, there are no established methods for longitudinal home-based monitoring to determine the effectiveness of positive pressure ventilation in achieving normocapnia.

We hypothesized that the barriers to performing PSGs have led to underrecognition of NH in patients with neuromuscular disorders. In this study, we report our experience with using a monitor that measures transcutaneous P_{CO_2} (tc-P_{CO_2}) and oxygen saturation by pulse oximetry (Sp_{O_2}) for unsupervised overnight studies in the home setting to detect NH in individuals with a variety of neuromuscular disorders.

Methods

Informed consent

Permission for retrospective analysis of patient medical records was granted for this study by the institutional review board. The monitoring studies that were reviewed were performed between December 2009 and June 2011.

Participants

The study population consisted of patients seen at a multidisciplinary clinic for treatment of NMRF. These patients are managed jointly by a pulmonologist and a physical medicine and rehabilitation specialist. The motor deficit of patients with spinal cord injury (SCI) was defined according to the International Standards for the Neurological Classification of Spinal Cord Injury.[9]

List of abbreviations:

ALS	amyotrophic lateral sclerosis
BiPAP	bilevel positive airway pressure
BMI	body mass index
ET-P_{CO_2}	end-tidal partial pressure of carbon dioxide
FVC	forced vital capacity
NH	nocturnal hypoventilation
NIV	noninvasive ventilation
NMRF	neuromuscular respiratory failure
OSA	obstructive sleep apnea
P_{CO_2}	partial pressure of carbon dioxide
PSG	polysomnogram
SCI	spinal cord injury
Sp_{O_2}	oxygen saturation by pulse oximetry
tc-P_{CO_2}	transcutaneous partial pressure of carbon dioxide
TV	tracheostomy ventilation

Home-based monitoring

Monitoring was performed only when the patients were clinically stable for at least 4 weeks. A respiratory therapist brought a SenTec Digital Monitor[a] to the patient's home on the day of the study. This monitor measures and records tc-P_{CO_2}, Sp_{O_2}, and heart rate. The therapist calibrated the monitor and attached the skin probe below the clavicle. The patient/caregivers were instructed to start recording at the beginning of the overnight sleep period, and to turn the monitor off when the patient awoke the following morning. The data were then downloaded and analyzed by V-STATS software,[a] using automated drift-correction of the P_{CO_2} signal. The manufacturer's reported resolution is 1mmHg for P_{CO_2} and 1% for Sp_{O_2}. With the use of this device to compare drift-corrected tc-P_{CO_2} with arterial P_{CO_2} in a sleep laboratory setting, there was close correlation ($R=.946$) and agreement between measurements (range of differences, -4.9 to $+6.5$mmHg).[10] Bland-Altman analysis demonstrated that the discrepancy was >7.5mmHg in only 1% of measurement pairs.[10]

Pulmonary function testing

Spirometry was performed by a pulmonary function laboratory equipped with MedGraphics spirometers.[b] Studies were performed according to the guidelines published by the American Thoracic Society and European Respiratory Society.[11] Predicted values were calculated according to standard reference equations.[12]

ET-P_{CO_2} measurements

A Tidal Wave 715A monitor[c] was used to measure ET-P_{CO_2} during outpatient evaluations when the patients were clinically stable.

Statistics

Comparisons between groups were made by *t* tests for continuous variables and chi-square tests for categorical variables. Simple logistic regression was used to predict the odds of NH. *P* values less than .05 were considered significant. All data analysis was performed on SAS software, version 9.2.[d]

Results

The characteristics of the study population are summarized in table 1. The patients had a mean age ± SD of 46.9±16.6 years (range, 20–75y), and 68.6% were men. Sixteen patients (45.7%) had SCI, and 68.8% of these had motor deficits at or above the C5 level. The mean interval ± SD since SCI was 13.5±10.8 years (range, 2–37y). Of the 19 patients who had neuromuscular disorders other than SCI, 5 had multiple sclerosis, 2 each had ALS, cerebral palsy, or Duchenne muscular dystrophy, and 6 had other miscellaneous diagnoses. Fifteen patients (42.9%) were already using nocturnal ventilatory support: bilevel positive airway pressure (BiPAP)[10] or mechanical tracheostomy ventilation (TV).[5]

The indications for overnight monitoring are summarized in table 2. The most common reason for the study, in 16 cases