Utility of sleep studies in neurologic practice

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Summary

Sleep disorders are frequent in patients with neurologic disease. This article provides an approach to the patient with sleep complaints that can be implemented during the course of a neurologic evaluation. Recognition of a sleep complaint is the key that leads to use of appropriate scales and sleep diaries to form a differential sleep diagnosis. Choosing the correct sleep test is essential to confirm diagnosis and plan therapy. We describe the important sleep tests for practicing neurologists: polysomnography, multiple sleep latency test, and maintenance of wakefulness test, as well as actigraphy and oximetry. The approved use of limited channel home tests (also known as “out of center testing,” or “portable monitoring”) is reviewed and an algorithm provided to guide the approach to the sleepy patient.

Sleep disorders are pervasive in patients with neurologic disease, as comorbidities or primary diagnoses, and may even be the harbinger of future neurologic disease, as in REM sleep behavior disorder (RBD) foreshadowing Parkinson disease. In 2011, the NIH estimated that between 25% and 30% of the adult general population has sleep or circadian rhythm disorders.¹ The International Classification of Sleep Disorders is now in its third iteration and lists more than 80 distinct sleep disorders, many of which are specific to neurology.² Awareness of the prevalence of sleep disorders and the effect they have on neurologic conditions is the first step to managing patients and choosing the most appropriate studies.

Neurologists have a long history of testing brain function with electrophysiologic techniques. The first sleep studies were performed by Hans Berger in 1928 when he recorded “electroencephalograms” of human brain activity that were different when the subject was awake or asleep.³ Gradually a picture of sleep emerged as a state exemplified by high

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amplitude slow waves and spindles, while wakefulness had low amplitude waves and alpha activity. REM sleep was only discovered in 1951 by Nathaniel Kleitman and Eugene Aserinsky observing sleeping infants with eyes darting under closed lids.⁴ This was followed by observations of shortened REM latency in depression and narcolepsy. EEG later became well established as an essential tool in neurology to examine brain activity in both wakefulness and sleep. Routine use of additional monitoring of breathing, heart rate, oxygen saturation, and other physiologic parameters was introduced later when sleep apnea was discovered. This combination of monitoring parameters evolved into the polysomnogram (PSG) we know today, which is still considered the fundamental tool of sleep medicine. Additional sleep testing includes multiple sleep latency test (MSLT), maintenance of wakefulness test (MWT), actigraphy, oximetry, and limited channel testing that is often done at home.

This overview will allow the practitioner to understand the advantages and limits of sleep testing as well as the indications and data obtained from various sleep test procedures to ensure proper implementation of these in clinical practice.

Clinical evaluation

As with many neurologic diseases, in sleep medicine patient history is the cornerstone of diagnosis. Even in patients with vague neurologic complaints such as “fuzzy thinking,” fatigue, lack of energy, or depressed mood there may be an underlying sleep problem. Paresthesia-like symptoms occur in many neurologic conditions including neuropathy or demyelination, but in addition may indicate a sleep disturbance such as restless legs syndrome, especially when symptoms occur in the evening time. A complete neurologic evaluation should include some basic sleep history questions about timing of sleep and daytime sleepiness, dissatisfaction with night sleep, and events that may precede or accompany sleep. If a sleep complaint is identified, a more detailed history is indicated. A family member familiar with the patient's sleep can often provide additional details (table 1). Some sleep conditions, such as adjustment insomnia, can be identified and treated without the use of formal electrographic recordings or medications.

The sleep history may take only a few minutes to complete and helps guide the differential diagnosis. For example, nocturnal spells may not be related to epilepsy but could be related to arousal disorders such as night terrors and sleepwalking that mimic ictal events.

Daytime drowsiness is an especially important symptom, as it may result in fall asleep accidents with serious consequences. The drowsy driver may be sleepy due to sleep deprivation, untreated sleep apnea, narcolepsy, or a side effect from prescription medications.

Once a sleep disorder is suspected, the neurologist should proceed with a sleep evaluation that combines the history with a physical examination (figure 1). The physical examination should include the following key elements: vital signs (blood pressure, pulse and respiratory rates), body mass index, neck circumference, detailed head and neck examination, facial morphology, assessment of the pharynx and nasal passages, and a Malampati score (which measures the crowding of the oral airway based on tongue size relative to oropharyngeal size, see figure e-1).⁵

Sleep diaries are useful tools to quantify a patient's sleep complaints and may suggest a different disorder from what was expected. The American Academy of Sleep Medicine (AASM) has provided a suitable sleep diary template (figure e-2).⁶ The patient who states he or she has not slept in 10 years may have lost the ability to internally measure sleep. Sleep patterns in diaries can point to circadian rhythm disorders or sleep onset or sleep maintenance insomnia. While insomnia is typically a clinical diagnosis and does not require formal sleep

Supplemental Data

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Table 1 Useful sleep history questions

General sleep habits
Bedtime
Sleep onset time
Evening routine
Wake time
Nocturnal awakenings
Timing
Duration
Frequency-associated symptoms
Headache
AM
Nocturnal
Leg movement
Urge to move
Leg discomfort
Periodic limb movement
Painful leg cramps
Dream reenactment behavior
Daytime alertness
Naps
Drowsy driving
Decreased school/Job performance
Sleep paralysis
Hypnagogic hallucinations
Apnea
Snoring
Nasal congestion
Tonsils
Weight change
Gasping
Witnessed apnea
Sleep position
Parasomnia
Timing after bedtime
Sleepwalking
Night terror vs stereotyped
Inappropriate and repetitive ictal behavior
Night eating
Gastrointestinal reflux
Nocturia
Erectile dysfunction
Bruxism
Mood disorder/anxiety

Figure 1 Choosing the right sleep study

The selection of the suitable sleep test, when appropriate, facilitates the workup and treatment of a patient with sleep-related symptoms. Excessive daytime sleepiness related to inadequate night sleep follows a path to the cognitive therapies without necessarily performing an all-night study. Sleep diaries and actigraphy may be useful tools in these patients. Patients with snoring and daytime sleepiness despite adequate night sleep require a polysomnogram (PSG), and if there is a high index of suspicion for sleep apnea (or an insurance requirement), a limited channel home study may be substituted in selected patients. If the ancillary symptoms of narcolepsy are found in the sleepy patient or the initial PSG is negative, a PSG/multiple sleep latency test (MSLT) should be considered to diagnose narcolepsy. It is very important to perform the testing for narcolepsy before stimulant therapy is given as these medications may invalidate the study. AHI = apnea-hypopnea index; ALS = amyotrophic lateral sclerosis; CBT = cognitive-behavioral therapy; CHF = congestive heart failure; DSPS = delayed sleep phase syndrome; MSL = mean sleep latency; PLMS = period limb movements of sleep; RBD = REM sleep behavior disorder; RLS = restless legs syndrome; SOREM = sleep-onset REM period.

testing, sleep maintenance insomnia may indicate sleep disruption due to a comorbid condition requiring additional testing. Figure e-3 provides a flow sheet with a useful algorithm for evaluating the sleepy patient in the office.

Validated sleep questionnaires supplement subjective history:

- Epworth Sleepiness Score is a useful tool to monitor sleepiness longitudinally in an individual patient.⁷
- Berlin Sleep Questionnaire helps identify patients with sleep apnea.⁸
- STOP BANG Questionnaire screens preoperative patients for obstructive sleep apnea (OSA).⁹
- International Restless Legs Syndrome Study Group Rating Scale measures severity of restless legs syndrome.¹⁰
- Insomnia Severity Index evaluates insomnia.¹¹
- Pittsburgh Sleep Quality Index queries sleep quality over the past month.¹²
- Patient Health Questionnaire-9 provides evidence for underlying depression.¹³

Objective testing

At the conclusion of the clinical assessment there is usually a good understanding of the sleep differential diagnosis and what testing will best confirm the clinical impression (figures 1 and e-3). Some of these tests are facility-based and others are ambulatory or home-based (table 2). Four categories of sleep monitoring devices are used in the diagnosis of sleep disorders.¹⁴ Type 1 and 3 are most commonly used.

- Type 1, standard, attended, in-laboratory PSG
- Type 2, comprehensive, portable, unattended PSG

Table 2 Comparison of different sleep testing

Type of sleep test/indication	Location of testing	Video recording option	Extended EEG recording option	Sleep stages	Attended test ^a	Comments
Polysomnography						
Full spectrum of sleep-disordered breathing (e.g., obstructive, mixed, or central sleep apnea)	Facility-based ^b	Optional ^c	Optional ^c	Yes	Yes	
CPAP titration		Optional ^c	Optional ^c	Yes	Yes	
Neuromuscular disorders		Optional ^c	Optional ^c	Yes	Yes	Nocturnal respiratory concerns e.g., in ALS, muscular dystrophy
Parasomnia ^d		Recommended	Recommended	Yes	Yes	Some uncomplicated without injuries parasomnias, such as disorders of arousal, nightmares, enuresis, sleep talking, and bruxism, can usually be diagnosed clinically
Narcolepsy		Optional ^c	Optional ^c	Yes	Yes	The PSG is followed by MSLT
Sleep-related epilepsy		Recommended	Recommended	Yes	Yes	Expanded EEG montage
Periodic limb movements of sleep		Optional ^c	Optional ^c	Yes	Yes	
MSLT						
Narcolepsy	Facility-based	Optional ^c	Optional ^c	Yes	Yes	Often used to correlate EDS with short mean sleep latency
Idiopathic hypersomnia				Yes	Yes	
MWT						
Wakefulness assessment	Facility-based	Optional ^c	Optional ^c	Yes	Yes	
HST						
Selected obstructive sleep apnea	Ambulatory	No	No	No	No	Contraindicated in presence of comorbidities such as cardiac arrhythmias, stroke, coronary artery disease, pulmonary disease (e.g., COPD), or congestive heart failure
CPAP titration		No	No	No	No	In some cases an auto-titrating CPAP device is used combined with HST instead of a standard in-laboratory CPAP titration study
Actigraphy						
Circadian rhythm disorders	Ambulatory	No	No	No	No	Advanced or delayed sleep phase syndrome, free running type

Abbreviations: ALS = amyotrophic lateral sclerosis; CPAP = continuous positive airway pressure; COPD = chronic obstructive pulmonary disease; EDS = excessive daytime sleepiness; HST = home sleep testing; MSLT = multiple sleep latency test; MWT = maintenance of wakefulness test; PSG = polysomnography;

^aSleep technologists are able to respond to observation based on the sleep center protocol and add, e.g., CPAP, video recordings, and administration of oxygen, and respond to emergencies.

^bAlthough ambulatory is possible, the facility-based PSG remains the gold standard.

^cIn certain clinical situations (paroxysmal arousals or seizures), additional EEG derivations and video recording are recommended.

^dInclusive of disorders causing concerns for injury or raising safety issues, such as disorders of arousal from non-REM sleep (significant confusional arousals, sleepwalking, sleep terrors), REM sleep behavior disorder, and sleep-related psychiatric disorders.

Actigraphy provides an acceptably accurate estimate of sleep patterns in normal healthy adult populations and inpatients suspected of certain sleep disorders.

- Type 3, modified portable sleep apnea testing (often cardiorespiratory studies that do not record sleep)
- Type 4, continuous single or dual parameter recording (e.g., oximetry)

Home sleep testing (HST) devices were recently newly classified based on measurements of Sleep, Cardiovascular, Oximetry, Position, Effort, and Respiratory (SCOPER) parameters.¹⁵

Polysonnography The facility-based standard PSG provides the most reliable and complete information for the evaluation of sleep and sleep-related breathing disorders¹⁶ (figure 2). A PSG records central and occipital EEG, surface chin and leg EMG, left and right eye electro-oculograms (EOGs), ECG, snoring, nasal/oral airflow, nasal pressure transducer, thoracic and abdominal effort with respiratory inductance plethysmography belts, pulse oximetry, and body position.⁸ Video can be recorded throughout the night to observe the patient and preserve any behavioral episodes that may occur. Video is subsequently correlated with PSG-recorded sleep-related events such as parasomnias, including RBD, and seizures. The standard PSG montage can be extended by additional EEG electrodes and enhanced further with movement detection in cases of suspected nocturnal movements¹⁶ (figure 2, A–D).

Useful PSG parameters include:

- Total sleep period time (min)
- Sleep efficiency index (%)
- Sleep and REM sleep latency (min)
- Arousal index (number of arousals per hour)
- Wake after sleep onset (min)
- Sleep stages
- Number and index of obstructive/mixed and central apneas (apnea-hypopnea index [AHI])
- Number of respiratory effort–related arousals (RERAs), limitation in breathing that results in increased respiratory effort and culminates in an arousal
- Respiratory disturbance index, which includes the average number of episodes of apnea, hypopnea, and RERAs per hour of sleep
- Minimum oxygen saturation (%)
- Number of periodic limb movements of sleep with and without arousals
- EEG abnormalities
- ECG abnormalities

Indications for PSG include sleep-related breathing disorders, narcolepsy or other hypersomnia, parasomnias, sleep-related seizure disorders, and periodic limb movement disorder. Nocturnal choking or unexplained awakenings during the night may require a PSG. PSG is routinely indicated for the diagnosis of sleep-related breathing disorders and for continuous positive airway pressure (CPAP) titration once the diagnosis is established¹⁶ (figure 2, A–D).

The titration of CPAP is most commonly performed during a PSG, either in a second, separate titration PSG after a baseline recording established OSA or more commonly in a split night study. In a split night study, a baseline recording of sleep parameters and breathing is taken in the first part of the night, followed in the second half of the night by the CPAP titration, requiring the patient to come only once to the sleep center.

Figure 2 Polysomnography samples

Depicted are standard recording montages including the following leads: central (C3-M2, C4-M1), frontal (F3-M2, F2-M1), and occipital (O1-M2, O2-M1) EEGs; left and right eye electrooculograms (EOGs); mental/submental EMG (chin EMG); ECG; snore volume (snoring); nasal pressure transducer (nasal airflow); nasal/oral airflow; arterial oxyhemoglobin saturation (SpO_2); and abdominal and thoracic plethysmography. (A) 30-second epoch of patient in stage N2 sleep with snoring. Note the regular breathing pattern and normal pulse oximetry. (B) Patient in stage N2 sleep with snoring and hypopneas. Note the irregular breathing pattern, EEG arousals, ECG artifact in the EEG, and drops in the pulse oximetry. (C) Patient in stage N3 sleep with periodic limb movements of sleep. (D) 21-year-old patient with Arnold-Chiari Type II malformation, syrinx, and skull-based surgery in stage N2 sleep with central apneas and hypopneas. Note the absence of respiratory effort during the central apnea, rare drops in the pulse oximetry, absence of snoring, and the respiratory arousal-related movements of the legs. CPAP = continuous positive airway pressure.

Multiple sleep latency test The facility-based MSLT includes central and occipital EEG derivations, left and right eye EOGs, mental/submental EMG, and ECG.¹⁷ The MSLT consists of 4–5 nap opportunities performed at 2-hour intervals.¹⁷ The initial nap opportunity begins 1.5–3 hours after termination of the PSG.¹⁷ Sleep onset and REM onset are measured. The MSLT is done to assess excessive daytime sleepiness and support a diagnosis of narcolepsy.¹⁷ It is performed the morning after a PSG. The PSG rules out sleep fragmentation, for example due to sleep-disordered breathing, and assures the patient has slept adequately (at least 6 hours) the night before. Sleep logs, actigraphy, or both may be obtained for 1 week prior to the MSLT to assess sleep-wake schedules. A patient should be free of stimulants or other CNS-acting drugs that affect sleep latency and REM sleep for 2 weeks before the test. Mean sleep latency (MSL) of 10 minutes or more is not supportive of significant sleepiness, while an MSL of less than 8 minutes is suggestive of excessive sleepiness. To diagnose narcolepsy a patient should also have 2 or more sleep-onset REM periods (SOREMs). Afternoon SOREMs are more significant than those occurring during the first or second MSLT naps. However, the MSLT alone is not pathognomonic for narcolepsy and must be interpreted in the context of other clinical symptoms (figure e-3).

Maintenance of wakefulness test The facility-based MWT is performed with the same recording setting as the MSLT.¹⁷ The 4-trial MWT consists of 40-minute trials performed at 2-hour intervals, with the first trial beginning about 1.5–3 hours after the patient's usual wake-up time.¹⁷ The main difference from the MSLT is in the instruction to the patient; for the MWT, patients are instructed to stay awake during the study periods. The trial is terminated after 40 minutes or if the patient unequivocally falls asleep. Although the MWT provides an objective, validated assessment of the ability to remain awake for a defined length of time,¹⁷ the normative values are less universal. The MWT may be indicated in patients with excessive sleepiness to assess response to wake-promoting treatment. It is used less commonly than the MSLT. It is most often requested by employers concerned about their employees' ability to stay awake on the job.

Home sleep testing devices Type 3 sleep monitoring devices, also known as HST devices, are used unattended in the home of the patient. A minimum number of channels include oronasal air-flow, respiratory effort, and blood oxygenation.¹⁵ HST does not record sleep, and statistics such as the AHI are calculated assuming the patient slept for the duration of the recording.¹⁵ This can lead to an underestimate of respiratory events. Therefore, an HST can be performed in the setting of moderate- to high-likelihood OSA in the absence of comorbid conditions (e.g., intrinsic lung disease, neuromuscular conditions, or other sleep disorders).¹⁵ HST is approved by the Centers for Medicare & Medicaid Services due to studies demonstrating that an ambulatory approach is equivalent to in-laboratory testing in terms of adherence to positive pressure therapy and resolution of sleep apnea symptoms in patients with a high pretest probability of OSA.¹⁸ HST should be performed under the auspices of an AASM-accredited comprehensive sleep medicine program.¹⁵ HST is not appropriate for the diagnostic evaluation of OSA in patients suspected of having other sleep disorders, including central sleep apnea, periodic limb movement disorder, insomnia, parasomnias, circadian rhythm disorders, or narcolepsy (figure 1).¹⁵

Contraindications to home sleep study:

- Patient is 18 years old or younger
- Moderate or severe chronic obstructive pulmonary disease
- Moderate or severe congestive heart failure—New York Heart Association class III or IV
- Cognitive impairment (inability to follow simple instructions)
- Neuromuscular impairment
- Suspicion of a sleep disorder other than OSA (e.g., central sleep apnea, narcolepsy, restless legs syndrome, circadian rhythm disorder, parasomnias, periodic limb movement disorder)
- Previous technically suboptimal home sleep study (2 nights of study attempted)
- Previous 2-night home sleep study that did not diagnose OSA in a patient with ongoing clinical suspicion of OSA
- Patient is oxygen-dependent for any reason
- History of cerebrovascular accident within the preceding 30 days
- History of ventricular fibrillation or sustained ventricular tachycardia

HST may be indicated for the diagnosis of OSA in patients for whom in-laboratory PSG is not possible by virtue of immobility, safety, or critical illness.¹⁵ HST may be indicated for monitoring the response to non-CPAP treatments for OSA, including oral appliances, upper airway surgery, and weight loss.¹⁵ Practice patterns in sleep medicine have had to adapt to the changing climate of regulation from government and commercial payers.¹⁹

Actigraphy Actigraphy measures movement of a limb and uses advanced algorithms in the data analysis to suggest a “sleep pattern.” Periods of movement are interpreted as wake and lack of movement implies sleep. Actigraphy provides an acceptably accurate estimate of sleep patterns in normal healthy adult populations and inpatients suspected of certain sleep disorders.²⁰ More specifically, actigraphy may be useful in the evaluation in patients with circadian rhythm disorders, advanced sleep phase syndrome, delayed sleep phase syndrome, and

shift work disorder.²⁰ However, actigraphy does not measure sleep as it is commonly defined. To be most useful, actigraphy should be used in combination with sleep diaries or sleep logs that describe the subjective experience of sleep.

Pulse oximetry Pulse oximetry was, in the early years of pulmonary medicine, a common tool to identify Pickwickian syndrome (a condition combining obesity, hypoventilation, and somnolence) or severe sleep apnea syndrome by detecting the sawtooth pattern on oxygen desaturation waveforms (waveform derived as a plot of SaO_2 vs time).^{21,22} It is now used mostly to ensure CPAP therapy has adequately corrected oxygen desaturation in a severe or complex sleep apnea patient. Although isolated overnight oximetry is widely used in respiratory conditions, it does not allow for sufficient assessment of sleep disorders (figure 1).

CONCLUSION

A fundamental key to recognizing sleep disorders is to include a sleep history as a portion of a standard neurologic evaluation. Sleep disorders are highly prevalent in the population as a whole and more so in patients with neurologic disease. Having identified a sleep complaint, a more detailed history helps refine the differential diagnosis. Sleep testing is an essential adjunct to our clinical examination in diagnosing sleep disorders.

Attended in-lab PSG remains the most useful tool to observe and measure sleep and nighttime sleep events. The PSG can analyze the physiologic data from brain, respiratory, cardiac, and muscular systems, aided by the accompanying visual recording and technician observations. Thus, an accurate diagnosis can be made by combining clinical and technical findings.

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