Polysomnography (PSG): Indications, Technique & Sleep Scoring

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PSG: HISTORICAL OVERVIEW

Polysomnography (PSG) is the monitoring of physiological parameters and physiological or pathological events in sleep.

Electroencephalographic (EEG) activity in wakefulness and in sleep in humans was initially described in 1928.[1] The earliest overnight sleep studies were performed in the 1930s using a polygraph to record EEG activity and electro-oculograms (EOG) on paper.[2] Major milestones in the history of sleep medicine include the identification of rapid eye movement (REM) sleep in 1953, the description of normal sleep cycles in 1957 dividing sleep into non-REM and REM periods, and the recording of muscle atonia in REM sleep.[3,4,5]

Current PSG techniques are based on the parameters used in the widely accepted standard scoring system for sleep stages outlined by Rechtschaffen and Kales in1968.[6] Modern PSG involves monitoring and recording EEG, EOG, electromyography (EMG) and other physiologic data used to analyze sleep architecture, cardiopulmonary function and limb movements in sleep.

INDICATIONS FOR PSG

Polysomnography is useful in the diagnosis, therapy and follow up of sleep related disorders. The International Classification of Sleep Disorders divides sleep related disorders into 3 major categories: [7]

(1) Dyssomnias: Disorders of initiating and maintaining sleep, and disorders of excessive daytime sleepiness. These include intrinsic sleep disorders (eg. narcolepsy, sleep apnea, restless legs syndrome (RLS), periodic limb movement disorder (PLMD), extrinsic sleep disorders (eg. related to sleep hygiene or sleep environment) and circadian rhythm disorders (eg. shift work sleep disorder, jet lag, delayed sleep phase syndrome).
(2) Parasomnias: Abnormal movements and behaviours occurring in sleep. These include arousal disorders (eg. confusional arousal, sleep walking, sleep terrors), sleep-wake transition disorders, REM-sleep related parasomnias
(3) Sleep Disorders Associated With Medical or Psychiatric Disorders.

Not all sleep related disorders require a PSG for diagnosis. PSG should not be routinely used to screen or diagnose patients with insomnia. There are no absolute contraindications to PSG, nor any serious safety issues. The usual indications for PSG are to investigate excessive daytime sleepiness (looking for disturbances in sleep architecture) and abnormal movements in sleep (to rule out epileptiform activity and record parasomnias), and for Continuous Positive Airway Pressure (CPAP) titration. Less

frequently performed are the special studies such as nocturnal penile tumescence for erectile dysfunction and pH studies for gastroesophageal reflux. Guidelines have been published describing the indications for PSG. [8,9,10]

PSG FOR DIAGNOSIS

a. To record and quantify apneas in suspected sleep related breathing disorders when sleep related symptoms are present, eg. snoring, witnessed apneas, awakening with choking sensations, shortness of breath, excessive daytime sleepiness and morning headaches.

b. To evaluate abnormal sleep patterns like difficulty initiating or maintaining sleep, frequent arousals, restless sleep, and unrefreshing sleep with resultant excessive daytime sleepiness. PSG is not routinely indicated in these settings, many types of insomnia can be diagnosed with a good sleep history alone.

c. To record and quantify leg movements in the wakeful period before sleep onset, and excessive movements disrupting sleep eg. in suspected RLS and PLMD

d. To record suspected parasomnias in non-REM sleep (eg. Confusional arousals, sleep terrors), and REM sleep (eg. REM-sleep behaviour disorder), and to rule out epileptiform activity in these settings.

e. To evaluate suspected sleep state misperception, to confirm subjective perception of sleep quality.

f. To rule out other causes of excessive daytime sleepiness in suspected narcolepsy (typical tetrad: sleep attacks, cataplexy, hypnagogic hallucinations and sleep paralysis). A multiple sleep latency test (MSLT) is an essential adjunct to PSG for this diagnosis, typically showing two or more sleep onset REM periods.

g. Re-evaluation of recurrent symptoms after initial improvement with CPAP therapy, weight loss or surgery.

h. Other indications include: Evaluation of gastroesophageal reflux (PSG with gastroesophageal pH monitoring), impaired erectile function (PSG with a nocturnal penile tumescence study) and unexplained nocturnal events (PSG with extended EEG montage and video recording).

PSG FOR GUIDING THERAPY

a. CPAP titration in patients with sleep related breathing disorders.

b. A combination of diagnostic overnight PSG and CPAP titration, the "Split-Night Study". This option is not ideal because of the shorter recording time for sleep related respiratory events and the shorter time for accurate positive airway pressure titration.

c. Pre-operative evaluation before somnoplasty for snoring, to rule out sleep apnea.

d. Re-evaluation of CPAP requirement after significant weight loss or upper airway surgery.

PSG FOR FOLLOW-UP

    a. Follow-up PSG after medical (eg. weight loss, oral appliances) or surgical intervention for sleep apnea, to document normalization of apnea-hypopnea index.
    b.. Follow-up PSG after pharmacotherapy for movement disorders in sleep, to document reduction in or abolition of abnormal movements eg. periodic limb movements in sleep.

LIMITATIONS OF PSG

There are several limitations of polysomnography such as the wide variation in quantitative sleep variables for different age groups, the paucity of PSG data in the pediatric population for use as controls, the first night effect (decreased sleep efficiency and quality due to sleeping in an unfamiliar environment and the discomfort of being hooked up to recording equipment), the use of common drugs which can affect normal sleep (eg. antidepressants, sedatives, stimulants), and the lack of consensus on scoring criteria for respiratory events and differences in recording techniques among sleep laboratories. Ideally each laboratory should study its own control subjects to establish norms and to identify any significant variations in sleep patterns between laboratories due to differences in the recording technique or the laboratory environment. A study may have to be repeated if findings from a single overnight PSG are ambiguous, or if inadequate representative sleep is recorded for accurate quantitative and qualitative analysis.

POLYSOMNOGRAPHY: RECORDING TECHNIQUE AND SLEEP SCORING

RECORDING TECHNIQUE

The polygraph is an instrument which records data which is amplified and converted to a digital signal. Computer based digital systems facilitate data storage, scoring and interpretation of sleep studies. Data is recorded from the electroencephalogram (EEG), the electro-oculogram (EOG), the electromyogram (EMG), the electrocardiogram (ECG), the airflow channel, respiratory effort channels, the snore microphone and pulse oximeter. Audiovisual (including video-EEG) recording is added when parasomnias, seizures or other paroxysmal events are suspected.

The ground electrode is placed on the patient's forehead. A minimum of 4 channels is needed to study sleep architecture (1 EEG, 2 EOG and 1 EMG), but usually more channels (12-16) are used in the routine PSG. High quality amplifiers and filters are used to enhance signals of interest and minimize artifacts. Calibration should be performed at the beginning and the end of the study.

The EEG filter is set to include slow activity such as slow wave sleep ($\leq$ 2 Hz) and exclude high frequency interference, such as 60 Hz or EMG artifacts. Filters ranging from 0.5 to 30 Hz are typically used in EEG recording. EOG filters have a narrower range to visualize rapid eye movements (REMs) (>1Hz) and slow eye movements

(SEMs) (0.25 to 0.5 Hz). EMG filters have a higher range to prevent interference from slow wave activity.

EEG electrode placement is based on the International 10-20 system. Only one channel (C3/A2 or C4/A1) is required to score sleep stages. Referencing C3 or C4 to an indifferent electrode (A1 or A2), frequently to the contralateral side, increases signal amplitude, which facilitates identification of EEG waveforms used to stage sleep (eg.vertex waves, K-complexes, sleep spindles, high voltage slow waves). The addition of O1/O2 derivations helps to assess the posterior background rhythm and also serves as a back-up for the other EEG electrodes.

Electro-oculography (EOG) detects rapid eye movements (REMs) and slow eye movements (SEMs). Rapid eye movements occur in phasic bursts and are a defining feature of REM sleep. Rapid eye movements (including blinking) are also seen in wakefulness and help to identify the awake stage when background activity is not well defined. Slow eye movements occur in the transition from wakefulness to drowsiness and are helpful in defining stage 1 non-REM sleep.

EMG recording of muscle activity is useful in several ways. The most important is the chin EMG which monitors the axial muscle tone, useful in distinguishing REM (when muscle tone is the lowest of the study) from non-REM sleep stages (when muscle tone is relatively elevated), and identifying movement arousals in REM sleep. EMG activity in the leg (tibialis anterior) and forearm (extensor digitorum) muscles reflects excessive leg and arm movements in wakefulness and in sleep. These are quantified as periodic limb movements in wake or sleep (PLMW/PLMS).

Respiratory effort is measured using thoracic and abdominal belts for chest and abdominal wall movements. Airflow is measured usually with nasal thermistors or nasal pressure transducers. Pulse oximetry, capnography and ECG give additional useful information in evaluating apneas. The presence of oxygen desaturation, hypercarbia or arrhythmias helps assess severity of disease.

PSG features of normal sleep are summarized in Table 1.

Common scoring definitions are summarized in Table 2.

Table1. PSG FEATURES OF WAKEFULNESS & SLEEP

	EEG	EOG	EMG
AWAKE	Reactive posterior background rhythm (α frequency: 8-13 Hz)	REMs	Elevated, tonic EMG activity
STAGE 1 Drowsy (comprises 5-10% of total sleep time)	Decreased background activity Low voltage mixed frequency (LVMF) background activity (2-7Hz) Vertex waves (biphasic sharp transients, maximal centrally)	SEMs	Tonic EMG activity, less than in the awake state
STAGE 2 (30-50% of total sleep time)	LVMF background activity Sleep spindles (waxing & waning, 12-14 Hz, > 0.5s long) K-complexes (biphasic vertex waves, > 0.5s long)	No eye movements	Low level tonic EMG activity
STAGE 3	20% - 50% high voltage slow wave (HVS) activity HVS: < 2 Hz, amplitude > 75µV measured in the central EEG channels (C3/A2 or C4/A1)	No eye movements	Low level tonic EMG activity
STAGE 4 (With stage 3 comprises 20-25% of total sleep time)	>50% HVS activity comprising of an epoch Sleep spindles and K complexes may occur infrequently	No eye movements	Low level tonic EMG activity
STAGE REM (20-25% of total sleep time)	LVMF background activity "Sawtooth waves" : 2-5 Hz negative vertex waves usually occurring with phasic REMs	Phasic REMs (occur with bursts of phasic EMG)	Absent or low level tonic EMG, lowest EMG activity of the whole study

Table 2. SCORING DEFINITIONS

Arousal	An abrupt EEG frequency shift (α or θ frequency or > 16 Hz, not including spindle frequency) $\geq$ 3s long, preceded by $\geq$ 10s of sleep Arousals in REM sleep are scored only when the chin EMG amplitude also increases concurrently Arousals may or may not be associated with body movements or respiratory events
Apnoea	Absence of or > 90% decrease in airflow compared to baseline lasting $\geq$ 10s Classified as central, obstructive or mixed
Hypopnoea	Any of the following respiratory events lasting $\geq$10s are scored: $\geq$ 50% reduction of airflow $\geq$ 30% reduction of airflow (but <50%) associated with $\geq$ 4% oxygen desaturation
Movement time	Scored only during sleep when > 50% of an epoch is obscured by movement artifact
Limb movements	Periodic limb movements (jerks) are scored in sleep only when there are $\geq$ 4 limb movements in sequence occurring > 5s but < 90s apart. A limb movement is an increase in the EMG activity lasting 0.5 to 5s with an amplitude > 25% of the burst of EMG activity recorded during biocalibration.

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