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POLYSOMNOGRAPHY: A COMPREHENSIVE REVIEW

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ABSTRACT
Polysomnography (PSG) is a diagnostic methodology that records and interprets a wide array of physiological signals during sleep. It plays a central role in evaluating sleep-related disorders, especially obstructive sleep apnea (OSA), periodic limb movement disorder (PLMD), and narcolepsy. By capturing neural, muscular, cardiac, and respiratory activity overnight, PSG provides critical insights into sleep architecture and disturbances. With recent technological advancements, including portable monitoring systems and artificial intelligence (AI)-based scoring tools, PSG has become more accessible and precise. This review explores the essential components, applications, and emerging innovations in PSG.

KEYWORDS: Polysomnography, Obstructive Sleep Apnea, Sleep Architecture, Portable Sleep Testing, Neurophysiological Monitoring, Sleep Disorders.

INTRODUCTION

Polysomnography (PSG) serves as a cornerstone in the clinical evaluation of sleep-related conditions, offering a detailed physiological profile of a patient's sleep cycle. Since its inception in the 1960s, PSG has evolved into a multi-channel diagnostic technique capable of identifying complex sleep disturbances such as obstructive sleep apnea (OSA), central sleep apnea, REM behavior disorder, and periodic limb movement disorder.[1] By synchronously measuring brain activity, eye movements, muscle tone, respiratory effort, airflow, and blood oxygen levels, PSG facilitates a comprehensive understanding of sleep architecture and pathology. Despite emerging technologies and portable alternatives, PSG continues to be recognized as the most reliable method for diagnosing and characterizing sleep disorders, forming the basis for effective therapeutic planning.[2]

COMPONENTS OF POLYSOMNOGRAPHY

Polysomnography captures a range of physiological data streams simultaneously to evaluate sleep quality and detect abnormalities. Each component offers insight into a specific aspect of the sleep cycle:

Electroencephalography (EEG): EEG readings help distinguish between different sleep stages by analyzing frequency and amplitude of brain wave activity.[3]

Electrooculography (EOG): EOG tracks eye movement, allowing identification of REM versus non-REM sleep phases.[4]

Electromyography (EMG): EMG measures muscle tone, particularly in the chin and limbs, aiding in the diagnosis of REM sleep behavior disorder and limb movement disorders.[5]

Electrocardiography (ECG): ECG provides heart rate and rhythm information, assisting in detecting nocturnal arrhythmias.[6]

Airflow Monitoring: Devices such as nasal cannulas and thermistors monitor the passage of air to identify apneas and hypopneas.

Respiratory Effort Sensors: Chest and abdominal belts track thoracoabdominal movements, distinguishing between obstructive and central apneas.[7]

Pulse Oximetry: SpO_2 sensors measure blood oxygen saturation, helping assess the severity of respiratory disruptions.[8]

TYPES OF POLYSOMNOGRAPHY

Polysomnography is categorized into four main types based on the complexity of monitoring and the environment in which the study is conducted. These classifications help tailor diagnostics to the clinical needs and accessibility of the patient:

Type I: This is the traditional in-lab polysomnography performed under direct supervision of a sleep technician. It includes a full montage of EEG, EOG, EMG, ECG, airflow, respiratory effort, and oxygen saturation. It is the the benchmark for comprehensive sleep analysis.[9]

Type II: Conducted in a home setting, Type II PSG includes the same range of parameters as Type I but is unattended. It provides similar diagnostic capabilities with improved comfort and convenience.
Type III: Often referred to as home sleep apnea testing (HSAT), this type records at least four parameters such as airflow, respiratory effort, heart rate, and SpO_2. It is commonly used for screening moderate to severe obstructive sleep apnea.[10]
Type IV: A limited study that typically involves one to three channels, such as oxygen saturation and airflow. While useful for initial screening, it lacks the specificity and breadth for definitive diagnosis.[11]

Type	Setting	Parameters Recorded	Technician Present	Clinical Use
Type I	Sleep Lab	EEG, EOG, EMG, ECG, airflow, respiratory effort, SpO_2	Yes	Gold standard for comprehensive evaluation
Type II	Home	Same as Type I	No	Alternative to in-lab PSG
Type III	Home	≥4 channels (airflow, effort, heart rate, SpO_2)	No	Moderate to high probability of OSA
Type IV	Home	≤3 parameters	No	Preliminary screening

CLINICAL APPLICATIONS

Polysomnography is integral in the evaluation of a variety of sleep disorders. The data obtained during monitoring guide diagnosis and treatment decisions across several clinical scenarios:
Obstructive Sleep Apnea (OSA): PSG identifies episodes of airway obstruction, accompanied by oxygen desaturation and microarousals. It determines the apnea-hypopnea index (AHI), essential for grading severity.[12]

Central Sleep Apnea (CSA): Characterized by absence of respiratory effort during sleep, CSA is distinguishable via PSG and is often associated with cardiac or neurological conditions.[13]

Narcolepsy: PSG followed by a Multiple Sleep Latency Test (MSLT) confirms the diagnosis by demonstrating rapid sleep onset and abnormal REM latency.[14]

REM Sleep Behavior Disorder (RBD): PSG detects sustained muscle tone during REM sleep, which is otherwise normally absent, helping differentiate RBD from other parasomnias.[15]

Periodic Limb Movement Disorder (PLMD): Repetitive limb movements are recorded and quantified to assess their impact on sleep continuity and quality.[5]

RECENT TECHNOLOGICAL ADVANCEMENTS

1. Portable and Home-Based Monitoring

With increasing emphasis on accessibility and patient comfort, portable PSG systems and home sleep apnea tests (HSAT) have gained popularity. These tools enable patients to undergo sleep studies in familiar environments, reducing first-night effects and logistical barriers. While in-lab PSG remains more comprehensive, studies show that home-based devices can provide comparable diagnostic accuracy in patients with a high pretest probability of moderate to severe OSA.[16]

2. Artificial Intelligence and Automated Scoring

AI-driven algorithms are becoming instrumental in streamlining the scoring of sleep studies. Deep learning networks now assist in automating sleep stage classification, respiratory event detection, and artifact rejection. These tools not only reduce the time required for manual review but also improve inter-scorer consistency. Although AI is not a replacement for human oversight, it serves as a valuable adjunct in clinical workflows.[17,18]

3. Wearable and Multimodal Sleep Technology

Wearables such as headbands, smartwatches, and under-mattress sensors have advanced significantly. Devices incorporating EEG, PPG, accelerometers, and acoustic sensors offer sleep-related insights beyond simple actigraphy. While not yet a substitute for PSG, these innovations are useful for longitudinal sleep monitoring and screening, particularly in resource-limited settings or for population-level studies.[19]

4. Integration with Personalized Medicine

Multi-parametric sleep databases allow for the development of individualized profiles, aiding in early detection and tailored therapy. This includes integrating genetic markers, circadian rhythm data, and lifestyle information.[20]

CONCLUSION

Polysomnography remains an indispensable tool in the diagnostic arsenal for sleep medicine. With advancements in home-based testing, AI integration, and wearable technology, the accessibility and accuracy of PSG continue to improve. However, standardization and validation remain crucial to maintaining diagnostic fidelity. As sleep disorders gain recognition for their impact on public health, innovations in PSG will play a vital role in personalized and preventive sleep medicine.

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to the content of this review article.

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