REVIEW ARTICLE

How to interpret the results of a clinical polysomnogram

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Abstract

Heightened public awareness of sleep disorders has significantly increased the demand for sleep studies. There is ever increasing number of sleep studies being done and report of the results are shared by the sleep specialists and the primary care physicians. Understanding the information discussed in the overnight sleep study report is crucial as it provides significant insight into the sleep pathophysiology in relation to patient symptoms. The purpose of this article is to provide a simple and easy method to interpret the reported results of polysomnography for the physicians and other health care providers. This will facilitate better understanding of the underlying pathophysiology of the sleep disorder and appropriate management of patients.

Introduction

Polysomnography, popularly known as the "Sleep study" has been used for decades to diagnose and quantitatively evaluate the severity of sleep disordered breathing. Since there is heightened public awareness of sleep disorders, recently there is a significant increase in the demand for sleep-related evaluations and resultant sleep studies. Sleep disordered breathing is a common public health problem affecting up to 4% of middle-aged adults[1]. The potential life-threatening cardiovascular[2], neurocognitive and metabolic complications[3] related to untreated sleep disordered breathing have intensified the need for making an early diagnosis. Increasing number of referrals is made to the sleep specialists by the primary care physicians. Once the test is done the report of the sleep study is sent to the primary care physician with the treatment recommendation. Currently, there is no standardization of the report processing and formatting; reports are more or less based on certain elements that provide quantitative information regarding the patient's sleep and its deviation from the normal. The primary care physician's understanding of these results is instrumental in continuous management of the patients. This article intends to provide a simple and easy method to interpret reported results of the polysomnography.

The sleep study reports are typically arranged in sections containing patient information, which includes their qualifying sleep related symptoms, that constitute the indications for the testing, the technical details, quantitative data regarding distribution of different stages of sleep called sleep architecture and sleep staging.

The technical details document the number of electroencephalographic (EEG), electro-oculogram (EOG), Chin and leg electromyogram (EMG), electrocardiogram channels and their activity. The air flow is measured at the nose and mouth by a pressure transducer and a thermistor. The chest and abdominal wall movements are recorded by plathysmographic strain belts. The oxygen saturation is sampled by continuous pulse oximetry and the snoring microphone is used for recording the snoring and its intensity. Multiple simultaneous parameters are recorded using the electrodes and belts arrangement called a Montage. The

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indications for the study are recorded in the context of patient complaints, history, medical, psychosocial and sleep-related problems as well as their medications. Each of these elements has a significant impact on the recording of the data and the interpretation of the sleep study.

Next section of the report generally includes the sleep architecture; that includes total recording time and/or time in bed along with total sleep time. The *total recording time* is the total amount of time during which the patient is in bed with recording equipment activated. The amount of time actually spent in bed is important limiting factor for the total sleep time and sleep stages. A patient who spends only three to four hours in bed cannot reasonably accumulate normal amounts of sleep and may not go through all normal stages and cycles of the sleep. Therefore, a low total time in bed may be of clinical significance and may suggest a diagnosis of insufficient sleep.

Time since the lights are turned off (Lights out) as patient attempts to sleep, to the time patient actually falls asleep as evidenced by EEG and behavioral parameters changes consistent with sleep is reported as *sleep latency*. Sleep latency is the time in minutes from "lights out" that marks the starting of total recording time to the first epoch scored as sleep. Sleep latency is perhaps one of the important parameters. Sleep latency also indicates if reasonable attention was given to the patient's sleep diary and the "lights out" time was reasonably close the patient's habitual bedtime at home. Clearly, if the lights are turned out earlier than the patient's usual bedtime, sleep latency would be spuriously long, and the patient may not fall asleep until his usual sleep time is reached. Similarly, if the "lights out" time is later than the patient's usual bedtime, the patient will be sleepy, and spuriously short sleep latency will be recorded. It is of utmost importance that the patient's usual habitual sleep time is incorporated into the patient's sleep study design and "light out" time is matched with it.

The *total sleep time* is the total amount of sleep scored during the total recording time. This includes time from sleep onset to sleep offset and is distributed through out the sleep time as minutes of Stage N1 sleep, Stage N2 sleep, Stage N3 and REM sleep. All these times are described in minutes. A low total sleep time may be of clinical significance and indicate that the patient slept for an insufficient period of time due to non-medical/ non-physiological reasons, certain medical or sleep disorders or as a result of effect of the medications. Long total sleep time may suggest prior sleep deprivation, medical conditions or effects of the medication. High levels of sleep fragmentation, as defined by recurrent awakenings and/ or frequent stage shifts may result in complaints of non-restorative sleep even when an apparently normal total sleep time is present.

Sleep efficiency is another important parameter that refers to percentage of total time in bed actually spent in sleep. It is calculated as sum of Stage N1, Stage N2, Stage N3 and REM sleep divided by the total time in bed and multiplied by 100. Sleep efficiency gives an overall sense of how well the patient slept, but it does not distinguish frequent, brief episodes of wakefulness. A low sleep efficiency percentage could result from long sleep latency and long sleep offset to lights on time with otherwise normal quantity and quality of sleep in between. Many laboratories report *total wake time*, that is, the amount of wake time during the total recording time in minutes after the sleep onset. The total amount gives a general estimation for overall quality of sleep. Total wake time is the reciprocal of total sleep time. A high total sleep time percent is always associated with low total wake time percent and vise versa.

An important reported parameter is *wake after sleep onset*, also known as "WASO". This refers to periods of wakefulness occurring after defined sleep onset. This parameter measures wakefulness, excluding the wakefulness occurring before sleep onset. Wake after sleep onset time is a better reflection of sleep fragmentation.

Wake time after sleep offset is known as "WASF" and refers to wakefulness that occurs after sleep offset. Long periods of wakefulness following an atypically early morning awakening could be consistent with one of the classic manifestation of depression. This can be found in elderly patients who have no difficulty in falling asleep but wake up after three to four hours of sleep and are unable to return to sleep. This pattern may be seen in patients who suffer with depression or anxiety and possibly an effect of medications.

Another crucial reported parameter is *rapid eye movement latency* also known as REM latency. Rapid eye movement latency is the time from the sleep onset to the first epoch of REM sleep; therefore, it depends on the patient's sleep latency. The REM sleep cycles every 90 to 120 minutes intervals throughout the night. The

changes in REM sleep latency are considered potential biological markers for a number of sleep-related disorders. The REM sleep is very sensitive to the affects of medication, sleep deprivation and circadian rhythm disorders. The knowledge of patients' current medications and the quality of sleep the night before the sleep study therefore, is extremely important to review. The short REM latency may result from withdrawal from tricyclic antidepressants or MAO inhibitor medications. Amphetamines, barbiturates and alcohol have a similar effect. Patients with a history of narcolepsy, sleep apnea and depression may also have short REM latency. Similarly, long REM latency may result from use of REM-suppressing medications, including tricyclic antidepressants, MAO inhibitors, amphetamine, barbiturates and alcohol. Sleep apnea and periodic limb movement of sleep, as well as first night effect can also lead to long REM sleep latency.

Sleep study report describes the percentages of various sleep stages. The normal percentage of each stage is reported with the number of total REM Stage sleep cycles recorded over night. In adults, approximately 5% of the total sleep time is Stage N1; 50% Stage N2 and 20% is Stage N3 sleep. The remaining 25% is REM stage sleep[4, 5].

Non-rapid eye movement sleep

Sleep staging is described in a separate section of the report. Stage N1 sleep is associated with the transition from wakefulness to sleep and is considered a direct measure of daytime alertness and the subjective refreshing quality of the sleep. The quantity and the percentage Stage N1 sleep is an estimate of the degree of sleep fragmentation. A high percentage of the Stage N1 sleep is generally a result of frequent arousals caused by sleep disorders, like sleep apnea, periodic limb movement of sleep or snoring. The other causes of sleep disruption, including the environmental disturbances as well as the first-night effect may also lead to increased amount of Stage N1 sleep.

Stage N2 sleep predominate the sleep stages with 50% of the total sleep time. It follows the Stage N1 sleep and continues to recur throughout the night. Low percentage of Stage N2 sleep may be a result of sleep fragmentation, increased REM or slow wave sleep N3 or a result of obstructive sleep apnea related arousals. Increased amount of Stage 2 sleep may also be noted in age-related changes in sleeping pattern and may be a result of medication effect.

Stage N3 is considered the deep sleep. It is sometimes referred as slow wave sleep. The Stage N3 sleep generally cycles frequently in the first third of the night and begins to reduce towards the second half of the night. A high amount of Stage N3 sleep is noted during the rebound sleep such as recovery sleep after sleep deprivation, initiation of nocturnal CPAP treatment or treatment of periodic limb movement syndrome. Less amount of Stage N3 sleep is noted as a side effect of certain medications including benzodizapines, tricyclide antidepressants and barbiturates. The episodes of night terror sleep walking, sleep talking and confusion arousals also occur during the Stage N3 sleep[6]. Stage N3 sleep is also known to suppress the occurrence of sleep-disordered breathing[7].

Rapid-eye movement sleep

The exact function of the rapid-eye movement sleep (REM) is uncertain. However, it occupies approximately 25% of the total sleep time. The REM sleep cycles every 90 to 120 minutes throughout the night with progressively increasing periods of cycle time. REM sleep is associated with more frequent and longer duration apneas, hypopneas and severe hypoxemia. REM sleep suppresses periodic leg movements of sleep[8]. Certain medications suppress the REM sleep include amphetamines, barbiturates, tricyclide antidepressants, MAO inhibitors, anticholenergics and alcohol. Certain sleep disorders, including sleep apnea, REM behavior sleep disorders and nightmares occur in REM sleep. High amount of REM sleep is noted during recovery sleep after selective deprivation of REM sleep. REM sleep rebound occurs after discontinuation of REM sleep suppressing medications, alcohol and initiation of continuous positive airway pressure (CPAP) therapy.

Respiratory data reporting

The respiratory data section of the report describes respiratory data including all the episodes of apneas lasting over 10 seconds, hypopneas lasting over 10 seconds, central and mixed apneas. The *obstructive apnea hypopnea index* (OAHI) is calculated based on the sum of total numbers of apneas and hypopneas divided by the total number of hours of sleep. The obstructive apnea hypopnea index is considered normal if it is less than 5

events per hour, and abnormal in the range of mild from 5 to 14 events per hour, moderate 15 to 30 events per hour and severe over 30 events per hour.

The effort to breath is recorded by the chest and abdominal belts. In normal breathing the chest and abdomen move in and out in synchrony but during the periods of airway obstruction the paradoxical movements are noted in these parameters. This movement correlates with the flow of air in and out of nose and mouth while the flow or pressure changes are monitored by special cannula, the thermistor and the pressure transducer, placed at nostrils and mouth. The report describes these observations especially in cases of upper airway resistance syndrome (UARS), also called "respiratory effort related arousals" or RERA. When the reduction in the airflow is present without any oxygen desaturations and the increasing effort to breath is documented by the chest and the abdominal belts along with simultaneous termination of the event by a cortical arousal recorded in the EEG. This disorder is associated with fragmented sleep due to arousals throughout the night and may cause significant daytime sleepiness. When RERAs are included in the apnea-hypopnea index (AHI), it is reported as respiratory disturbance Index (RDI)[9].

The sleep study reports generally describe the oxygen saturation data recorded by a calibrated pulse oximeter and report baseline oxygen saturation as well as the lowest oxygen saturation recorded during the night. There is a detailed description of desaturation episodes described in relation to the sleep stages and the percent of time the desaturation lasted. This data gives a sense of patient's exposure to oxidative stress and the risk of developing cardiovascular and metabolic complications.

Cardiac data reporting

Electrocardiograms are routinely recorded using a single lead during a full night diagnostic and therapeutic polysomnogram. Cardiac arrhythmias are common findings during normal sleep and with sleep-disorder breathing. The most common finding is sinus arrhythmia noted during the normal breathing. Bradycardia-tachycardia is common with sleep disordered breathing. In general, bradycardia relates to the episode of apnea, followed by tachycardia during resultant arousal. The sinus pauses less than 3 seconds, bradycardia with rates over 30 beats per minute and Type 1 Second degree heart block also known as Mobitz I or Wenckibach block are generally considered normal during the sleep. Other arrhythmias if observed are mentioned in the report include 3rd degree AV block associated with asystole over 3 seconds, 3rd degree block with bifascicular or trifascicular block, Type 2 Second degree heart block also known as Mobitz' II block that require immediate attention of the sleep physician. A variety of other abnormal rhythms include atrial fibrillation, atrial or ventricular bigeminy and atrial and ventricular premature contractions are noted during the PSG recording. Many of these arrhythmias are benign in nature. Sleep laboratories have protocols for responding to these observations especially if potentially life threatening arrhythmias are noted.

Body Position Data

Body position is recorded throughout the sleep period, as it significantly affects the frequency, duration and severity of the sleep disorder breathing. The supine body position is important because of the gravitational affects. Sleep apnea may occur primarily in supine position and is referred as positional sleep apnea. A combination of REM sleep and supine position is important during the CPAP titration studies as most obstructive apneas and hypopneas tend to occur in this setting.

Muscle movements and bruxism data

Sleep study report describes the recording of movements in sleep. Leg movements recorded on anterior tibialis muscle and chin movement on masseter muscle are generally present while the person is awake and has normal tone in the skeletal muscles. The muscle tone is reduced while the person is asleep in non-REM sleep and absent is REM sleep. Periodic leg movements in sleep are bursts of EMG activity measured in the anterior tibialis muscle. These leg movements sometimes are associated with arousal and can lead to significant fragmentation of sleep and resultant excessive daytime sleepiness. The periodic leg movements in sleep occur almost exclusively during non-REM sleep. Some EMG activity is frequently noted during the phasic REM sleep and is considered normal physiologic expression of the REM stage. It correlates with the rapid eye movements simultaneously being recorded by EOG. The frequency of the period leg movements in sleep increases with age. Teeth clenching and grinding are reported both as EMG observation, microphone sound recording and direct listening and visual observation by the night time attending technologist.

Hypnogram Data

The hypnogram provides a panoramic graphic view of all simultaneously recorded variables on the axis of time. It gives an excellent account of sleep stages and its architecture as it relates to the wakefulness, sleep onset, cycling of Non-REM and REM sleep, frequency of sleep stage changes, sleep fragmentation, amount of light sleep (N1 and N2) versus deep sleep (N3) throughout the sleep time. In real time it demonstrates the apnea and hypopnea events, oxygen saturations, arousals, chest and abdominal movements and body position. If CPAP is used the effect of certain positive pressure can be directly visualized on sleep and airflow parameters. An excellent clinical impression can be obtained by review of the hypnogram in terms of the total sleep time, severity of abnormal breathing events, desaturations, leg movements and body positions.

Practice implications

The detailed review of the sleep study report is important for the referring physician to correlate patient's presenting sleep complaints to the result of the sleep study. Patients may also report their post-treatment residual problems and complications to them. Multiple recommendations can be made based on the observations in the sleep study report. The clinical management decisions regarding normalizing the long sleep latency may be made by practicing good sleep hygiene and thus avoiding the over the counter sleep aids and prescription hypnotics. Improvement in the sleep efficiency can be accomplished with increase in total sleep time in relation to total time in bed and potential causes of poor sleep efficiency can be explored. A good example is chronic pain syndrome that affects the sleep of many patients. Sleep quality significantly improves after adequate pain control is achieved.

An understanding of the affect of medications on sleep architecture and staging helps the primary care physician to manage sleep disorders as well as the primary disorder for which these medications were started in the first place. In general, REM sleep is suppressed by MAO inhibitors and tricyclide antidepressant, amphetamines, barbiturates and alcohol. Withdrawals from these medications cause rebound and excessive REM sleep. Benzodiazepines increase the amount of Stage N2 sleep and reduce Stage N3 sleep.

Sleep reports are concluded with the recommendations regarding the management plan including the use of CPAP therapy, consideration of other treatment modalities like oral appliances and surgical intervention. The type and the size of the mask and whether a warm or cold humidifier is recommended for patient comfort and prevent drying of secretions. "RAMP time", a gradual increase in pressure over many minutes as patient tries to fall asleep is recommended for patients who may not tolerate high CPAP pressures. If a mouth air leak is noted while using a nasal mask, a chinstrap is recommended to keep the jaw from falling open.

Overall review of the sleep study report provides an excellent account of what was recorded over 6 to 8 hours of sleep during the nighttime. Multiple variables affect the sleep pattern including the *"first-night effect"* when the patient can not sleep well in the sleep laboratory and has a different sleeping pattern than usual[10]. The *"reverse first-night effect"* is when the patient sleeps better in the sleep laboratory compared to their home as in case of psycho-physiologic insomnia and frequently observed *"night to night variability"* in sleep[11]. It is therefore important to realize that in a patient with high pre-test probability of sleep disordered breathing, a negative sleep study may not rule it out[12].

A clear understanding of the sleep study report facilitates proper patient follow up and enables primary care physician to recognize the need for arranging a follow up appointment with the sleep specialist, any equipment related troubleshooting and to address any noncompliance issues.

References

1. **Young T**, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep disordered breathing among middle-aged adults. *N Engl J Med*.1993;328:1230–5.
2. **Bradley TD**, Floras JS. Obstructive sleep apnoea and its cardiovascular consequences. *Lancet*. 2009 Jan 3; 373(9657):82-93.
3. **Hirshkowitz M**. The clinical consequences of obstructive sleep apnea and associated excessive sleepiness. *J Fam Pract*. 2008 Aug; 57(8 Suppl):S9-16.
4. **Pressman MR** (2002). Primer of Polysomnogram Interpretation. Boston: Butterworth Heinemann.
5. **Iber**, C; Ancoli-Israel, S; Chesson, A; Quan, SF for the American Academy of Sleep Medicine (2007). The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications. Westchester: American Academy of Sleep Medicine.

6. **Lee-Chiong TL**, editor. Sleep: a comprehensive handbook. Hoboken, N.J.: John Wiley & Sons; 2006.

7. **Ratnavadivel R**; Chau N; Stadler D; Yeo A; McEvoy RD; Catcheside PG. Marked reduction in obstructive sleep apnea severity in slow wave sleep. *J Clin Sleep Med* 2009; 5(6):519-524.

8. **Sasai T**, et al**,** Clinical significance of periodic leg movements during sleep in rapid eye movement sleep behavior disorder. *J Neurol* 2011 Nov; 258(11):1971-8.

9. **Espiritu**, Joseph Roland D. (2008). "Sleep-Related Breathing Disorders". In Schmitz, Paul G. (Ed.), *Internal Medicine: Just the Facts*, p. 663. McGraw-Hill Medical.

10. **Tamaki M**; Nittono H; Hayashi M et al. Examination of the first night effect during the sleep-onset period. *SLEEP* 2005; 28(2):195-202

11. **Lorenzo JL**, Barbanoj MJ. Variability of sleep parameters across multiple laboratory sessions in healthy young subjects: the "very first night effect". *Psychophysiology* 2002 Jul; 39(4):409-13.

12. **Meyer T. J.,** Eveloff S. E., Kline L. R., Millman R. P.1993, One negative polysomnogram does not exclude obstructive sleep apnea. *Chest* 103:756–760.