Sleep Diagnosis: Polysomnography and Home Sleep Apnea Testing

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Abbreviations

AADSM	American Academy of Dental Sleep Medicine
AHI	Apnea-hypopnea index
CMS	Centers for Medicare and Medicaid Services
CPAP	Continuous positive airway pressure
CSA	Central sleep apnea
DSA	Dental sleep appliance
EEG	Electroencephalogram
EKG	Electrocardiogram
EMG	Electromyography
HSAT	Home sleep apnea test
ILSS	In-lab sleep study
LOC	Left outer canthus
MAD	Mandibular advancement device
MSA	Mixed sleep apnea
OSA	Obstructive sleep apnea
PAT	Peripheral arterial tone
PLM	Periodic limb movements
PSG	Polysomnography
R/LAT	Right and left anterior tibialis
RDI	Respiratory disturbance index
REM	Rapid eye movement

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RERA	Respiratory event-related arousal
ROC	Right outer canthus
TRT	Total recording time
TST	Total sleep time
UARS	Upper airway resistance syndrome

7.1 Introduction

Polysomnography is commonly referred to as a sleep study. The name is derived from the Greek root *polos*, for "many," the Latin word *somnus* for "sleep," and the Greek word *graphia* meaning "writing." A diagnostic polysomnogram can be performed in a sleep laboratory [in-lab sleep study (ILSS)] or home setting [home sleep apnea test (HSAT)]. Interpreting sleep studies requires knowledge of several fields of medicine. The following chapter is going to explain the main features of the two types of polysomnographic studies, deal with their advantages and disadvantages for interpretation purposes, and touch upon their use in the field of dental sleep medicine.

7.2 Polysomnography: In-Lab Testing

During in-lab polysomnography (PSG) test, patients are required to sleep in the lab. A sleep technician stays with the patient and constantly monitors the devices and records the major events. Most in-lab studies will typically have the following channels: central monopolar recording, occipital mono- or bipolar recording, chin electromyography (EMG), right and left anterior tibia (R/LAT), right outer canthus (ROC) and left outer canthus (LOC), electrocardiogram (EKG), snoring MIC, nasal/oral airflow, thoracic effort, abdominal effort, oxygen saturation (SaO_2), and body position [1]. The test will measure breathing parameters that have specific definitions [2].

The typical definitions of sleep breathing events are obstructive sleep apnea (OSA), central sleep apnea (CSA), mixed sleep apnea (MSA), hypopnea, and respiratory event-related arousal (RERA). OSA is defined as a cessation of airflow for at least 10 s. The event is obstructive if during the apnea, there is effort to breathe. CSA is defined as a cessation of airflow for at least 10 s, and there is no effort to breathe. MSA begins as a central apnea, but toward the end, there is effort to breathe without airflow. Hypopneas have several clinical definitions, and there is no clear consensus. These tend to be dependent on the insurance company covering the cost of the sleep study. The Centers for Medicare and Medicaid Services (CMS) approved the definition of hypopnea as an abnormal respiratory event with at least a 30% reduction in thoracoabdominal movement or airflow as compared to baseline, lasting at least 10 s, and with >4% oxygen desaturation. Obstruction is often inferred from thoracoabdominal paradox, the shape of the flow signal, or when snoring intensity increases during the event. The alternative definition is a clear amplitude

reduction of a validated measure of breathing during sleep (but less than a 50% reduction from baseline) that is associated with an oxygen desaturation of >3% or an arousal. The apnea-hypopnea index (AHI) will vary depending on which scoring rule the sleep lab uses [2]. This is an important factor to consider when you review a sleep study result. RERAs are defined as a sequence of breaths with increasing respiratory effort leading to an arousal from sleep.

With these parameters, we arrive at the most important definition that you will need to know as a sleep dentist what is apnea-hypopnea index (AHI).

The AHI is calculated by dividing the number of apnea or hypopnea events by the number of hours of sleep. The AHI values for adults are categorized as follows [3, 4]:

Normal: AHI < 5.

Mild sleep apnea: AHI ≥ 5 and <15.

Moderate sleep apnea: AHI ≥ 15 and <30.

Severe sleep apnea: AHI ≥ 30.

The AHI is of crucial importance when reviewing a sleep study. In the past, we were also able to include the term respiratory disturbance index (RDI), which included RERA events (Fig. 7.1). This is typically no longer acceptable for diagnosis of OSA but is considered when diagnosing upper airway resistance syndrome (UARS). Some insurance carriers will allow RDI for coverage, but it is not commonly seen.

After AHI, other parameters, such as total recording time (TRT) and total sleep time (TST), should be taken into consideration. Sometimes people stop breathing for several minutes. Long episodes of hypoxia can relate to severity but the AHI is still more important. As a matter of fact, brief episodes of hypoxia (low oxygen) are a stronger predictor of mortality [5]. This is because short respiratory event duration is a marker for low arousal threshold in humans.

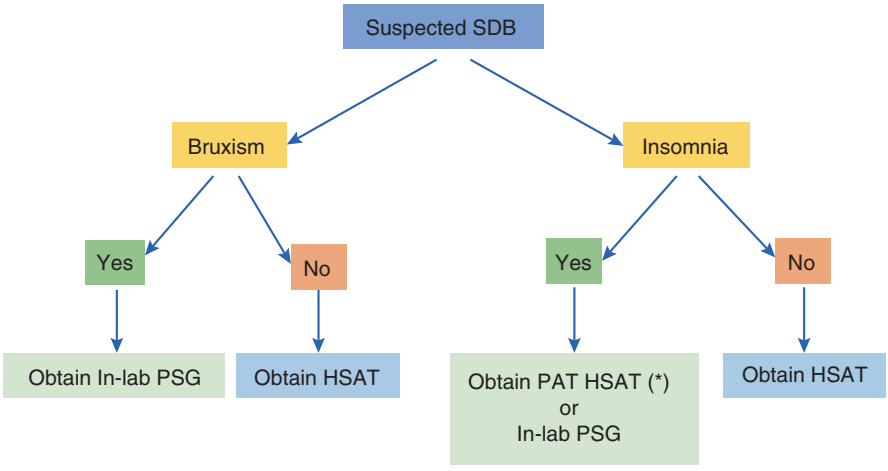

Fig. 7.1 Suggested Algorithm 1 (DSM-PSG order workflow): *HSAT* home sleep apnea test, *PAT* peripheral arterial tonometry, *PSG* polysomnogram, and *SDB* sleep-disordered breathing. (*) PAT or other HST devices that can measure total sleep time

The other key parameter for a sleep dentist is the arousal index or occurrence of awakenings per hour. These can be caused by abnormal breathing and movement or can be spontaneous. These arousals can occur from periodic limb movements (PLM) and from bruxism. When it comes to choosing between continuous positive airway pressure (CPAP) and a dental sleep appliance (DSA) also known as a mandibular advancement device (MAD), signs of bruxism often settle the issue. DSA's therapy has a dual purpose, opening the airway and protecting the enamel. CPAP could still be an equally good choice with the simultaneous application of a mouth guard or a bite splint even if there are signs of bruxism. CPAP and DSA can also be used in combination for severe OSA cases. A dentist is not going to treat CSA as this is something to be treated by a sleep physician.

7.3 Home Sleep Apnea Testing

The approach to home sleep apnea testing (HSAT) is much simpler. The studies typically have four channels of data. Most of them fall under the category of a class III device. They will usually have a pulse oximeter, a flow sensor, and some type of respiratory effort belt. The alternative technology consists of peripheral arterial tone (PAT) that uses algorithms specific to respiratory events and each of the sleep stages. It would be a good idea to become familiar with each of the devices that are on the market for HSAT. When analyzing HSAT results, the type of platform under which the patient was tested should always be considered, that is, the number of channels measured. It is also important to know if the data refers to measuring breathing only. Some home testing devices measure breathing and total sleep time.

When analyzing HSAT results, the most important parameter is again the AHI. It is also critical to review the TRT. TST is rarely seen since these devices typically do not measure sleep. This measure is more accurate with PAT technology devices. Other devices that measure TST include the Sleep Profiler and PSG2 by Advanced Brain Monitoring and the ARES device by SleepMed Inc. First and foremost, it is important to understand that home sleep testing is simply an adjunct to the in-lab study. If there are patients with a negative HSAT but you are confident they have OSA, then refer them to the sleep lab for a PSG. Most patients will prefer sleeping in their own home. PSGs and HSATs do not compete with each other, rather they complement each other.

There are many different companies in the home sleep testing market, and it can be difficult to keep up with the classification of their devices and the parameters being tested. *Sleep Review* magazine has a compilation of the most commonly, commercially available devices [6]. This 18-device comparison was published on their website on August 31, 2020. Some of the home sleep testing companies will use different HSAT devices. A sleep dentist should always focus on the AHI and the total sleep or recording time. Some of these devices can detect positional data with a reasonably good accuracy. They will use accelerometers to determine the position during sleep. This will allow you to reference the AHI with regard to the patient's position. You may have a patient that is close to their optimal protrusive bite

position. When looking at positional data, they may have improvement when sleeping non-supine. If a patient achieves his/her goal in a certain sleep position, then positional therapy is recommended. Philips has a positional sleep apnea device known as the NightBalance, and the advanced brain monitoring makes a device known as the Night Shift Sleep Positioner which may be considered for positional therapy. For more information on positional therapy, refer to Chap. 12.

7.4 Pros and Cons for In-Lab PSG Testing and HSAT

In the sleep lab, the polysomnographic technician deals with a myriad of sensors, amplifiers, filters, and computer systems to capture the massive amount of data that involves a sleep study. As a dentist you will typically receive the results of either in a lab or a home sleep study. Making sense of the studies will seem difficult at first, but with practice and experience, it will become easier. It is much more difficult to interpret a home sleep study due to limited information obtained from these channels than an in-lab sleep study. When in doubt, test the patient in the sleep lab (Fig. 7.2).

Most patients prefer to sleep in their own bed. This is certainly an advantage of HSAT. There are scenarios where patients sleep better in the sleep lab. These are situations where their home conditions are suboptimal. They may live in a noisy neighborhood or have caretaker responsibilities or have pets in the bedroom that may awaken them.

Sometimes patients are disturbed by the unfamiliar ambiance of a sleep lab and are unable to sleep or they do not sleep well. If the patient did not have over 2 h of sleep, then the test may be considered invalid. This phenomenon (i.e., when the patients did not sleep well due to their first time in the sleep lab) is commonly

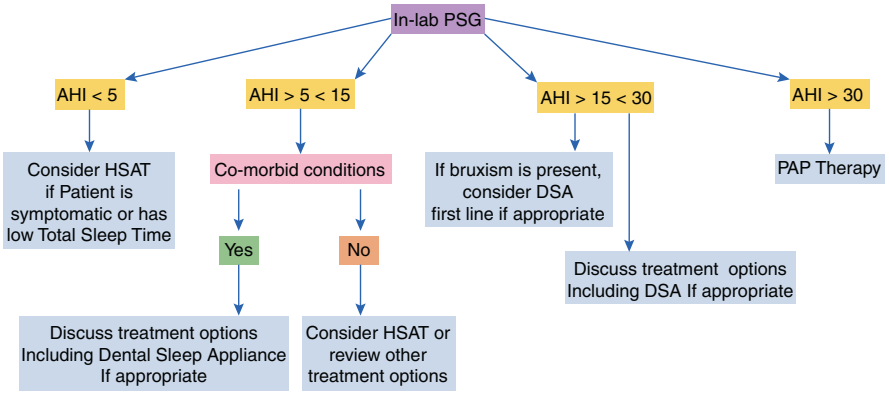

Fig. 7.2 Suggested Algorithm 2 (In-lab): *PAP* positive airway pressure, *HSAT* home sleep apnea test, *AHI* apnea hypopnea index, *RDI* respiratory disturbance index, and *PSG* polysomnogram. Comorbid conditions: documented hypertension, excessive daytime sleepiness, impaired cognition, mood disorders, insomnia, ischemic heart disease, and history of stroke; *DSA* dental sleep appliance; in-lab PSG, Level I sleep study

referred to as the "first night effect." The sleep doctor might advise the patient to sleep in the lab to perform a DSA titration, so the polysomnography technician (sleep tech) is able to titrate the DSA to its most optimal position.

In-lab sleep studies are also done for parasomnias, CSA, movement disorders, and hypersomnias. Since HSATs do not measure movement, you will typically not receive any feedback with regard to bruxism or periodic limb movements (PLM). If there is a question of suspected movement, an in-lab study is always preferable.

The other advantage of the in-lab study is that EEG will determine sleep staging. Most home studies only measure breathing, so there is no direct measure of sleep time or staging. There are some devices that can do this in the home setting. There is developing technology that is looking at bruxism detection in the home setting. In the sleep lab, you measure the brain via the EEG, and it is common to find that most patients will worsen their AHI in REM sleep, and some will have OSA only in REM. Some home devices will estimate REM and non-REM.

When it comes to covering DSA or CPAP therapy, most insurance companies will follow the CMS rules, and only patients with an AHI over 5 will be covered. If they have an AHI between 5 and 14, they will need a comorbid condition for the DSA or CPAP to be covered. These include documented hypertension, excessive daytime sleepiness, impaired cognition, mood disorders, insomnia, ischemic heart disease, or history of stroke. If the AHI is 15 or more, then the DSA is covered. If the AHI is over 30, then it is typical for most insurances to have their own policies. Many of them will require a documented CPAP failure to cover the DSA.

The comfort zone for sleep physicians has always been in-lab PSG. Given the limited amount of limited data on a HSAT, it can be difficult to accurately make a sleep apnea diagnosis. If a home study is borderline or does not yield a positive diagnosis, an in-lab PSG study is typically approved by most insurance companies. You will find that home testing will often be requested by patients. Patients may ask "How am I going to sleep with all those wires on my body?" Also, the market pressures to decrease testing costs have led to the rapid growth of HSAT.

In 2017, the American Academy of Sleep Medicine published a position statement on HSAT [7]. The statement, which is published in the October 15 issue of the *Journal of Clinical Sleep Medicine*, comprises the following positions:

> Only a physician can diagnose medical conditions such as OSA and primary snoring. The need for, and appropriateness of a HSAT must be based on the patient's medical history and a *face-to-face examination* by a physician, either in person or via telemedicine. A HSAT is a medical assessment that must be ordered by a physician to diagnose OSA or evaluate treatment efficacy.

This contrasts with a consensus statement from the American Academy of Dental Sleep Medicine (AADSM). AADSM proposes that a "qualified dentist" can administer a HSAT and then provide a physician with access to HSAT data and pertinent patient information. See Fig. 7.3 for the algorithm for HSAT. The guideline stipulates that a dentist should have at least one of the following: (1) diplomate certification in dental sleep medicine by a nonprofit organization, (2) designate the dental director of a dental sleep medicine facility accredited by a nonprofit organization, or (3) obtain the designation of "qualified dentist" [8].

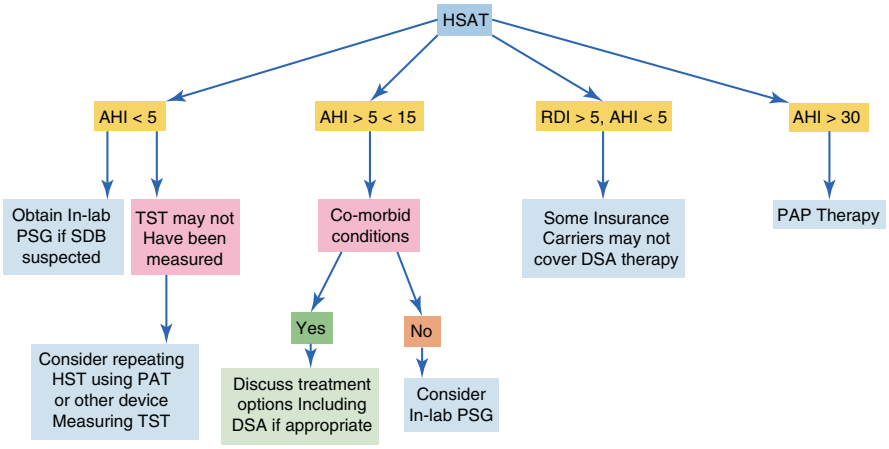

Fig. 7.3 Suggested Algorithm 3 (HSAT): *PAP* positive airway pressure, *HSAT* home sleep apnea test, *AHI* apnea hypopnea index, *RDI* respiratory disturbance index, *PSG* polysomnogram, *DSA* dental sleep appliance; and in-lab PSG, Level I sleep study. Comorbid conditions: documented hypertension, excessive daytime sleepiness, impaired cognition, mood disorders, insomnia, ischemic heart disease, and history of stroke

7.5 Most Private Health Insurance Companies Will Follow the Same CMS Criteria

A custom fabricated mandibular advancement oral appliance (E0486) used to treat OSA is covered if these criteria are met. The beneficiary has a face-to-face clinical evaluation by the treating practitioner prior to the sleep test to assess the beneficiary for obstructive sleep apnea testing. As used in this policy, treating practitioner refers to a licensed MD, DO, nurse practitioner, clinical nurse specialist, or physician's assistant working within their scope of practice. The term treating practitioner does not include a dentist (DDS or DMD) [9].

For the purpose of this chapter, we will assume that you will practice dental sleep medicine with consultation and collaboration of a medical provider. This collaborative approach will produce the best outcome for the patient and help protect the dentist in case of any legal pitfalls.

It is this author's opinion that in a typical sleep practice there is a greater than 80% likelihood that a patient will test positive for OSA when they are referred by a dentist. This percentage is lower when the patient was referred from a medical clinic. Dentists are particularly good at screening for sleep-disordered breathing as they are experts in putting together the symptomatology with the anatomical characteristics of a sleep apnea patient. This could also be because medical practitioners are not routinely trained in dentistry. The dentist typically is trained to look for malocclusion, scalloped tongue, ankyloglossia, and signs of bruxism. These are all common in obstructive sleep apnea-hypopnea syndrome (OSAHS) patients.

Depending on your geographical location and accessibility to sleep lab testing, the degree of in-lab PSG versus home studies will vary. Typical in-lab PSG studies are used for multiple sleep abnormalities, but the vast majority are done for OSA. Since the late Christian Guilleminault described OSA as a clinical syndrome in 1973, millions of people have been diagnosed with this disease [10].

Another factor in HSAT is complexity. Many patients would choose an in-lab PSG study since it is simply easier for them to deal with the testing parameters. Some of these home sleep testing devices can be cumbersome and overwhelming for patients. It is the author's opinion that PAT devices are simple and easy to use by most patients. Some currently used devices allow for multiple night testing, giving a more accurate picture.

Sometimes there is a discrepancy between in-lab PSG and in HSAT results. It is important to ask patients about their sleep habits. One example includes alcohol intake before bedtime. Many patients who consume alcohol on a regular basis will have significantly higher AHI at home. If they are sent for an in-lab PSG study, they may not consume any alcohol. This could lead to a discrepancy between the studies.

Patients with insomnia will often have a difficult time sleeping during their studies. Since most of the HSATs do not measure sleep, there may be an inaccurate picture of TST. In these situations, one can use PAT or other devices to measure TST. It is always important to ask the patients how many hours they think they slept. If there is any concern, then refer the patients to the sleep lab for testing.

There are several new devices on the market that come in a disposable platform. This may be ideal from an infection control and hygiene standpoint. If one ends up doing the testing out of your dental practice, it is particularly important to keep watch over quality control and hygiene protocols. You must make sure the equipment is sterilized and the quality controls are met on a regular basis.

Another factor to consider is the power source for the HSAT device. Although some have rechargeable internal batteries, most of them use disposable batteries. Alkaline batteries work good, but lithium batteries work the best. Although lithium batteries are more expensive, they are lighter and last longer. The lighter the weight of the device, the more comfortable the patient. It is also important to look at the size of the oximetry digital probes and assure they match the finger of the patient. These come in different sizes and some use disposable oximetry probes.

It is important to keep in mind the patient's normal sleep–wake cycle. For individuals who do shift work, it is best to test them when they routinely sleep regardless of the shift. If a person sleeps during the day, then test him/her during the day. It is recommended to test patients at the end of a shift cycle. If they work as a firefighter or police officer, they may do several shifts per week and then have a break. It is best to test them after their shift cycle ends. This author prefers to test patients at the end of the week rather than the beginning of the work week. People typically will be more tired as the week progresses and this will yield a more accurate test result.

Another factor to consider with regard to HSAT is rapid eye movement (REM). Many patients will have a deficiency of REM sleep. Since most people have a higher AHI in REM sleep, they will often have a deficiency of this sleep stage. Many of the HSAT devices commercially available do not measure REM sleep or differentiate

between the different sleep stages. This could be problematic if the dental patient has a REM sleep deficiency to start with. Once a patient is fitted with a DSA, they will likely increase dreaming. When repeating an HSAT, their AHI could be paradoxically higher. This could create a puzzling scenario where one thinks that the patient was made worse. The reality could be that they are now dreaming more because the mandible is more optimally positioned. If the HSAT device measures REM sleep, one would be able to have a more accurate picture from the beginning. This will help with the subsequent DSA titration studies.

After the AHI, what are the principal questions you should always think about as a sleep dentist evaluating home sleep studies?

Did the device measure total sleep time?

Did the device measure REM sleep?

Did the device measure positional data?

It is a good idea to keep copies of all the sleep studies. It is surprising how many patients had a sleep study done in a sleep lab that is no longer in business. It is good practice to give the patients a copy of their sleep study for their records.

It is also a good idea to have an established relationship with a sleep physician. Even if the sleep study was not done in this doctor's practice, you can still collaborate on the test results. Call them if any questions arise or collaboration is needed on the treatment plan. If a sleep study is too old, then a more recent one will be required by the insurance carrier.

When dealing with pediatric and adolescent patients, the question of HSAT may come up. There are two devices commercially available that are FDA approved for children to take the test at home. It is this author's opinion to avoid HSATs on children and adolescents. One should approach these on a case-by-case basis. Most patients under the age of 18 do well in the in-lab PSG study and rarely experience the first night effect. This is a term used in sleep medicine that denotes the insomnia produced by sleeping in the sleep lab for the first time.

Three algorithms are developed which may help dentists in decision-making. It is likely these will soon change as new technologies reach the market. There are HSATs in the final stages of development that can evaluate for bruxism while testing for OSA. The next decade will surely bring exciting developments in the world of sleep medicine and dental sleep medicine.

These three DSM algorithms will assist the dentist when ordering and reviewing sleep studies.

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