Interpretation of a polysomnographic record

Interpretación de un registro polisomnográfico

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Abstract

The polysomnography consists of the simultaneous record of the neurophysiological and cardiorespiratory variables to evaluate the sleep quantity and quality and to identify the respiratory events, as well as its cardiorespiratory and neurophysiological impact. The sleep includes the interaction between the brain stem and the cortex. It’s an active and reversible metabolic process, which represents a complex physiological interrelationship. The sleep is divided in REM and non-REM sleep periods. The non-REM sleep period is subdivided in stages from 1 to 4, being the 3 and 4 the slow sleep phase. By means of the polysomnography the sleep apnea syndrome may be studied, which is important to recognize because it is associated with deterioration of the quality of life, arterial hypertension, cardiovascular- and cerebro-vascular diseases, and traffic accidents. Moreover, sleep apnea syndrome has been associated to obesity, which forms a part of the metabolic syndrome, and to insulin resistance as an independent factor, suggesting that it can be a predisposing factor for diabetes type 2 and metabolic syndrome. Increased inflammatory markers in sleep apnea syndrome are reduced after CPAP treatment.

Keywords: polysomnography, sleep apnea-hypopnea syndrome, metabolic syndrome, obesity, breathing sleep disorders, diagnosis.

Introduction

The polysomnography (PSG) is the recommended method to study the night sleep and its alterations. It consists of a simultaneous record of the neurophysiologic and cardio-respiratory variables that allow us to evaluate the quantity and quality of the sleep, as well as identifying the different respiratory events and the cardio respiratory and neurophysiological repercussion. The record of the electroencephalography activity (EEC) should include at least two derivations, usually the right and left central, known as C3 and C4 in the 10-20 system, and preferably the occipital derivations (01 and 02) to be able to distinguish better the alpha activity and the transition from the wakefulness to sleep. In order to recognize the sleep phases, it is necessary to record the ocular movements by means of an electrooculogram (EOG), and the muscular tone by means of an electromyogram (EMG), usually in the chin. In addition, electrodes (bowl shape or piezoelectric) are used which allow us to gather the movements of the inferior extremities, and sensors to establish the body position.

The digital modern systems of PSG allow recording long periods; analyzing and handling the signals obtained in the root trace and record them in an ambulatory manner. In spite of these advances, the records should be revised and analyzed manually, as there is no sleep reading automatic system, which has offered reliable results so far.

The study of the respiratory and cardiac parameters includes the signal of the oxygen saturation (SaO2) by means of a pulse oximeter, the record of the respiratory efforts with thorax-abdominal bandages and the measurement of the nasal-oral flow by
means of pneumotachographs, thermistors, or more recently nasal cannulas, as they help identifying the ventilatory efforts related to the increased micro-awakening of the respiratory route.

**The normal human sleep**

The human sleep is a reversible brain process during which there is a very small or null response to external environmental stimulus. It is a complex interrelation of physiologic and behavioral processes that usually (though not always) appear together with a lying body posture, quietness, closed eyes, etc. It is an active metabolic process that comprises the interaction between the brain stem and the cerebral cortex. There are different sleep phases, and each phase has its own regulator mechanisms and presumably, different functions.

The sleep is divided in two stages named “REM sleep” (rapid eye movement) and “non-REM sleep” (non-rapid eye movement). The non-REM sleep is subdivided in four phases, and the two last ones are globally named as “slow sleep”. The REM sleep can be divided in two phases: phasic and tonic. Both the REM sleep and the non-REM sleep are associated to dynamic changes in the central nervous system and in the immunology and endocrinous system.

**Non-REM sleep**

The non-REM sleep occupies a 75-80% of the total sleep time (TST). The phase 1 supposes a 3-8% of the TST and occurs frequently in the transition of the wakefulness to sleep or after the arousals (unnoticed intra-sleep micro-arousals). During this phase, the alpha activity diminishes which is a characteristic of the wakefulness and a pattern of low voltage brain waves and mixed frequencies arise. The electromyographic activity diminishes and the electrocooculogram shows slow ocular movements. “Vertex V” waves might appear towards the end of this phase. The phase 2 starts after 10-12 minutes after phase 1, and occupies 45-55% of TST. The characteristic findings include the “slow spindles” and the “K complexes”. A scarce quantity of delta waves can appear. The EMG activity is also reduced. The phases 3 and 4 suppose a 15-20% of TST and constitute a “slow wave” sleep. The phase 3 is characterized by presenting a moderate quantity of slow and of great amplitude EEG waves, while the quantity of these waves in the phase 4 is very important. As regards to the EOG, while the sleep phase’s progress, the ocular movements are less frequent, until reaching the REM sleep. In the “slow sleep”, the muscular tone is reduced compared to the wakefulness or the phase 1.

**REM sleep**

The REM sleep occupies a 20-25% of the TST. The first phase of REM appears after 60-90 minutes of the beginning of the sleep. The EEG waves are of low voltage, mixed frequencies and slow alpha waves (1-2 Hz slower than the wakefulness alpha waves) and theta waves (figure 1). Based on the EEG, the EOG and the EMG, the REM sleep might be divided in two phases: tonic and phasic. The tonic phase includes the desynchronized EEG, atony of the skeleton muscles and suppression of the mono and polysynaptic reflexes. The phasic REM is characterized for showing fast ocular movement in all directions, phasic variations of the blood pressure and cardiac frequency, irregular breathing, tongue movements and myotonic contractions of the submentonian muscles and of the limbs. Short periods of apnea or hypopnea might appear during this periods.

The terminology and the stadiification system in force developed in a consensus meeting held in 1968 and sponsored by the UCLA-Brain Information Service, which was collected and published by Rechtschaffen and Kales. The American Academy of Sleep Medicine (AASM) modified recently this classification, after introducing changes into the terminology. Thus, the phase SI-S4 changed to N1, N2 and N3 (S3+S4). With the new stadiification, the total sleep time, the efficiency or REM phase hardly changes, but it affects the distribution of the non-REM sleep.

**Normal sleep pattern**

The first sleep cycle in a healthy adult starts in phase 1, which persists generally during 1-7 minutes. In this moment, it is easy to wake up by means of external stimulus. After a short period, the phase 2 starts, characterized by the onset of “sleep spindles” or by the “K complexes”; this phase is kept approximately during 10-25 minutes. Here it is more difficult to wake the individual up. While the phase 2 progresses, there is a gradual increase of the slow waves (≤2 cycles/second) of high voltage (>75 µV). The phase 3 is normally maintained during a few minutes in the first sleep cycle and achieves the transition towards the phase 4 as the slow waves and of low voltage start occupying a greater proportion of the EEG activity.

When this proportion is higher than 50%, we speak about phase 4, which is generally kept during 20-40 minutes in the first cycle of the sleep.

The first cycle of the REM sleep appears after this period, which is normally short (1-5 minutes) and another sleep cycle.
starts again, generally entering into the phase 1 or 2. When the cycles progress, the percentage of slow sleep becomes lower, occupying less time in the second cycle, and are able to disappear totally in the later cycles, increasing the duration of phase 2 gradually. Also the duration of the REM phase increases progressively in each cycle. The mean duration of the first cycle is of 70-100 minutes, of the second cycle of 90-120 minutes and the posterior cycles of 90-110 minutes. The progression of these cycles is depicted in the so-called “hypnogram”, which is the temporal representation of the different phases of the sleep1 (figure 2).

The duration of the night sleep depends on many factors; therefore it is difficult to define which would be the normal one. Most of the adults refer sleeping approximately 7 hours and a half during the week and 8 hours and a half during the weekends, though there is a great inter-individual variability and “night by night” in the same individual.1 With age, the duration of the sleep is modified, as well as the hypnogram characteristics.

Sleep functions
The sleep is a different state of wakefulness together with a great electrical brain activity and endocrinology and immunology variations highly organized and complex2 4. Intuitively, we can think that the sleep has a restoring function due to the quiescence that the individual adopts during this period, to the tiredness manifestations that precede it and the satisfaction and plenitude feelings that follow it. The lack of sleep alters the coordination and the motor functions, while a long and restoring sleep restores the loss functions and relieves the motor failures. After clinical observations in neurological patients, it is believed that the sleep helps restoring the activity of the neurotransmitters in multiple levels of the nervous system.7 According to Siegel, the REM sleep helps to desensitize the brain receptors, which are overloaded of the continuous bombing during the wakefulness hours.5 Other authors believe that the REM sleep would consolidate the memory.7

There are also important interrelations between the sleep, the circadian rhythms and the physiology of the endocrine system. The production of growth hormone and the secretion of the prolactin are produced during the sleep, mainly during the slow sleep and is inhibited by the presence of arousals. The adrenocorticotropic hormone and the melatonin depend mainly on the circadian rhythms. The secretion of the thyroid and cortisol-stimulating hormone follow a night production rhythm according to the circadian pattern, and the production during the sleep is inhibited.8

The maintenance of the normal sleep is also very important for an adequate functioning of the immunitary system. The complete privation during a night causes an increase of in the activity of the natural killer cells acutely and temporary in healthy volunteers. However, if the privation is higher than 24-48 hours, there is a reduction in the activity of these cells, in the sub-classes of lymphocytes and in the production of cytokines and the suppression of the production of antibodies is caused. All these effects are reversible, becoming normal with the recovery of the sleep.5

Respiratory alterations during the sleep: sleep apnea syndrome
The sleep apnea-hypopnea syndrome (SAHS) consists of the onset of recurrent events of air passage limitation during the sleep due to an anatomic-functional alteration of the upper respiratory tract that leads into a collapse, causing reductions of the SaO2 and micro-arousals leading to a non restoring sleep, to excessive night somnolence and neuro-psychiatric, respiratory and cardiac disturbances.10 The factors that favor the collapse include the narrowing of the upper respiratory way (“anatomic factor”), an excessive loss of muscular tone (“muscular factor”) and the defect in the protector reflexes (“neurological factor”), the main determinants of this disturbance are the obesity and the masculine sex, though there are other involved, as the tissular distribution in the neck, the ventilatory control and the age, which at the same time modifies the previous ones. Each of them is genetically determined and modulated by the environment influences.11

The obesity increases the SAHS risk 10-14 times, mainly in middle-aged patients, through the deposit of fat in the upper respiratory tract, by reduction of the naso-faringeal caliber (or by changes in its form), or inducing hypoventilation. These effects might be additive through a gene or group of genes that might have an influence both on the ponderal mass and on the ventilatory control. Other genetic factors related to the metabolism, the thermo genesis, the deposit of fat and the diet habits contribute to the obesity development. Likewise, the regional deposit of fat is a higher relative risk factor than the body mass index (BMI) and a fat deposit has been observed in the anterolateral area of the neck, even in non-obese individuals with SAHS.11

The number of apneas (complete cessation of the breathing) plus hypopneas (partial cessation of the breathing) divided into the hours of sleep make up of the apnea-hypopnea index (AHI). An AHI >5-10 is considered abnormal. However, the abnormal AHI does not define a SAHS by itself. Recently, the American Academy of Sleep Medicine defined the SAHS as the presence of an abnormal respiratory disturbance index (RDI), considered as the addition of the AHI besides the respiratory efforts associated to micro-arousals (RERA). An AHI >5 associat-
ed to symptoms and relevant clinical signs is considered as diagnostic of the SAHS (table 1).

The National Consensus issued by the Spanish Sleep Group defines the SAHS as an excessive somnolence picture, cognitive-behavioral disturbances as well as respiratory, cardiac, metabolic or inflammatory, secondary to repeated events of obstruction of the upper respiratory tract during the sleep. These events are measured with an AHI. An AHI ≥ 5 associated to symptoms related to the disease and not explained by other causes confirm the diagnosis. The night somnolence is the symptom that determines at present the clinical decision of starting treatment with continuous positive area pressure through the nostrils (nasal CPAP), though there are evidences that the CPAP might be indicated regarding to the cardiovascular risk in paucisymptomatic patients.

The respiratory alterations that might appear during the sleep are: apnea, defined as the interruption of the ventilation during a minimum of 10 seconds, or the reduction of the flow signal over 90% of the previous signal amplitude; the hypopnea, defined as a reduction in the air flow of 30-90% during a minimum of 10 seconds, together with a temporary arousal and/or desaturation of the oxyhemoglobin and, finally, the RARE due to a partial obstruction of the upper respiratory tract together with an arousal (table 2).

Both the apneas and the hypopneas might be: obstructive, when together with an increase of the thorax-abdominal effort; central, if this effort is absent, and mixed, as a combination of both. The number of apneas plus hypopneas divided into the sleep hours make up the apnea-hypopnea index (AHI) (figure 3).

Sleep apnea syndrome and metabolic alterations
In the developed countries, the SAHS constitute a health problem of first magnitude, up to the point that it has been compared as regards to social and economic costs, with the one that causes the smoking habit. On the other hand, it has been demonstrated that the SAHS is associated to the worsening of the life quality, to the presence of blood hypertension and the development of cardiovascular and cerebrovascular diseases and that it is related to the onset of traffic accidents. Likewise, the SAHS constitutes an important cause of morbidity in children, it is associated to neuro-cognitive and behavioral disturbances and increases the mortality.

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**Table 1. Definition of SHAS according to the American Academy of Sleep Medicine**

<table>
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<tr>
<th>Condition</th>
<th>Description</th>
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<tbody>
<tr>
<td>a. A RDI ≥5 including the presence of micro-arousals associated to</td>
<td>respiratory efforts, plus one of the following ones, which cannot be</td>
</tr>
<tr>
<td>b. Excessive day somnolence</td>
<td>explained by other causes</td>
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<tr>
<td>c. Two or more of the following:</td>
<td>• Asphyxia during the sleep</td>
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<tr>
<td>• Recurrent arousals</td>
<td>• Clumsiness at arousal</td>
</tr>
<tr>
<td>• Fatigue during the day</td>
<td>• Concentration difficulties</td>
</tr>
<tr>
<td><strong>SAHS: a + (b or c)</strong></td>
<td></td>
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</tbody>
</table>

RDI: respiratory disturbance index; SAHS: sleep apnea-hypopnea syndrome.

**Table 2. Definition of respiratory events in the polysomnography**

<table>
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<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>Obstructive</td>
<td>Absence or reduction &gt;90% of the respiratory signal (thermistances, nasal cannula or pneumotachograph) over 10 seconds of duration in the “presence” of respiratory continuous effort detected by the thorax-abdominals bandages</td>
</tr>
<tr>
<td>Central</td>
<td>Absence or reduction &gt;90% of the respiratory signal (thermistances, nasal cannula or pneumotachograph) over 10 seconds of duration in the “absence” of respiratory continuous effort detected by the thorax-abdominals bandages</td>
</tr>
<tr>
<td>Mixed</td>
<td>It is a respiratory event that usually starts with a central component and ends with an obstructive component</td>
</tr>
<tr>
<td>Hypopnea</td>
<td>Perceptible reduction (&gt;30 and &lt;90%) of the amplitude of the respiratory signal over 10 seconds of duration (thermistances, nasal cannula or pneumotachograph) together with desaturation (&gt;3%) and/or an arousal of the EEG</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Period &gt;10 seconds of progressive increase of the respiratory effort (usually detected by means of the measurement of the esophageal pressure) that ends with an arousal. Optionally, the effort can also be detected using a nasal cannula and/or the addition of the thorax-abdominal bandages when there is a period of limitation to the greater flow or equal to 10 seconds and lower than 2 minutes, without a marked reduction of the flow amplitude and that ends with an arousal</td>
</tr>
<tr>
<td>efforts related to arousal (RERA)</td>
<td></td>
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Different epidemiological studies have evidenced that the SAHS is a very prevalent disease, which affects 4–6% of the males and 2–4% of the females in the general adult population. Moreover, 24% of the men and 9% of the middle aged women show an AHI higher than 5. The SAHS has been associated to the obesity, which is part of the metabolic syndrome (MS). We could consider that the SAHS represents a new risk factor for the development of the syndrome; therefore a metabolic evaluation should be performed to the diagnosed patients. The SAHS has been associated independently to the insulin resistance, suggesting that it can be an important factor for the development of T2D. The presence of SAHS increases between 5 and 9 times the risk of suffering the MS. If the insulin resistance is a precursor condition of DM and at the same time the MS predisposes to the diabetes, the SAHS might contribute to both and perpetuate the cycle in this way. In spite of the fact that the central obesity is a determining factor in the MS, it seems that the alterations in the metabolism of the glucose are independent of the obesity level. In fact, several transversal studies have found an independent nexus between the seriousness of the SAHS and the glucose intolerance, the insulin resistance and the DM. Probably, the treatment with CPAP might show a benefit on the sensitivity to the insulin and the postprandial and night glucose levels, both in healthy individuals and in diabetic subjects.

The pathogenic mechanism that triggers these consequences is related to the repetitive events of the upper respiratory tract obstructions that occur in the SAHS and that entail fragmentation of the sleep, intermittent hypoxia and a secondary reoxygenation phenomenon. These events cause oxidative stress, activation of the inflammation and endothelial alteration, which might result in atherosclerosis, cardiovascular phenomena (hypertension, coronary disease, ictus, arhythymias...) and insulin resistance. Figure 4 depicts the pathogeny of the cardiovascular events regarding to the SAHS schematically.

In several works it has been demonstrated that the increase of the inflammatory markers (IL-6, PCR, TNF-alpha, etc.) in the SAHS can be corrected after treatment with CPAP or uvulopalatopharyngoplasty, through which some factor related to the SAHS is associated to the activation of the inflammatory phenomena. The most recent studies have focused their attention in the role of the NF-kB factor, which is an element that induces the transcription of the genes involved in the production of cytokines and intervenes in the inflammation and production of prothrombotic markers related with atherosclerosis phenomena, as well as in metabolic alterations as the insulin resistance (figure 5). Its activation takes place when eliminating the inhibitor by different stimulus, virus, bacteria, free radicals, cytokines, intermittent hypoxia, etc.

Once activated, it promotes the synthesis of elements of the inflammatory cascade and clotting factors, contributing to the onset of atherosclerosis. The NF-kB factor is only found in atherosclerotic vessels; therefore we asked ourselves if these changes induced by such factor could be preventable or reversible acting on it. The inhibition of this factor has not been completely evaluated on cardiovascular events. Some work suggests a reduction of the infarction risk or its magnitude. These findings confirm the important role of the NF-kB factor as a link nexus between the SAHS and the cardiovascular events.

Conclusions
The PSG, besides providing us information about the sleep structure, allows performing the diagnostic approach of the night
Practical considerations

- The polysomnography is the simultaneous record of neuro-physiological and cardio-respiratory variables that allow us to evaluate the quantity and quality of the sleep, as well as identifying the respiratory events and their cardio-respiratory and neuro-physiological repercussions.
- The non-REM sleep (or “slow sleep”) occupies 75-80% of the total sleep time. The REM sleep (or “fast sleep”) occupies 20-25% of the total sleep time and is divided into two phases: tonic and phasic. During this last one when short periods of apneas and hypopneas can appear.
- A respiratory alteration index ≥5 associated to relevant clinical symptoms and signs are requested for the diagnosis of the sleep apnea-hypopnea syndrome.

Declaration of potential conflict of interests
Dr. Eusebi Chiner Vives states that there are no conflicts of interest.

References