SCORING SLEEP: THE RULES FOR LOOKING INSIDE

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ABSTRACT

Polysomnography is the most comprehensive sleep study, a multi-parametric recording test (electroencephalography, electrooculogram, chin and limbs electromyogram, respiratory and cardiac functions and permanent video-recording), used as an important diagnostic tool for the sleep disorders. Sleep architecture or the sleep macrostructure is a term used to describe the divisions of sleep into specific sleep stages using electroencephalographic (EEG), electrooculographic (EOG) and electromyographic (EMG) criteria: NREM (non-rapid eye movements) stages – N1, N2 and N3, and REM (rapid eye movements) stage.

Keywords: polysomnography, scoring sleep, rapid eye movement sleep, sleep stages, sleep events, arousals, sleep epoch

DEFINITION OF POLYSOMNOGRAPHY AND HYPNOGRAM

Polysomnography (PSG) is an objective diagnostic test during which a number of physiologic variables are measured and recorded during sleep with permanent video-monitoring. The PSG is being recorded into a quiet and comfortable room (with permanent audio and video recording) with an adjacent room where the technicians stay and watch the patient.

Sleep architecture or the sleep macrostructure is a term used to describe the divisions of sleep into specific sleep stages using electroencephalographic (EEG), electrooculographic (EOG) and electromyographic (EMG) criteria.

To understand and compare the sleep studies, the polysomnography (PSG) must be described using a common ”language”. The first manual of scoring sleep was published by Rechtschaffen and Kales, in 1968, fifteen years after the rapid eye movement (REM) sleep was discovered. In 2004, the American Academy of Sleep Medicine (AASM) revised the sleep scoring, keeping the rules for staging (N1, N2, N3, N4 for NREM and R for REM sleep) but adding rules for arousals, respiratory events, sleep related movements disorder and cardiac abnormalities. AASM reviewed the scoring rules many times and, at this moment, we are using the 2014 AASM Manual for Scoring Sleep and Associated Events, version 2.1. This comprehensive and continuously evolving resource provides rules for scoring sleep stages, sleep events, standard montages and electrode placements. These rules are used in the interpretation of the polysomnography (PSG) for building up the full hypnogram. (1)

PARAMETERS AND EVENTS OF SLEEP

The general parameters used in PSG are: *electroencephalogram*, *electrooculogram*, *chin electromyogram*, *leg electromyogram*, *airflow*, *respiratory effort*, *oxygen saturation*, *electrocardiogram* and *body position*. These are all recommended parameters. The clinicians may also use some optional parameters depending on each patient (transcutaneous PCO2, esophageal pressure etc.). (1)

The sleep scoring data includes: *lights out clock time, lights on clock time, total sleep time*, *total re-*

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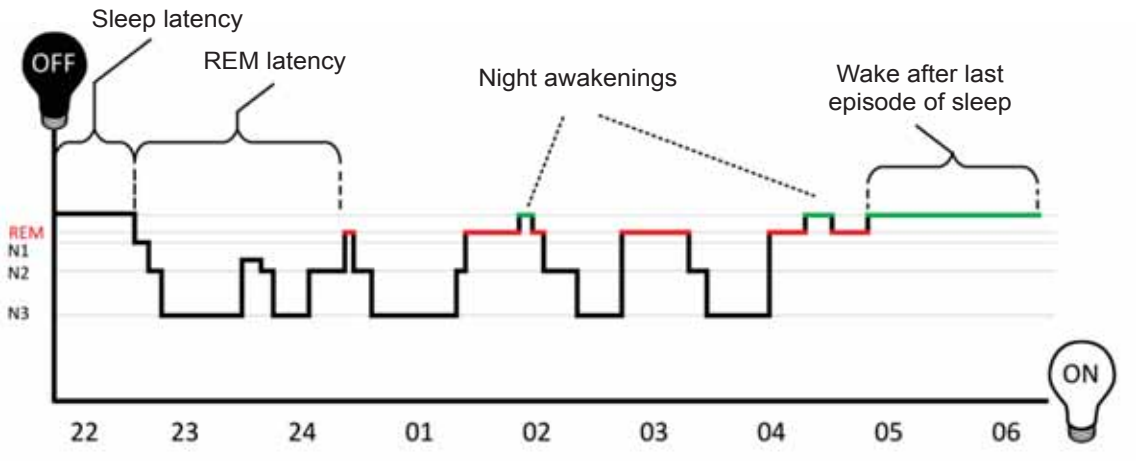


FIGURE 1

cording time, *sleep latency*, *REM latency*, *wake after sleep onset* and *sleep efficiency*. (1)

The events during the PSG can be: *arousals*, *cardiac events*, *respiratory events and movement events*. The arousal events include the number of arousals and the arousals index. The cardiac events during sleep refer to average heart rate, highest heart rate, bradycardia, asystole, tachycardia, atrial fibrillation or other arrhythmias. The respiratory events during sleep include the number of obstructive, central or mixed apnea/hypopnea, apnea-hypopnea index, Cheyne-Stokes breathing, arterial oxygen saturation (mean value and minimum value), and occurrence of hypoventilation. The movement events can be: periodic limb movements of sleep (PLMS), alternating leg muscle activation (ALMA), hypnagogic foot tremor (HFT), excessive fragmentary myoclonus (EFM), bruxism, REM-sleep behavior disorder (RBD) and rhythmic movement disorder (RMD). (1)

The recommended EEG derivations are: F4-M1, C4-M1, and O2-M1 (M1 is the left mastoid) and F3-M2, C3-M2 and O1-M2 (M2 is the right mastoid). The EEG electrodes position is determined by the international 10-20 system. But we can use larger montages, taking into consideration the clinical suspicion regarding the patient (for example, if we have a problem of differential diagnosis between nocturnal epilepsy and parasomnia, we must use a more detailed montage that can mark out the epileptic and epileptiform discharges). The recommended EOG derivations are: E1-M2 (E1 is placed 1 cm below the left outer canthus) and E2-M1 (E2 is placed 1 cm above the right outer canthus). For the chin EMG we use three electrodes: one in the midline 1 cm above the inferior edge of the mandible, one 2 cm below the inferior edge of the mandible and 2 cm to the right of the midline and the last one 2 cm below the inferior edge of the mandible and 2 cm to the left of the midline. (1)

Using all these electrodes in the right placement (EEG, EOG, EMG), we can score each epoch of 30 seconds of the sleep recording (starting point is the light-off moment and ending point is light-on moment) with wake (W), NREM1 (N1), NREM2 (N2), NREM3 (N3) or REM (R) and it is not going to be an easy work because almost every PSG contains between 800-1,000 epochs.

Scoring sleep. In the next chapter of this article, we are going to describe the elements of each stage of sleep and illustrate them with characteristic epochs for each stage from the archive's recordings of **Emergency University Hospital of Bucharest – The Epilepsy and Sleep Center**.

Stage W is characterized by alpha or beta rhythm on EEG, eye blinks, rapid eye movements (which are also seen in REM sleep), slow eye movements or reading eye movements on EOG and normal or high chin muscle tone on EMG. (Fig. 2)

We score *stage N1* when we see low-amplitude, mixed-frequency EEG activity (predominantly theta) and/or vertex waves, slow eye movements on EOG and a diminution of the EMG tone. (Fig. 3)

Stage N2 appears with the occurrence of K-complexes and/or sleep spindles; the EOG usually shows no eye movement activity and the chin EMG is lower than in N1 stage. (Fig. 4)

Stage N3 is the slow-wave-sleep stage with slow-frequency and high-amplitude EEG activity (delta activity) with more than 20% of each epoch. Pathological activity that meets the slow wave activity criteria, such as those generated by metabolic encephalopathies, epileptic seizures or epileptiform activity must not be counted as slow wave activity of sleep. Stage N3 replaces the N3 and N4 stages used in Rechtschaffen and Kales rules. (Fig. 5)

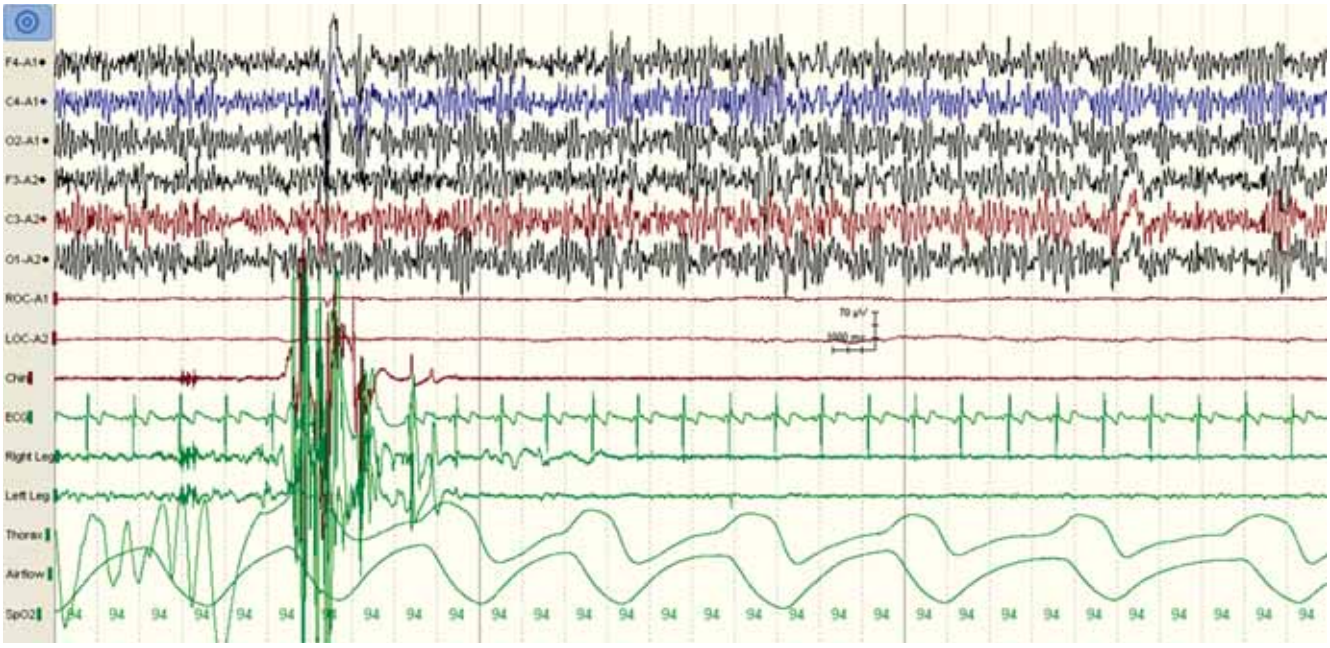


FIGURE 2

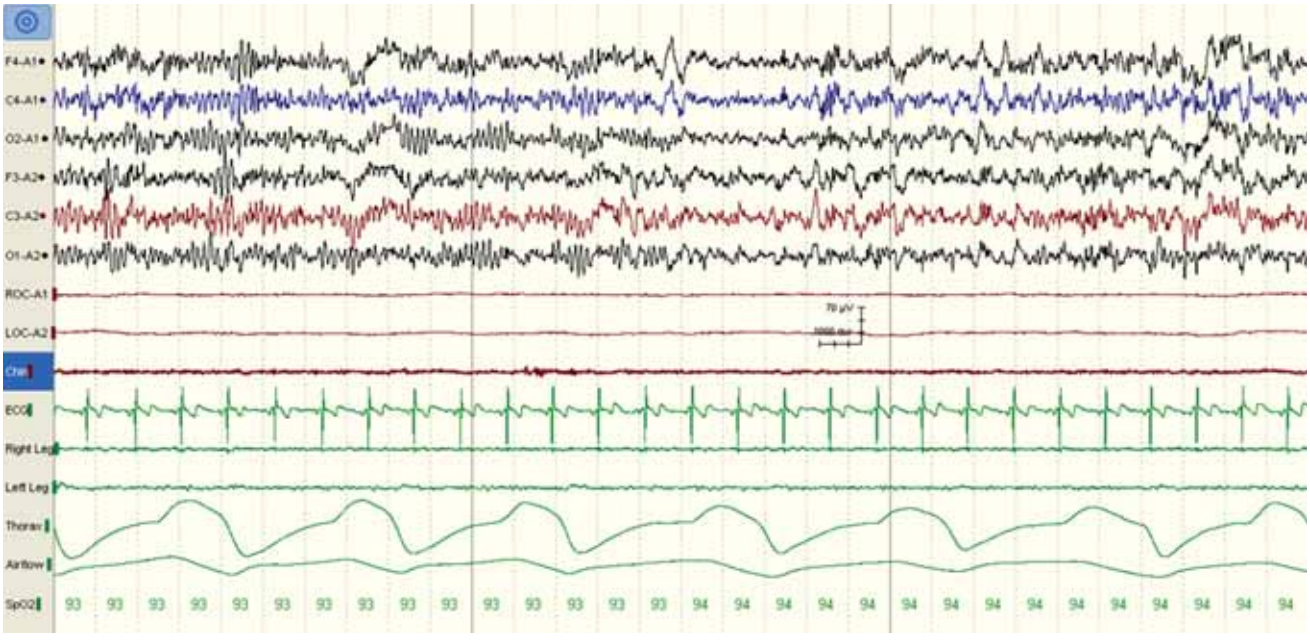


FIGURE 3

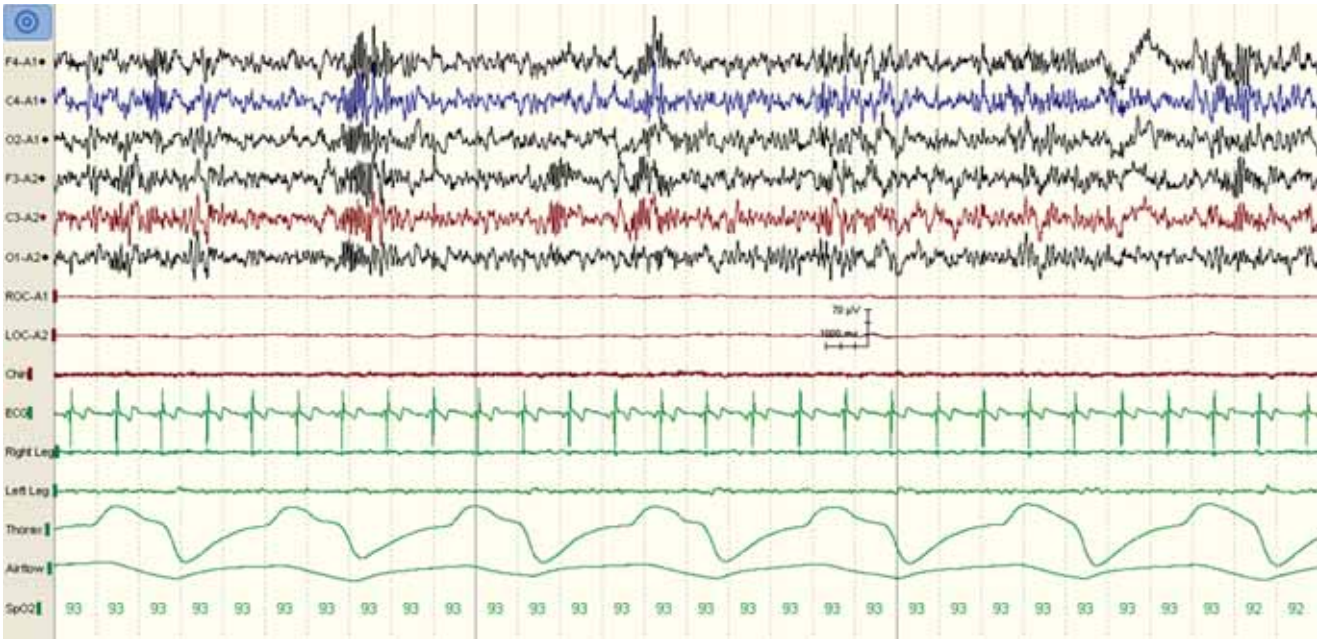
The typical elements for *stage R* are low-amplitude, mixed-frequency activity on EEG (it often resembles the N1 activity), sometimes saw-tooth waves (they are not mandatory for staging R), rapid eye movements on EOG and very low EMG tone. (Fig. 6)

For detailed and complex explanation of each scoring stage and particular situations, we advise you to read the AASM scoring manual for adults and children. (1)

Each staged epoch will contribute to the generation and structure of hypnogram which is going to include the sleep events too. In this way, looking at the hypnogram, we can describe the number and aspects of sleep cycles, time in bed, total sleep time (TST), the sleep onset latency (SOL), number of awakenings, wake after sleep onset (WASO), wake-up time, REM latency, wake after last episode of sleep and sleep efficiency (percent of time in bed spent asleep).

After staging, we must review the whole recording to look for events and mark them (arousals, movements, cardiac events, respiratory events).

In the end, we have a complex recording of sleep that is going to allow us together with the history,



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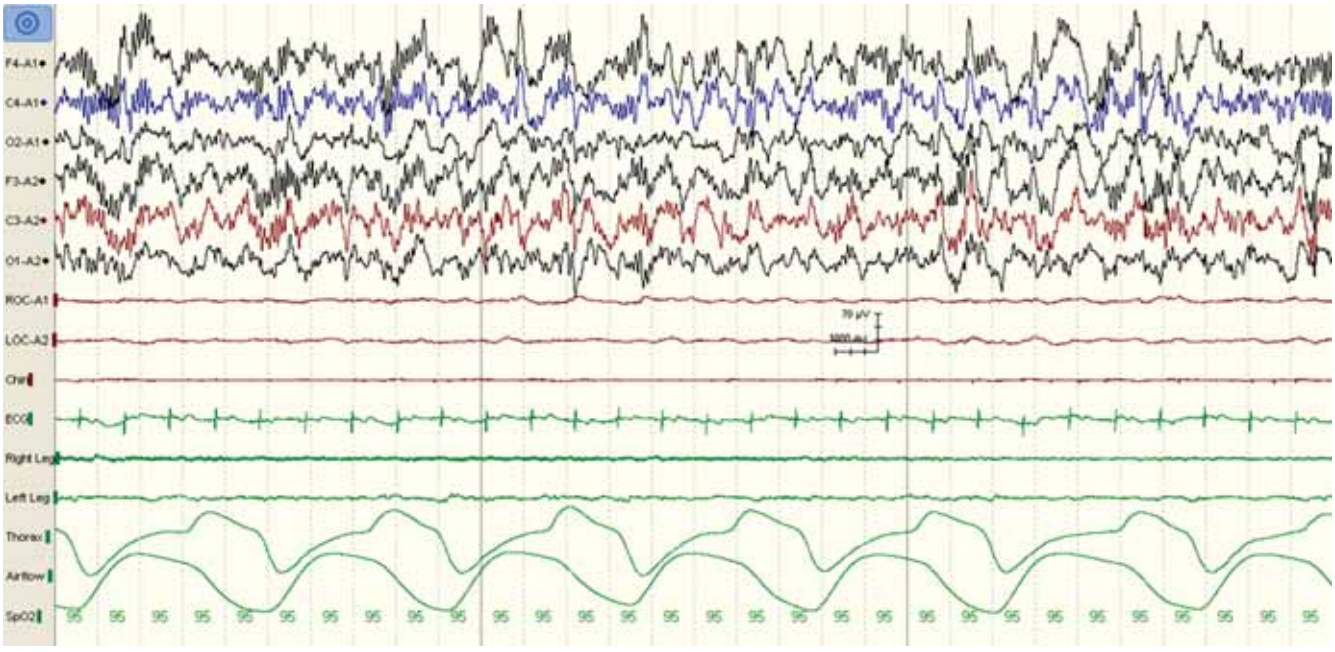


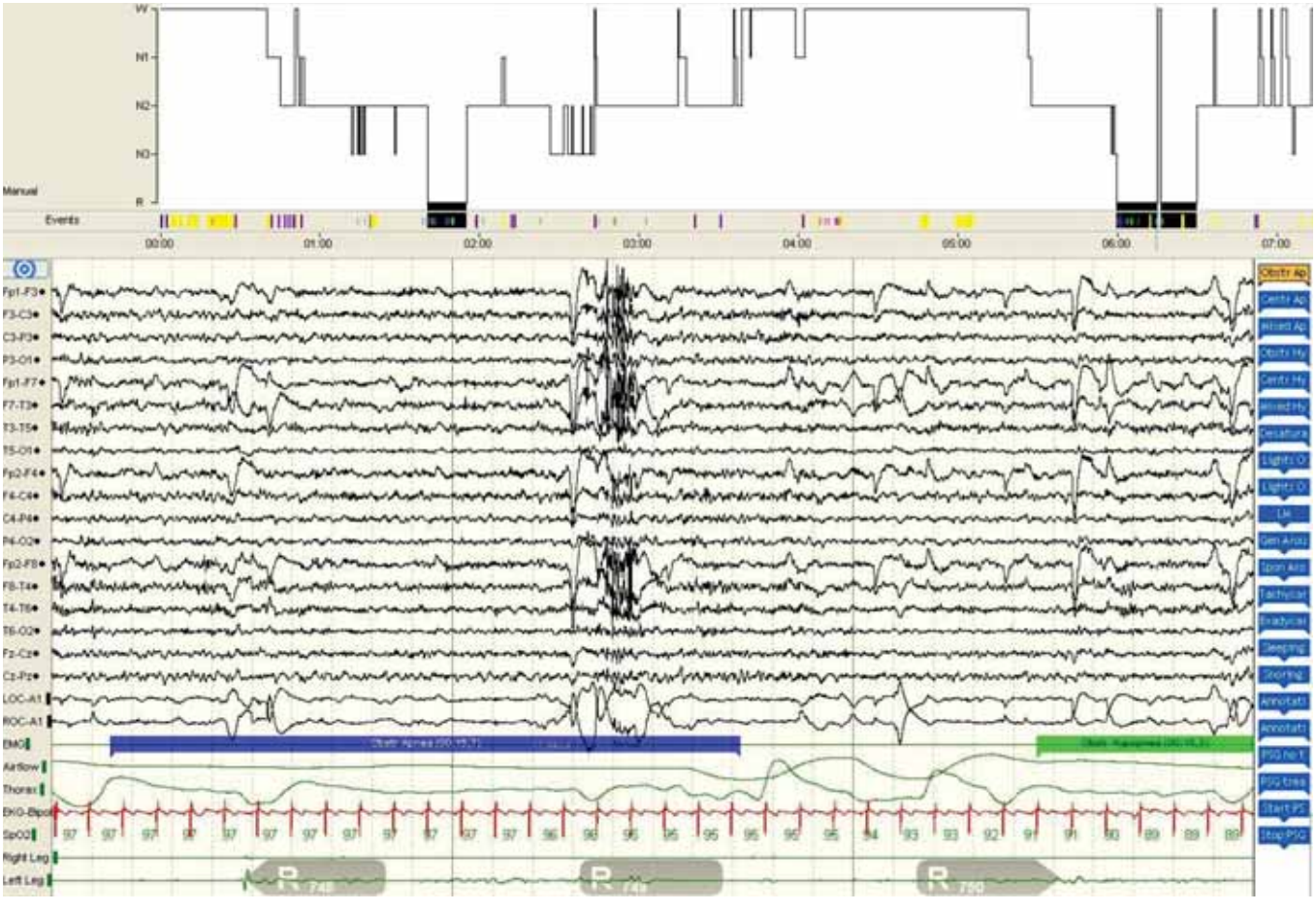
FIGURE 5

physical exam, sleep questionnaires and a sleep diary to come much closer to the right diagnosis of the sleep disorder. Sometimes, other paraclinic sleep tests are needed: video-electroencephalography (in the differential diagnosis of epilepsy), the multiple sleep latency test (when narcolepsy is suspected), maintenance of wakefulness test (which can be a predictor of driving performance) or actigraphy (when the sleep diary is not reliable). (2)

Using the AASM scoring manual, the inter-scorer agreement (in a study that included 1,800 epochs, more than 3,200,000 scoring decisions, more than 2,500 scorers, most with 3 or more years of experience) in a large group is approximately 83%, a level similar to that reported for agreement between expert scorers. Agreement was highest for stage R sleep with stages N2 and W approaching the same level. Scoring agreement for stage N3 sleep was 67.4% and was lowest for stage N1 at 63.0%. (3)

PSG examples. In the last, we would like to present you two hypnograms, following the AASM sleep scoring rules, from our Sleep Department from the Emergency University Hospital of Bucharest. (Fig. 7)

FIGURE 6



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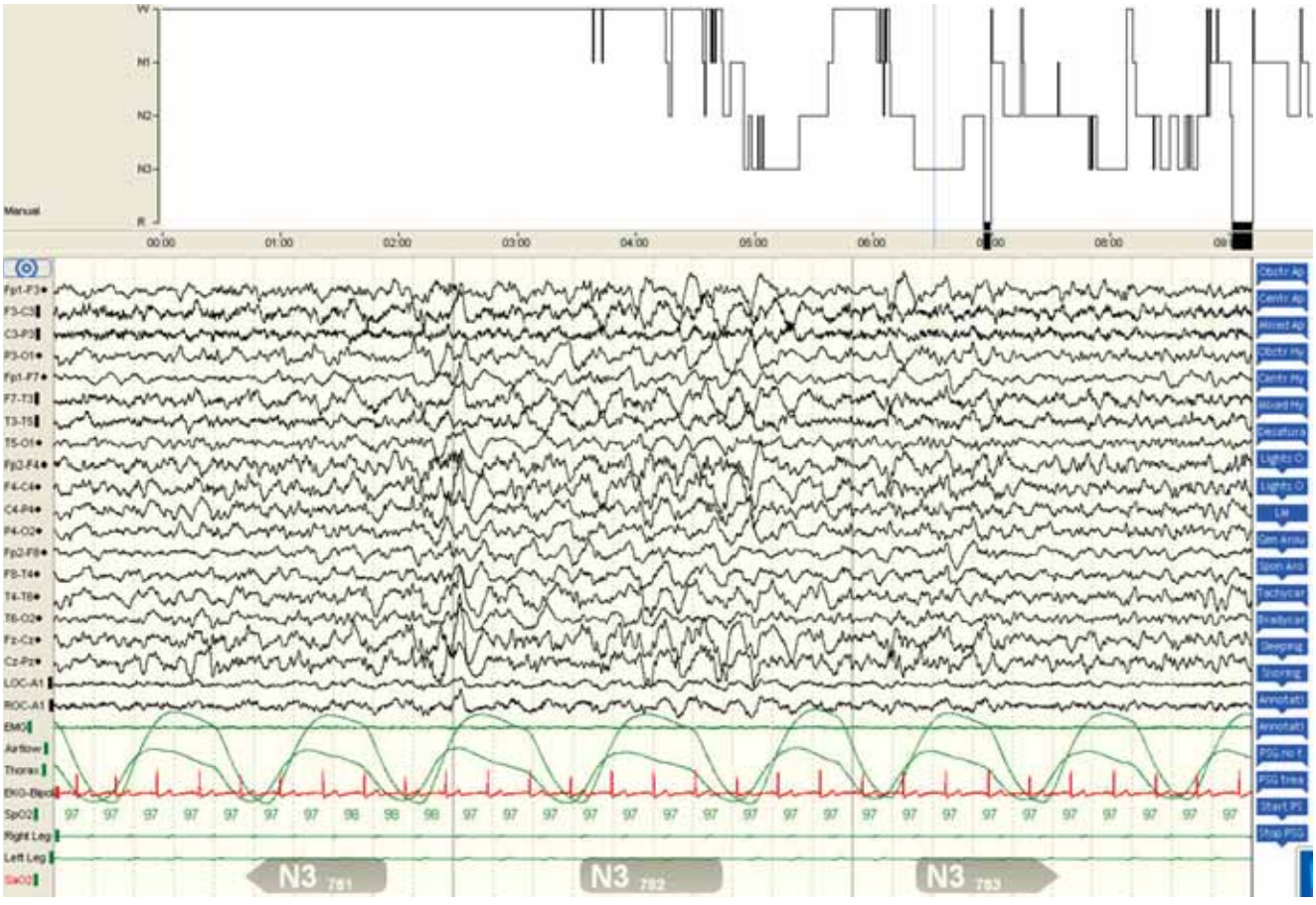

FIGURE 8

Female patient, 71 years old, with mild obstructive sleep apnea only in REM sleep and supine position. The polysomnography was mandatory for diagnosing the sleep breathing disorder and its severity, as a cause of her day-time symptoms (fatigue and excessive daytime sleepiness). The gold standard treatment for her is the APAP (Automatically-adjusting Positive Airway Pressure). (Fig. 8)

Female patient, 24 years old, with chronic sleep-onset insomnia. The polysomnography recording showed us the frequent arousals and waking periods during sleep, the poor sleep efficiency, the predominance of the light sleep and ruled out other sleep problems.

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