Chapter: 7

Fundamentals of Polysomnography

By definition, polysomnography is the collective monitoring and recording of physiologic data during sleep. Traditionally three primary measures, namely EEG, EMG and EOG are used to assess different stages of sleep-wakefulness. To record EEG, or electroencephalogram, six electrodes (labeled C3, C4, A1, A2 O1, and O2) and one ground electrode are placed around the cranium to record electrical activity across the brain, using the 10-20 system of electrode placement. Some people think that it is sufficient to record from only four EEG electrodes (C3, C4, A1, A2) and one ground electrode. On the other hand, others use eight EEG electrodes (labeled C3, C4, F3, F4,O1,O2 , A1, and A2) and one ground electrode. Ear or mastoid process (A1, and A2) electrodes are used as reference electrode. EOG, or Electrooculogram, is recorded by placing one electrode above and to the outside of the right eye, and another electrode below and to the outside of the left eye. EMG, or Electromyogram is actually recorded from two sites. In the classical recording for classification of sleep-wakefulness three leads are placed on the chin (one in the front and center and the other two underneath and on the jawbone). But one more EMG is recorded in the modern polysomnography for assessment of limb movements. For that purpose two leads are placed on the inside of each calf muscle, about 2-4cm apart.

Allan Rechtschaffen and Anthony Kales originally outlined the criteria for identifying the stages of sleep in 1968. The American Academy of Sleep Medicine (AASM) updated the staging rules in 2007. In the classical format originally proposed by Rechtschaffen and Kales (1968), sleep-wakefulness is divided into awake stage, four stages of non-REM sleep (slow wave sleep) and REM Sleep. During awake stage EEG alternates predominantly between beta and alpha activity. Alpha activity is observed when the subject is relaxed and the eyes are closed. Beta activity is observed when the subject is alert with eyes open and scanning the visual environment. During this period EOG activity may be abundant or scarce, depending on the amount of visual scanning. EMG may be high or moderate depending on the degree of muscle tension.

Stage 1 of slow wave sleep is characterized by a decrease in alpha activity. During this period the EEG consists mostly of low voltage, mixed frequency activity, with much of it in 3-7 Hz (theta) rhythm. The subject may have vertex sharp waves in the EEG. EOG activity is mostly absent, but slow rolling eye movements appear. The EMG is moderate to low during this stage. Stage 2 of slow wave sleep is indicated by the appearance of sleep spindles (12-14 Hz sinusoidal waves of waxing and waning pattern), against the background of low voltage, mixed frequency EEG of stage 1. In addition K complexes appear in the EEG. They are negative sharp waves followed immediately by slower positive component ($\geq$0.5s). Eye movements (EOG) are rare during this period, and EMG is low to moderate. Stage 3 of slow wave sleep is marked by the appearance of delta waves in the EEG . These EEG waves have slow frequency (<2cps) and high amplitude (>75µV), occupying ≥20 ≤50% of record. EOG and EMG continue as before. There is a quantitative increase (≥50%) in delta waves (>75µV) during stage 4 of slow wave sleep, so that they come to dominate the EEG tracing. EOG continues as before, but the EMG shows slight further reduction.

REM Sleep is characterised by reverting of EEG to a low voltage, mixed frequency pattern similar to that of awake stage. Saw tooth waves will be recorded in the EEG. Bursts of prominent rapid eye movements (REM) appear in the EOG. EMG is virtually absent, but small muscle twitches may occur against the background.

In the modern polysomnography many variables other than EEG, EMG and EOG are recorded. They include Electrocardiogram (ECG) with two or three chest leads, respiratory effort, by chest-wall and abdominal movement, nasal and/or oral airflow via thermistor or pneumotachograph, oxygen saturation (SpO2) via pulse oximetry, body position via mercury switches or by direct observation, and limb movements (arms and legs) using EMG. EKG/ECG (Electrokardiogram / Electrocardiogram) is recorded with the help of two electrodes placed on the upper chest near the right and left arms. These records are merely to note the heart rate and rhythm, and to serve the purpose of alerting the technician to a possible emergency situation. They also demonstrate whether apneic desaturation leads to arrhythmias or not. Airflow is monitored with the help of a thermistor or thermocouple sensor. This device looks similar to a nasal cannula and is secured just under the patient's nose. It senses the amount of air moving into and out of the airways and sends a signal to a physiological recorder. This tracing is used to determine the presence and extent of apneic episodes. Respiratory effort is assessed using a piezo crystal. Two Velcro bands, one placed around the chest under the breasts and one around the abdomen, serve to determine chest wall and abdominal movements during breathing. Each band has a piezo crystal transducer. The force of chest or abdominal expansion on the bands stretches the transducer and alters the signal to a physiological recorder. These leads, combined with the airflow sensor, help to detect apnea. Video cameras are used to monitor the patient. If the patient activity is taped while sleeping, the technician can review the tape at any time during the analysis. It helps to verify whether strange- looking waveforms were caused by the patient's movement, or due to any other reason. Oxygen saturation of blood is measured by a pulse oximeter probe placed on the finger, or earlobe of the patient.

Polysomnography may be indicated in patients of insomnia, hypersomnia, sleep-related breathing disorders, circadian rhythm sleep disorders, parasomnia, sleep-related movement disorders, sleep disorders associated with mental, neurological & other medical problems. In addition it would be required in nonpatient (community) services like screening and testing of pilots, night drivers and shift workers.

Polysomnograph equipment is nothing but a polygraph recorder equipped with AC and DC bioamplifiers, with user-selectable electrical filters and sensitivities. It should be capable of recording a minimum of 10 channels of physiologic data. If it is a paper recorder it should record the data at paper speeds from 10-30 mm/s. The polygraph may also be interfaced with an analog or digital storage device (cassette tape, optical disk etc.) that has the ability to store and to print all raw data collected during the study. A calibration signal of 50 μV/cm is most commonly used. It is essential to calibrate the recorder prior to, and after the study. EMG pen deflection of 2 μV/mm is common; however, the absolute magnitude of the amplitude is irrelevant, as the emphasis is on relative changes in the EMG amplitude. To record EEG and EOG, the recorder should have the sensitivity of 5.0-10.0 mm for a 50 microvolt signal. EEG and EOG signals are amplified with an AC amplifier, with high-frequency-filter at > 30-35 Hz, & low-frequency-filter at < 0.3 Hz. EMG signal is amplified with an AC amplifier, with high-frequency-filter setting of 70-120 Hz and a low-frequency-filter setting > 5 Hz. Two ECGs are recorded from Leads I, II, III, or Modified Central lead (MCL). No particular emphasis needs to be placed on signal amplitude provided the signal is large enough to be discernible. Output from respiratory effort and airflow-sensing devices, oxygen-saturation data, and body position determined with mercury switches, is recorded with the other data. If body position is monitored by direct observation, it should be noted whenever changes in position occur.

The major device limitation is the displacement of the electrode, and recording of electrical noise associated with EEG, EOG, and EMG monitoring. QRS-complex & P-wave may be obscured in ECG record, as paper (display) speed used during polysomnography may be slower. Record of chest and abdominal movement is affected if the gauge slips or if the patient changes position. Record of airflow with thermistors and thermocouples can provide only qualitative information. If pulse oximeter alarm is not disabled, the sound of this instrument during apneic events awakens the patient. A qualified technician should be in constant attendance to intervene if clinically indicated. Constant monitoring during polysomnography is essential as intervention is required if the physiologic signals are lost due to problems of instrumentation or become obscured by artifact. Infrared or low-light video cameras and recording equipment should permit visualization of the patient, by the technician, throughout the procedure. The technician should intervene if an acute change in physiologic status occurs and communicate these changes to appropriate medical personnel.

Some precautions may be required to avoid complications. Skin irritation may occur with electrode paste. Electrode paste remover (eg, acetone) should only be used in well-ventilated areas. Electrical isolation of polysomnographic equipments must be certified by qualified personnel. Collodion and acetone (which are inflammable) should be used with caution, especially in those patients who require supplemental oxygen. Patients with parasomnias or seizures may be at risk of injury during movements in sleep.

Infection control is another precaution to be taken. Practitioners should exercise appropriate precautions for spread of diseases. Non-disposable items for patient use (eg, pneumotachometers, face masks, electrodes) should undergo cleaning and sterilization procedures as recommended by the manufacturer. The syringe and flat-tipped needle used to inject transduction gel into the EEG, EOG, and EMG electrodes should be discarded after use. Body-position sensors, strain gauges, or piezoelectric belts may be exposed to gas sterilization, if they become contaminated with body fluids.