

Standard Polysomnography

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SUMMARY

The scope of polysomnography encompasses the monitoring of patients in a sleep testing facility using an array of medical equipment and technology and simultaneously recording that data on a multi-channel analog or digital system. Sleep technologists are specially trained to perform polysomnography (PSG) for the diagnosis and treatment of sleep and arousal disorders. They work as part of a team and under the direction of a physician credentialed in sleep medicine. The team works collaboratively to ensure the proper diagnosis, appropriate management, and education for individuals that experience sleep disorders. They follow patient-sensitive standards of care, which are the foundation for clinical/technical decision-making.

The sleep technologist prepares for and monitors the sleep study recording, requiring expertise in normal and abnormal sleep, and knowledge in multiple technical and medical monitors. Much of the utility of the polysomnogram (PSG) depends on the ability to correlate specific changes or abnormalities of one physiological parameter with specific conditions defined by another parameter or parameters. Consequently, polysomnography is a significantly more powerful and complex tool than could be provided by individual or independent measurements of each variable. The sleep technologist verifies and maintains the quality of the recording and can decipher artifacts from true physiological signals. The technologist can also recognize when medical intervention is required and responds according to the protocols provided by the medical director. Therefore, an attended polysomnography by a trained and credentialed sleep technologist produces the highest quality clinical data.

The standard diagnostic PSG requires the monitoring, recording, and evaluation of sleep stages and arousals, respiration, limb movements, snoring, oximetry, body position, and cardiac rhythm. The resulting documentation is used to diagnose or assess the treatment of sleep disorders (1).

KEY DEFINITIONS

Sleep testing facility – a hospital or independent clinic that performs sleep diagnostics and therapeutics.

Sleep technologist – refers to those who have passed the Board of Registered Polysomnographic Technologists (BRPT) examination and are identified by the Registered Polysomnographic Technologist (RPSGT) credential; the American Board of Sleep Medicine (ABSM) examination and are identified by the Registered Sleep Technologist (RST) credential; or the National Board of Respiratory Care examination and are identified by the Sleep Disorders Specialist (SDS) credential.

1.0 SCOPE

This technical guideline will include diagnostic polysomnographic evaluations, which are provided in a sleep testing facility and attended by a sleep technologist. This technical guideline does not address pediatric PSG evaluations, home or unattended PSG evaluations, or therapeutic intervention, such as the use of positive airway pressure (PAP), or oxygen for the purpose of titrating.

1.1 Indications for Standard Polysomnography

Standard polysomnographic evaluation is necessary because physiological functions change during the sleeping state and many disorders are specifically induced by sleep. Currently, over 80 specific disorders of sleep and arousal are identified in the *International Classification of Sleep Disorders (ICSD-3)* (2). A polysomnographic evaluation is one of the tools used by physicians that can result in a specific diagnosis of a sleep disorder that might otherwise remain obscure.

Polysomnography is recommended for the clinical suspicion of sleep disordered breathing with any of the following conditions:

- heart disease
- congestive heart failure
- coronary artery disease
- significant arrhythmias
- stroke
- significant tachyarrhythmias or bradyarrhythmias
- other respiratory disorders (i.e., other lung diseases and disorders associated with chronic alveolar hypoventilation and hypoxemia, COPD, asthma, other chronic lung diseases, and neuromuscular disease)
- parasomnias and seizure disorders
- narcolepsy

Polysomnography may be recommended for the clinical suspicion of:

- restless legs syndrome and periodic limb movement disorder
- depression with insomnia
- circadian rhythm sleep disorders

1.2 Patient Referral Dynamics

Standard PSG evaluations can be carried out within the sleep testing facility where patients are primarily physician referred and their subsequent care is the responsibility of the referring physician; or preferably within the sleep facility where patients are self-referred, physician referred or by the recommendation of a trained sleep clinician. Treatment plans are then formulated and implemented by the sleep specialist. Patient education is provided by the sleep technologist and compliance and outcomes are tracked.

2.0 RECORDING TECHNIQUES

2.1 Physiological Parameters Measured and Equipment Parameters

This section will discuss the physiological parameters that are necessary to record during standard PSG to provide adequate data for interpretation by the sleep specialist. Each parameter will be described

and the standard methodology for preparation and monitoring will be outlined. It is the goal of polysomnography to capture the best quality recordings of the physiological channels. All of the technical specifications noted are as per the *AASM Manual for the Scoring of Sleep and Associated Events* (3).

2.1.1 Routine Variables

2.1.1.1 Electrode Preparation and Application

Description

Electrodes used in polysomnography conduct biopotentials from the patient to the recording circuit. Electrodes are used to record EEG, EOG, EMG, ECG, and sometimes respiratory effort. The best recordings are artifact free and have the maximum waveform amplitude possible. Because subtle variations in current are muted by impedance, it is important to attain the lowest impedance possible. The pathway in question consists of the source of the current being measured in each locale of the body, the various levels of tissue, and the actual electrode cups and wires. It is through these layers that conductance is thwarted by impedance. Lower impedance allows higher conductance and produces larger amplitude waveforms.

The goal of electrode application is to obtain the lowest impedance possible without compromising patient comfort and skin integrity. For optimal signal quality, it is necessary to match the input impedance of all electrode pairs as closely as possible. Impedance mismatching allows excess current to pass through to the amplifier and can lead to artifact. Common mode rejection is the cancellation of voltages equal to both input electrodes. Impedance mismatching also impairs common mode rejection. Therefore, optimal signal quality is possible when impedances are low enough to maximize amplitude, are relatively equal, and take advantage of common mode rejection. The standard for electrode impedance upper limit is 5k ohms for EEG and EOG, and 10k ohms for EMG. *The guideline is that impedances are as closely matched as possible* (3).

Methodology

The area where the electrode is to be placed is prepared by abrading the skin to allow optimal impedance without disrupting the dermis. To maximize the signal quality and minimize patient discomfort, the sleep technologist should take care to scrub only the area where the electrode will be placed. Electrodes should be of ample length for input from the electrode site to the headbox.

Cup electrodes are filled with electrolyte or electrode paste, and then placed at the proper location, pressed firmly in place to ensure a good skin-to-electrode contact. For scalp electrode sites, a small amount of electrode paste is placed on a gauze square and placed over the electrode. Care should be taken to keep the electrode paste close to the electrode disc, as the electrode recording site is the entire area that the electrode paste touches. For other electrode sites, fill the electrode disc with electrode paste and secure it to the electrode site with tape or medical adhesive.

For electrode locations other than the scalp, various types of single use adhesive electrode discs are available as are “snap on” electrode wires of appropriate length (i.e. 60 inches).

After use, reusable electrode discs and wires should be cleaned and disinfected according to manufacturers or facility protocols for infection control.

2.1.1.2 Electroencephalogram (EEG)

Description

The EEG is the primary variable to document wakefulness, arousals, and sleep stages during the sleep study. A single central channel referenced to an ear mastoid site (C4-M1), a single frontal channel referenced to an ear mastoid site (F4-M1) and a single occipital channel referenced to an ear mastoid site (O2-M1) is sufficient for evaluating waveforms (3). The mastoid is located posterior to each ear. However, additional channels (C3-M2, F3-M2, O1-M2) are recommended to provide redundancy in case of electrode malfunction.

Methodology

The electrode locations should be determined through use of the *International 10-20 System of Electrode Placement* measurement system (4). Additional electrodes may be placed as deemed necessary by the sleep facility's medical director or physician's order. For example, the evaluation of a patient with a possible nocturnal seizure disorder may indicate the use of an expanded seizure montage. These additional electrodes should also be placed according to the *International 10-20 System of Electrode Placement*. Electrodes should be applied according to the skin preparation recommendations outlined in section 2.1.1.1. The amplifier settings and calibration requirements for the recording of the EEG signal will vary according to the equipment specifications, but should adhere to AASM standards as outlined in section 2.2.1.

2.1.1.3 Electrooculogram (EOG)

Description

The EOG recording aids the identification of various stages of sleep. For example, slow rolling eye movements are typically observed during Stage N1 sleep and rapid eye movements (REMs) occur during Stage R (REM) sleep.

Methodology

At least two channels of EOG are recommended. Each EOG channel records from an electrode placed 1 cm lateral and above (E2) or 1 cm lateral and below (E1) the outer canthus of the eye. An equal displacement of the electrodes ensures equal amplitude of the conjugate eye movements. A mastoid site (M2) is generally used as the reference for both EOG electrodes; however, if the M2 reference electrode fails, E1 and E2 should be referenced to M1. With these derivations, conjugate eye movements produce out-of-phase voltage deflections in the two channels; whereas simultaneous EEG activity is usually in phase.

To distinguish between vertical and lateral eye movement, additional EOG montages can be applied using electrodes placed 1 cm below and 1 cm lateral to the outer canthus of each eye referred to a supra-nasion reference electrode (Fpz) that produces deflections in phase with vertical eye movements and out of phase with horizontal eye movements. A supra-nasion reference electrode alone, however, may result in the integration of EEG activity with extra-ocular movement potentials. Consequently, other reference locations may be required for specific circumstances. Electrodes are applied according to

section 2.1.1.1. The amplifier settings and calibration requirements for the recording of EOG signals will vary according to equipment specification, but should adhere as closely as possible to AASM standards.

2.1.1.4 Chin Electromyogram (EMG)

Description

The recording of EMG activity in the chin area is used for determining the level of muscle tone, which gradually decreases as one progresses through the deeper stages of sleep. The lowest muscle tone of the recording is most often observed during Stage R (REM) sleep. This channel also provides supplemental information regarding patient movements and arousals and may be useful in distinguishing artifacts in other channels.

Methodology

Three electrodes should be placed to record chin EMG as follows: one placed in the midline 1 cm above the inferior edge of the mandible (mental), one 2 cm below the inferior edge and 2 cm to the left of the midline (submental), and one placed 2 cm below the inferior edge and 2 cm to the right of the midline (submental). A single channel is sufficient with either of the submental electrodes referenced to the mental electrode. An additional electrode may be placed on the masseter muscle on the jaw line and referenced to the mental electrode to better distinguish bruxism. However, if used, this additional electrode should be included as a separate recording channel. Electrodes are applied according to section 2.1.1.1. The amplifier settings and calibration requirements for the recording of the EMG signal will vary according to equipment specifications, but should adhere as closely as possible to AASM standards.

2.1.1.5 Limb Movement

Description

Additional causes of sleep disturbances include limb movement activity. Limb movements are often visually detectable during the monitoring process. Standard monitoring of the anterior tibialis muscles allows for the identification of leg movements and the determination of the severity of the disorder, for example, by quantifying the rate of movements as well as the correlation with EEG arousal. Limb EMG of the upper extremities may also be recorded if clinically indicated.

Methodology

For monitoring leg movements, surface electrodes should be placed longitudinally and symmetrically in the middle of the anterior tibialis muscle so that they are 2-3 cm apart or 1/3 of the length of the anterior tibialis muscle, whichever is shorter. Although one electrode can be placed on each leg and referenced together to record both legs on one channel, this is not optimal and may affect the scoring of periodic limb movements (PLMs) according to AASM published guidelines. Electrodes are applied according to section 2.1.1.1. The amplifier settings and calibration requirements for the recording of the EMG signal will vary according to equipment specifications, but should adhere as closely as possible to AASM standards.

2.1.1.6 Electrocardiogram (ECG)

Description

The ECG monitors the heart rhythm. A single ECG channel is sufficient for standard PSG monitoring. Additional leads may be placed if clinically indicated.

Methodology

The two standard ECG electrodes are applied in a lead II format. One electrode is placed below the right clavicle parallel to the right shoulder and a second electrode is placed on the torso at the fourth intercostal space on the left side parallel to the left hip. The placement used should be documented. Electrodes are applied according to section 2.1.1.1. The amplifier settings and calibration requirements for the recording of the ECG signal will vary according to equipment specifications, but should adhere as closely as possible to AASM standards.

2.1.1.7 Upper Airway Sound Recording

Description

Detecting snore bursts can be a valuable supplemental tool for determining and verifying the nature of arousals. There are several commercially available devices however snoring is typically measured with a snore microphone, piezoelectric sensor or nasal pressure transducer.

Methodology

The piezoelectric snore sensor or microphone should be placed over the trachea or on the side of the neck and can be secured with tape. The decision of where to place the device should be based on obtaining a good signal without compromising patient comfort. The sleep technologist should feel for the area of maximum vibration while the patient hums or snores. This will allow for recording of the snore sounds or vibration. Snoring can also be detected using a nasal pressure transducer. The polygraph settings for detecting snore sounds using a snore sensor or microphone are the same as those used for submental EMG detection.

2.1.1.8 Respiration (Measures of Airflow and Respiratory Effort)

Description

Airflow and respiratory effort channels are utilized during the standard PSG to monitor respiration and detect the presence of apneas, hypopneas, respiratory effort related arousals (RERAs) and other sleep related breathing events. It is important to record at least three respiratory parameters: nasal/oral airflow, thoracic effort, and abdominal effort.

Methodology

Various transducers may accomplish the recording of airflow exchange. A thermal sensor [either a thermistor, thermocouple or polyvinylidene fluoride (PVDF) sensor] is used in the detection of apnea. Pressure transducers offer a sensitive method of recording airflow and are used for both hypopnea and RERA detection. Pressure transducers used in sleep can be broken down by power source and by transducer type. In sleep testing today there are two types of power sources for pressure transducers: 1) replaceable batteries; 2) a piezo power source. There are also two types of pressure transducers: 1) a differential transducer (two ports); 2) a gauge transducer (one port). The differential transducer is usually battery-powered and the single port is piezo-powered. The differential transducer

measures the pressure difference between the two input ports. The gauge measures one pressure against ambient pressure. It is necessary to use both methods of measurement, thermal sensor and pressure transducer, to achieve accuracy from nasal and oral flow. It is equally important that both nasal and oral flow is monitored because air exchange can occur through a combination of these orifices (3). Secure flow sensors with tape.

Monitoring respiratory effort can be accomplished by several methods, including intercostal or diaphragmatic EMG electrodes, esophageal pressure monitoring, or calibrated or uncalibrated inductance plethysmography that permits differentiation between abdominal and thoracic movement. The most accurate measure of respiratory effort is esophageal pressure manometry; however, correct placement of the sensor is difficult and can cause patient discomfort and sleep disturbance. The recommended sensors are thoracoabdominal inductance plethysmography belts (3). Unless otherwise recommended by the manufacturer, the thoracic effort belt should be placed under the armpits, at or above the nipple line, while the abdominal effort belt should be placed at the level of the umbilical. Effort belts should be fitted snug, but not tight. Polyvinylidene fluoride (PVDF) effort sensors may be used as an alternative sensor for the detection of respiratory effort in adults.

The sleep technologist and medical director should evaluate the various flow and effort sensors available to determine the most appropriate for recording of these parameters in the sleep testing facility. Some of the points to compare would be the need for a calibrated signal for a quantitative signal versus qualitative signal, patient comfort, cost, replacement frequency, susceptibility to artifact, etc. The amplifier settings and calibration requirements for recording respiratory signals will vary according to equipment specifications, but should adhere as closely as possible to AASM standards. Because apneas, hypopneas, and RERA's frequently trigger arousals and interrupt the normal sleep cycle, it is important that respiratory effort and airflow are recorded to allow for the development of a sleep profile with which the breathing disturbance can be correlated.

2.1.1.9 Blood Oxygenation (Oxygen Saturation - SpO₂)

Description

The diagnosis of obstructive sleep apnea during the standard PSG requires the continuous monitoring and display of blood oxygen saturation levels to provide crucial information about the severity of the sleep related breathing disorder. Pulse oximeters are generally built in to or can be easily interfaced with the PSG acquisition equipment. It is necessary to carefully evaluate the pulse oximeter for use in the sleep facility for sampling rate and analog output to interface with the polygraph. The output on the oximeter must be through a DC amplifier and the signal must be displayed simultaneously with other pertinent PSG variables. In modern PSG systems, oximetry is integrated as a DC channel in the system amplifier. The polygraph DC amplifier requires calibration, and the output can be displayed linearly or numerically, depending on the acquisition system.

Whichever method is used to record pulse oximetry, the device must be capable of a signal averaging time of 3 seconds or less.

Methodology

Pulse oximetry transmits two wavelengths of light through a pulsatile vascular bed to measure arterial oxygen saturation. Pulse oximetry is frequently the method used to monitor blood oxygen levels in the

sleep testing facility because of the ease and comfort to the patient. Pulse oximetry measurement is most commonly performed using a finger probe, although other placements such as the earlobe or toe may be used depending on the patient. It should be noted that pulse oximetry does not reflect total gas exchange and therefore, cannot detect changes in PaCO₂. Artifacts may commonly occur due to movement, etc. The integrity of the pleth waveform directly correlates to accuracy of the saturation signal.

2.1.1.10 Capnography

Description

Capnography is a non-invasive method to measure a patient's carbon dioxide (CO₂) level and is useful in providing a breath-by-breath analysis of ventilatory status. Its use is standard in pediatric polysomnography and can be valuable in adult populations for evaluation for hypoventilation.

Capnography measurement in the sleep testing facility can be accomplished via end-tidal (ETCO₂) or transcutaneous (TcCO₂) monitoring. The graphical display, or capnogram, represents different phases of the ventilatory cycle. When expiration begins, values will read close to zero (0), as air from conducting airways (dead space) is measured. As expiration continues, values rise rapidly as CO₂-rich alveolar gas is measured. During the later portion of expiration, values reach a plateau and an end-expiratory CO₂ value (ETCO₂) is measured. As inspiration begins, the CO₂ value drops rapidly to zero (0) and remains there throughout the inspiratory phase. Normal ETCO₂ values are 35 - 45 mmHg. Elevated readings are associated with hypoventilation, while low values are associated with hyperventilation or anxiety.

Methodology

For a transcutaneous PCO₂ (TC PCO₂) recording, a TC CO₂/PO₂ electrode is placed directly on the skin and heated to 42 – 45 degrees centigrade. Care must be taken to ensure that the electrode temperature does not burn patients with fragile skin. The transcutaneous sensor measures the transpired PCO₂, which fairly accurately reflects tissue PCO₂. This is the preferred method for monitoring neonates in an intensive care setting; however, in adults it is accurate only in patients with good tissue perfusion.

End tidal capnography requires the use of a nasal or nasal/oral cannula or a tight fitting mask to produce numerical and graphical displays of CO₂ levels. Split cannulas for measurement of nasal pressure and ETCO₂ may be used during polysomnography to minimize the number of sensors placed at the nose.

The sleep technologist is expected to monitor the capnography values and trend data throughout the night. If values fall outside normal range, the technologist should take appropriate action as defined in the facility's safety and emergency policies in the Policy & Procedure manual. When in doubt, they should contact the medical director or physician on call. Calibration procedures, troubleshooting techniques, and cleaning methods should conform to the manufacturer's recommendations and facility protocols (5).

2.1.1.11 Body Position

Description

Many sleep disorders such as sleep disordered breathing can be exacerbated by body orientation during sleep. Therefore, a valuable tool for accurate diagnosis and treatment of sleep disorders is a

determination of body position on a continuous basis throughout the entire recording. Most body position sensors will generate five output signals: supine, prone, left lateral, right lateral and standing/sitting.

Methodology

Body position can be monitored with various commercially available body position monitoring devices. These devices typically use mercury switches or active RFID-based sensors and can be interfaced with the polygraph if an AC channel is available. Alternatively, the sleep technologist can manually observe the patient and document body position changes on the recording. For report generation, it is optimal to be able to correlate body position in the assessment of sleep disordered breathing. Simultaneously recorded EEG channels will determine if movements originate from wake or sleep and whether arousals correlate with limb or body movement (6).

2.1.1.12 Behavioral Observation

Description

The capability of observing the patient during the recording of the standard PSG is required for patient safety as well as clinical and technical assessment. The recommendation is to use both audio monitoring and digital video recording that is synchronized with the PSG recording.

Methodology

Patient observation can be performed using an audio and video monitoring system that allows the sleep technologist to observe and document patient behaviors (i.e., body position, body movements, etc.) during the study. Audio monitoring allows the patient to communicate with the sleep technologist and provides a mechanism for the technical staff to hear and document snoring sounds and other patient vocalizations during the sleep study. PSG data acquisition systems are generally equipped with digital video monitoring systems, which can be viewed on the computer monitor and archived simultaneously with the PSG data. Recorded video data must be synchronized with PSG data and have an accuracy of at least one video frame per second (3). Higher frame rates of 15 to 24 frames/second may be used for recording patients with seizure disorders, movement disorders and parasomnias. Exceeding 30 fps is not normally needed for recording PSG and can create a lag in the recording.

2.2 Recording Environment

Description

The standard PSG protocol is designed to obtain the maximum clinically relevant physiological information with the least disruption of the patient's normal sleep patterns. The sleep study should be initiated as close as possible to the patient's normal sleep time and conducted in a safe, private, quiet, dark, and comfortable room that resembles a bedroom or hotel room. Facilities must have a two-way intercom and the ability for continuous audio/video recording. Patients should be made aware of the camera's location and that the sleep testing is associated with continuous audio/video recording for the duration of time that the patient is in the testing room. The patient will be required to acknowledge this on the audio/video consent form.

Methodology

PSG acquisition equipment should be physically separated from the patient with appropriate shielding of light and sound. The control room should be close to patient rooms, and must be on the same floor with direct unhindered access to patients undergoing testing. Interruptions during the night can and should be kept to a minimum with the use of "back-up" electrodes and by merely changing the channel derivation in the montage. The bedroom must allow easy access for emergency personnel to reach patients. A bathroom must be available and at least one patient bedroom and bathroom should be handicapped accessible.

2.2.1 Montage Filter & Sensitivity Settings

The standard PSG recording montage should consist of the measurement of the above-defined parameters. 60 Hz notch filters should not ordinarily be used to record EEG or EOG, as this may conceal the presence of artifact, and the use of 60 Hz notch filters must be avoided in the EMG channels as EMG activity falls within the range of the 60 Hz notch filter. The sleep facility director should determine the specific montage and the equipment and recording devices used.

An example of a desirable montage is as follows:

Channel	Derivation	Sensitivity	High Frequency Filter	Low Frequency Filter	Sampling Rate
Left Outer Canthus	E1-M2	5-7 $\mu\text{v}/\text{mm}$	35 Hz	0.3 Hz	500 Hz
Right Outer Canthus	E2-M2	5-7 $\mu\text{v}/\text{mm}$	35 Hz	0.3 Hz	500 Hz
Chin EMG	EMG1 EMG2 EMG3	10-7 $\mu\text{v}/\text{mm}$	100 Hz	10 Hz	500 Hz
Frontal EEG	F4-M1 F3-M2	5-7 $\mu\text{v}/\text{mm}$	35 Hz	0.3 Hz	500 Hz

Central EEG	C4-M1 C3-M2	5-7 $\mu\text{v}/\text{mm}$	35 Hz	0.3 Hz	500 Hz
Occipital EEG	O2-M1 O1-M2	5-7 $\mu\text{v}/\text{mm}$	35 Hz	0.3 Hz	500 Hz
Left Anterior Tibialis	LAT1-LAT2	10 $\mu\text{v}/\text{mm}$	100 Hz	10 Hz	500 Hz
Right Anterior Tibialis	RAT1- RAT2	10 $\mu\text{v}/\text{mm}$	100 Hz	10 Hz	500 Hz
ECG	ECG1- ECG2	20 $\mu\text{v}/\text{mm}$	70 Hz	0.3 Hz	500 Hz
Snore Microphone	Snore	20 $\mu\text{v}/\text{mm}$	100 Hz	10 Hz	500 Hz
Pressure Flow	Pflow	20 $\mu\text{v}/\text{mm}$	15 Hz	DC or ≤ 0.03 Hz	100 Hz
Thermal Flow	Tflow	20 $\mu\text{v}/\text{mm}$	15 Hz	0.1 Hz	100 Hz
Thoracic Effort Belt(s)	Tho	10-100 $\mu\text{v}/\text{mm}$	15 Hz	0.1 Hz	100 Hz
Abdominal Effort Belt(s)	Abd	10-100 $\mu\text{v}/\text{mm}$	15 Hz	0.1 Hz	100 Hz
PAP	CPAP IPAP EPAP	DCx	5 Hz		100 Hz
SpO2	SpO2	DCx	5 Hz		25 Hz

Body Position	Pos				1 Hz
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2.2.2 Instrumentation

Description

The equipment used to gather, analyze, and store the data from the sleep study must be maintained and documented as such by a trained biomedical technician or other responsible party. Visual inspections of the physical condition of the equipment for flaws, deformities, wear and tear or other defects should take place monthly. If problems are noted, the equipment should be removed, tagged, and sent for repair by an authorized technician. Electrical safety testing by certified technicians or biomedical engineering should take place annually. All routine inspections and maintenance should be documented and logged including the frequency, person inspecting and location of the reports for compliance purposes.

Methodology

Differential amplifiers are designed to distinguish between the desired physiologic voltage at the exploring electrode site and all other unwanted voltages from the body and the external environment using common mode rejection. The standard minimum limit for PSG common mode rejection ratio is 10,000:1. The signal must be sampled often enough to provide an accurate waveform but not so often as to use unnecessary resources. According to Nyquist theory, this minimum rate is 2 times the highest frequency being measured, which is 200 Hz, and is also the minimum recommended setting for EEG, EOG, EMG, ECG and snore microphones (7). The desirable setting for these parameters is 500 Hz. Maximum electrode impedances should not exceed 5 kilohms for EEG, ECG, and EOG channels. Maximum electrode impedances should not exceed 10 kilohms for EMG channels.

Proper electrode placement, adequate site preparation, proper sampling, and appropriate filtering and amplification, provide a good physiologic basis for conversion to a digital representation. The digital signals must be displayed and recorded to maximize appropriate visualization of the recorded signals. Proper screen resolution is most often determined by the video equipment manufacturers and should not be altered to manipulate things like font size. For PSG viewing on the monitor, use the highest resolution available and recommended by the manufacturer. The minimum digital resolution is 12 bits per sample.

2.2.3 Calibration

Description

In order to validate the study, it is necessary to perform various pre- and post-calibrations to illustrate that the system was properly calibrated and all equipment and sensors are working correctly throughout the study. Calibrations also are utilized as a baseline for staging and scoring purposes and include verifying electrode impedances as outlined in section 2.1.1.1. These steps are required and must be recorded as part of the polysomnogram.

Methodology

Amplifier Calibration

The first calibration should be an all-channel calibration that passes a negative 50 μV DC signal for an epoch of 30 seconds at 10 mm/sec through the amplifiers while each recording channel is set to the same sensitivity and filtering. The resulting waveforms should be saved as part of the permanent record. If the waveforms do not show equal and correct amplitude, fall times and polarity then adjustments must be made to the channel in question until there is uniformity. Most modern digital PSG data acquisition systems will report errors with the amplifier automatically.

DC Instrument Calibration

Before the study is run a calibration check of all attached DC instruments, such as pulse oximeters and/or capnographs, must be made to ensure that minimum and maximum values correspond to physiologic variables. For example, the minimum and maximum readings of oximeters should be set to translate at 0 and 1 volt. Many digital PSG data acquisition systems have integrated these functions into the amplifiers.

Impedance Check

An impedance check must be performed and documented on the EEG, EOG, and EMG electrodes prior to lights off and after lights on. Optimal signal quality is possible when impedances are low enough to maximize amplitude, are relatively equal, take advantage of common mode rejection, and avoid impedance mismatching. The standard for electrode impedance upper limit is 5k ohms for EEG and EOG. The guideline requires impedances to be as closely matched as possible (3).

Physiological Calibration

After the amplifier calibration has been performed, physiological calibrations are conducted to ensure the quality of the recorded signal. This provides a reference while monitoring and for scoring and interpreting the polysomnogram. All calibration signals must be annotated.

Physiological Calibration Instructions

Ask the patient to lie supine, if possible, through the patient calibration procedure and follow the instructions listed below. Verify the quality of the signal and make adjustments as necessary to the electrodes and sensors or to the sensitivity, gain, polarity or filter settings. Replace or reapply electrodes or sensors as necessary.

Annotate the instructions given as the patient is instructed to perform the calibration procedures. Give the instructions slowly and clearly. Below is a standard set of patient calibrations. Follow the facility's calibration procedure, making sure that there is one calibration for each type of channel. Body position can be visually verified, and oximetry should be double-checked if not within a normal range. Instruct the patient to relax and try to lie still.

- Perform and document an impedance check of the EEG, EOG an EMG electrodes
- Record a minimum of 30 seconds of EEG with patient awake, lying quietly with eyes open
- Record a minimum of 30 seconds of EEG with patient awake, lying quietly with eyes closed
- Ask the patient to look up and down 5 times without moving head
- Ask the patient to look left and right 5 times without moving head
- Ask the patient to blink eyes 5 times
- Ask the patient to grit teeth and/or chew for at least 5 seconds
- Ask the patient to simulate a snore or hum for 5 seconds
- Ask the patient to breathe normally and assure that airflow and effort channel signals are synchronized

- Ask the patient to perform a breath hold (10 seconds)
- Ask the patient to breathe through the nose only (10 seconds)
- Ask the patient to breathe through the mouth only (10 seconds)
- Ask the patient to take a deep breath and exhale slowly (prolonged expiration – 10 seconds)
- Ask the patient to flex the left foot/raise toes on left foot (x5)
- Ask the patient to flex the right foot/raise toes on right foot (x5)
- Ask the patient to flex/extend the fingers on the left hand, as appropriate, if upper extremity EMG is recorded
- Ask the patient to flex/extend the fingers on the right hand, as appropriate, if upper extremity EMG is recorded
- Adjust EKG signal to provide a clear waveform; the R wave should deflect upward
- Perform and document a repeat impedance check of the EEG, EOG and EMG electrodes at the end of the PSG recording
- Repeat physiological calibrations at the end of the PSG recording

Begin “Lights Out” procedure. Instruct the patient to move to a comfortable sleeping position and go to sleep. Remind the patient that the sleep technologist is readily available and if the patient should need anything to call the sleep technologist.

Post Calibrations

At the end of the study, perform the “Lights On” procedure. Enter the room to wake the patient and turn on the light. Repeat impedance check and both amplifier and physiological calibrations before ending the recording.

2.3 Routine for Standard PSG

The protocol of the standard PSG should be clearly established by the sleep facility. Detailed clinical information about the patient's sleep-related problem as well as a medical history is required.

The sleep technologist should begin the audio/video recording and maintain the recording for the entire duration that the patient is in the testing room. The sleep technologist should apply the required electrodes and sensors to monitor the channels listed in the montage, ensure that all electrode impedances are acceptable, and confirm that the sensors and equipment are functioning properly. After all calibration procedures have been performed and the patient is provided with “overnight” instructions (if they need assistance, or need to go to the restroom, etc.), “Lights Out” should be clearly documented. The sleep technologist will continuously monitor the patient's clinical status and body position, and document changes on the sleep study and/or on a form designed by the sleep facility as defined by written protocol. Ideally, eight (8) hours of recording time should be obtained; however, a minimum of six (6) hours of recording time is recommended for a standard PSG. The sleep technologist will assist the patient as necessary during the recording (helping them to the bathroom, addressing comfort issues, etc.) Intervention with therapy (oxygen, PAP, etc.) may be initiated during the recording per the facility’s protocol. When the study is completed, “Lights On” should be documented and calibration procedures should be performed. Finally, the electrodes and monitoring devices should be removed with care and cleaned according to infection control standards.

2.4 Artifact Recognition and Correction

The sleep technologist is responsible for monitoring and maintaining the integrity of each recorded channel. This requires that the sleep technologist differentiate between normal and abnormal patterns

as well as patient generated variations vs. true artifact. Once an artifact is identified, the sleep technologist must determine when it is necessary to make appropriate interventions and adjustments. Ideally, all channels should be artifact-free during the recording. All room entrances and artifact corrections should be clearly documented.

The sleep technologist should use a systematic approach to troubleshooting artifacts by tracing the recorded circuit from the patient to the computer monitor. Environmental interference (fans, cell phones, etc.) may have an effect on the recording and artifacts generated by environmental factors should be annotated.

Typical patient circuit:



3.0 PSG DOCUMENTATION

The results of the PSG procedures must be presented in a comprehensive and concise report that summarizes all observations, interventions, and an analysis of the recorded physiological parameters.

This report is typically presented in a chart and/or electronic format and includes all information pertaining to the patient's care at the sleep testing facility. The sleep technologist is responsible for completing progress notes on a regular basis and a summary of the sleep study findings and events, highlighting the sleep technologist's observations and interventions of possible medical significance for the interpreting physician. In addition, the sleep technologist is responsible for ensuring that all other required documents are available before the study begins (history and physical, previous test results, referral, prescription/order for study, insurance information, bedtime questionnaires, consents, etc.). Polysomnography reports must include all the recommended parameters from section II of the current edition of *The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology, and*

Technical Specifications (3). The following sections delineate the minimum information that should be included in patients' charts.

3.1 Patient Identification

In compliance with the Health Insurance Portability and Accountability Act (HIPAA), the PSG data, including technicians notes, all questionnaires, results of the study, and all documents related to the patient should be clearly labeled on each page with at least two patient identifiers (full name, date of birth, medical record number, and/or date of the study). Any additional information, such as identification numbers required for retrieval can also be included. Likewise, all long-term storage media containing patient data should be adequately labeled.

3.2 Patient History

The patient's chart should contain sufficient medical history to document the reason the study was recommended such as obesity, snoring, hypertension, Mallampati score of class III or IV, history of stroke, or any significant existing medical conditions, current medications with dosages, and special therapy (i.e. supplemental O₂). Any previous relevant or surgical procedures the patient has had that might influence the study results and any previous sleep studies or diagnostic testing completed, such as nocturnal oximetry, should also be documented. A complete sleep history questionnaire completed prior to arrival at the sleep facility and/or a history and physical as documented by the referring physician should be available for each patient. As part of the technologist's review of the sleep history and physical, any special needs of the patient should be determined (i.e., physical limitations, emotional needs, and language barriers). The technologist should discuss any key items in the questionnaire with the patient, and clarify any incomplete or missing information.

3.3 Technical Documentation

3.3.1 Log

The sleep technologist should log notable events that occur during the study in chronological order. Notable events include "Lights Off", sleep onset, "Lights On", the sleep technologist entering or leaving the patient's room, the patient getting out of bed, initiating or adjusting PAP or oxygen therapy and why therapy is initiated or adjusted, position changes, technical difficulties, changes in the recording montage (filters, sensitivities, re-referencing, etc.), environmental disturbances, and any other observation that might be helpful to the interpreting physician.

3.3.2 Summary

The sleep technologist should completely summarize all technical and behavioral observations at completion of the standard PSG. This can be done on a form designed by the sleep facility, within the context of the format set forth by the manufacturer of the PSG data acquisition equipment, or on a flowsheet within an electronic medical record. The summary should include comments on sleep architecture, behavioral observations, limb movements, respiratory characteristics including respiratory events and desaturations, initiation of PAP or other interventions, if applicable, and heart rate/ECG observations. The technologist should also add any pertinent medical or sleep-related information discovered during patient assessment, testing, or before discharge.

3.3.3 Sleep Parameters

The report summary should include the details of the analysis of sleep stage scoring as well as clinical

event scoring (3).

3.3.3.1 Sleep Stage Parameters

Total Recording Time (TRT) is defined as the time from “lights out” to “lights on”. Total Sleep Time (TST) is the total time asleep after sleep onset. To determine how well the patient slept, the Sleep Efficiency (SE) is calculated by dividing the TST by the TRT and multiplying by 100.

Sleep studies are recorded in 30 second “epochs”. Sleep onset is defined as the first epoch scored as any stage other than stage W. Sleep Latency (SL) is the time from “lights out” to the sleep onset. Latencies to sleep stages are determined from sleep onset to the first epoch of that sleep stage.

Wake after Sleep Onset (WASO) is the total amount of time awake after the sleep onset epoch until “lights on”. To determine the percentage time spent in each of the sleep stages during the sleep study, the total minutes of the sleep stage is divided by the TST and multiplied by 100.

3.3.3.2 Clinical Event Parameters

To determine the severity of sleep disturbances, the indices of the clinical events scored are compared to normative values. The indexes are calculated by dividing the total number of clinical events by the TST. These indices include the apnea index (AI), hypopnea index (HI), apnea/hypopnea index (AHI), respiratory disturbance index (RDI), periodic limb movement (PLMS) index, PLMS with associated arousal index, Respiratory Effort Related Arousal (RERA) index, and the overall arousal index (Ari). Currently, computer based sleep acquisition systems calculate all the indices, TST, and other sleep related values to make report generation much quicker. Usually, the PSG equipment will analyze the heart rate and oxygen saturation and report the mean, maximum and lowest value by TRT, TST and sleep state (i.e. wake, NREM, and REM). The technologist is responsible for manually verifying each of these parameters.

3.3.4 Sleep Related Breathing Events

The study summary should document sleep related breathing events with respect to sleep state. Information should be provided concerning the respiratory rate while awake and asleep, the presence or absence of snoring, the presence of paradoxical breathing, the number, type, and index of apnea and/or hypopnea events, the longest apnea and/or hypopnea event, the mean and minimum oxygen saturation. Notation should be made if sleep state or body position is related to the apnea/hypopnea index and/or desaturation. The absence or occurrence of Cheyne Stokes breathing pattern and the duration (absolute or as a percent of TST) should be documented in all patients who demonstrate central apnea events.

3.3.5 Heart Rate/ECG Observation

The baseline heart rate during wake, average, and highest while asleep and the highest heart rate during the recording should be annotated and the summary should document, if observed, bradycardia (lowest rate observed), asystole (longest pause observed), sinus tachycardia (highest rate observed), narrow complex tachycardia (highest rate observed), wide complex tachycardia (highest rate observed) and atrial fibrillation with average heart rate documented. The occurrence of any other arrhythmia observed must be documented. All arrhythmias, interventions, and physician notifications should be documented with respect to frequency of occurrence and type, per facility protocol. It is particularly important to describe the occurrence of heart rate changes or arrhythmias with respect to sleep state (REM, NREM) and sleep related breathing events such as oxygen desaturations and apneic events (3,8).

3.3.6 Limb Movements

Limb movement activity is recorded from the extremities and must be evaluated in terms of frequency of occurrence (PLMS) and periodicity (PLMSI), sleep/wake status, and presence or absence of subsequent arousal (PLMSArI). Rhythmic leg movements observed during wakefulness can indicate Restless Legs Syndrome (RLS). The sleep technologist should ask about symptoms of RLS during patient assessment (difficulty initiating sleep due to a need to move) and document any relevant patient comments as well as evidence of RLS seen prior to or during the recording.

3.3.7 Behavioral Observations

Any unusual or atypical behavioral events occurring during the patient's sleep and/or during wakefulness should be documented by the sleep technologist during the standard PSG. The sleep technologist should objectively describe in detail what the behavior is and how it relates to the polysomnographic recording (i.e., nocturnal eating, enuresis, body rocking). When arousals are noted during the PSG recording, the sleep technologist should document the cause of the arousal, i.e., as the result of apneic events, limb movements, spontaneous or environmentally evoked. Awakenings, causes, and activities during the wake period should also be documented.

4.0 STANDARDS OF PRACTICE

4.1 Qualifications of Sleep Technologists

Sleep technologists must demonstrate knowledge of polysomnographic recording instrumentation, including operating procedures, proper electrode application, calibration methods and troubleshooting as well as the ability to recognize sleep stages as outlined in the AAST Sleep Technologist, Technician and Trainee Job Descriptions (9). The sleep technologist must have a thorough understanding of normal and abnormal sleep patterns and sleep disorders. The sleep technologist also must be certified in basic life support (BLS) through a program that includes hands-on skills assessment and the use of an automated external defibrillator (AED).

Staffing practices should adhere to accreditation guidelines for patient: technologist ratios that ensure staffing is adequate to address the workload of the center/laboratory and assure the safety of patients. This includes a maximum patient to technician ratio of 2:1 under *usual* circumstances for attended polysomnography (10). The facility should consider the experience of the technologists as well as the difficulty of the studies being performed when a deviation from a 2:1 ratio is required (11). All technologists should maintain the minimum CEC requirements outlined in their job descriptions. It is recommended that each facility employ at least one registered technologist, though the goal should be to have as many registered technologists as possible.

4.2 Sleep Facility Organization and Record Keeping

Patient charts, in either print or electronic format should be organized and available for appropriate use in the sleep testing facility. HIPAA guidelines should be followed regarding confidentiality of patient records (12). Equipment, sensor, and recording maintenance procedures should meet manufacturer standards. Additionally, the sleep technologists should follow their sleep facility departmental policy and procedure manual and document tasks that may be required to meet accreditation requirements, such as visual checking of the equipment on a monthly basis.

Storage of recorded PSG data on CD, DVD, hard drive, server, cloud based, or other media is required and should be both secure and easily available for retrieval. Storing the video recording, either digital or analog, is recommended, although not required. The length of storage for all patient data that is stored should be in compliance with the statutes set forth by the state in which the data is obtained and stored, often a seven-year minimum. For pediatric patients records must be kept 7 years past the patient's 21st birthday in most states.

4.3 Patient Safety in the Sleep Facility

In the context of the technical sleep study, patient safety begins from the point of the patient's arrival until the patient leaves the facility (see 4.4.5). Ordering and performing the appropriate test based on the patient's history and physical and previous test results are the responsibility of the sleep facility under direction from a board certified sleep physician.

The sleep facility must be safe and easily accessible to all staff and patients. The sleep facility must be handicapped accessible, meet fire code and health department regulations, and maintain electrical and mechanical safety. The patient rooms must be clean and have adequate audio and video monitors for patient safety and clinical assessment (10). The facility must have explicit policies and procedures to minimize the risk for assault or allegations of inappropriate behavior during the attended study (10). All products used on patients should have Safety Data Sheets (SDS) available in the sleep facility. The technologist must be trained in all aspects of patient safety and the technologist must be familiar with each patient's medical history. Technologists should follow the sleep facility policy related to patient safety and security.

4.3.1 Safety Equipment

The sleep facility should have equipment available for patient care and emergencies: resuscitation bags, back boards, oxygen, biohazard spill kits, sharps containers, separate (temperature monitored) refrigeration for patient medication, blood pressure cuffs, and first aid kits. An Automated External Defibrillator (AED) must be available in the facility. There should also be multi-class fire extinguishers available.

4.3.2 Electrical Safety

Electrical safety guidelines state that all equipment used must be properly grounded and have a dedicated grounded wall outlet. In addition, any equipment that is connected to the patient must be on an isolated circuit equipped with a breaker. The electrical safety of all patient-related equipment should be tested and documented yearly by trained biomedical staff or other approved electricians.

4.3.3 Mechanical Safety

The technologist must practice proper lifting/pushing techniques. All equipment involved with patient care must be located in a safe position relative to the patient.

4.3.4 Fire Safety

The technologist must be well acquainted with their facilities' fire plan in case of fire. This plan should account for the prevention of fire as well. In the event of fire, the technologist's ultimate priority is to remove patients from danger.

4.3.5 Patient Medical History and Current Medical Status

It is the sleep technologist's responsibility to know and understand the patient's medical history, allergies and current medical status in order to alter procedures, contact a physician, or transfer the patient for emergency care, as necessary.

4.3.6 Clinical Intervention and Emergency Procedures

The sleep facility should have written guidelines for initiating any medical intervention (supplemental oxygen, patient transfer, CPR). The technologist must be trained to recognize life-threatening changes in the patient's condition. Working in a nocturnal setting, the technologist must also take steps to insure their own vigilance.

There should also be a written plan for handling both internal and external disasters (e.g. tornado, fire, flood, etc.) (13). Annual cardiac or pulmonary emergency drills must be performed, and results reviewed and reported by the medical director and saved for a minimum of five (5) years.

4.3.7 Patient Discharge Guidelines

The sleep technologist should make certain that the patient has had enough sleep and does not appear to be under the influence of medication or alcohol before release from the sleep facility. An early release form should be completed per sleep facility policy when indicated. Patients who have not had enough sleep should be encouraged to stay and sleep (with visual monitoring) even if the recording has been discontinued, per facility policy. For this reason, it may be good policy to suggest that the patient arrange for transportation upon discharge.

4.4 Infection Control

4.4.1 Patient Contact Procedures

Sleep technologists should exercise universal precautions and additional precautions for prevention of the spread of infectious diseases as appropriate (14, 15, 16, 17). Frequent hand washing is essential for the protection of both patients and sleep technologists. All items that will be in contact with a patient must be cleaned and disinfected after use according to facility and/or manufacturer guidelines.

4.4.2 Equipment Decontamination

There must be clearly designated areas for clean and dirty equipment and sensors. These should be separate distinct rooms or areas to prevent cross contamination, in particular airborne contaminants.

4.4.3 Non-disposable or Reusable Items

Non-disposable or reusable items include items such as pneumotachometers, electrodes, respiratory belts, thermocouples, and body position sensors. Various disinfectant products are available commercially. These products are labeled with the instructions for disinfecting reusable items and the reusable items should have instructions for disinfecting and cleaning recommended by the manufacturer. When reusable items become contaminated and disinfecting is not feasible, gas or heat sterilization may be used, or the item should be properly disposed of. Bed linens should be handled with the assumption that biohazard could be present. Overall, it is recommended to use disinfecting products or procedures that are approved for the medical setting.

4.4.4 Disposable items

Disposable electrodes, sensors, nasal cannulas, or other single use items should be disposed of after use

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