The AASM Manual for the Scoring of Sleep and Associated Events

Rules, Terminology and Technical Specifications
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Rules, Terminology and Technical Specifications

Conrad Iber, MD, Sonia Ancoli-Israel, PhD, Andrew L. Chesson Jr., MD and Stuart F. Quan, MD for the American Academy of Sleep Medicine

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_AASM Manual for Scoring Sleep, 2007_
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Sleep that knits up the ravell'd sleeve of care,
The death of each day's life, sore labour's bath,
Balm of hurt minds, great nature's second course,
Chief nourisher in life's feast.


In its simplest and most positive terms, sleep is a desired state of unconsciousness. Each evening we willingly and most pleasantly surrender ourselves to a state of disconnection and vulnerability, expecting to be safe, restored, and comforted upon awakening many hours later. It is no small wonder that this state and its unique attributes have long provoked fascination. As the inquisitive science of sleep began to catalog the unique and varying texture of this state over the past 75 years, standard metrics were needed to characterize what could be observed. After many germinal studies and an evolving consensus at the time, standardized methods for characterizing normal sleep were published in 1968 by Allan Rechtschaffen and Anthony Kales.

Although the utility and durability of the first manual for characterizing normal sleep have served countless millions who have had sleep studies, the advancing science of sleep and the rapidly emerging field of sleep medicine require a more comprehensive system of standardized metrics that considers events occurring outside of normal brain activity. Sleep disorders are now recognized as a major public health burden that must be addressed in any standardized methodology for characterizing the events and nature of sleep. The explosion of technology and scientific information has provided many opportunities for evolution in this process of revising the manner in which we measure and catalog all the attributes of sleep.

In 2003, the Board of Directors of the American Academy of Sleep Medicine approved the proposed development of a new scoring manual. The vision of the development of a new manual was a very considered process, including a blueprint for future revisions which would address the needs of the ever-changing field of sleep. This process, which was initiated in 2004 and is described in the ensuing sections of this manual, has incorporated both a standardized review of evidence as well as a standardized method of consensus in order to draft rules, specifications, and terminology that may better reflect the current weight of scientific evidence and expertise in the field of sleep.

Although the development of the scoring manual has been supervised by a steering committee, its success and execution have hinged on the expertise and dedicated effort of the task force members who have executed both the evidence review and consensus processes as well as the committed and outstanding staff of the American Academy of Sleep Medicine (AASM) who provided invaluable logistical support.

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Conrad Iber, Chair
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DEVELOPMENT PROCESS

HISTORICAL BACKGROUND

The science of sleep emerged as a discipline as a result of the development of tools able to detect and record both the activity of the brain and the physiologic events that occur during this unique and sometimes vulnerable state. The germinal reports of methods that were eventually employed to characterize electrical activity of sleep include the recording of brain surface electrical activity in animals in 1875 and the subsequent demonstration of the ability to detect and characterize wakeful activity in humans with external scalp recordings in 1929. Detection and recording of electrical activity of the human heart had been developing at about the same time with identification of cardiac electrical waveforms by Einthoven in 1895 occurring at nearly the same time as the characterization of human brain activity. Although allusions to abnormal breathing during sleep date to antiquity, combining breathing and brain monitoring in physiologic recordings to identify pathologic conditions during sleep evolved in the mid-twentieth century. Respiratory recordings at this time identified periodic interruptions in breathing effort that were both obstructive and non-obstructive. Sleep recordings were termed polysomnography to recognize the multiple physiologic parameters that were being recorded during sleep. Additional parameters were added when limb myoclonus was described in 1953 and identification of its polysomnographic correlates were folded into the emerging image of normal and abnormal physiologic activity during sleep.

In 1937, scalp brain recordings during polysomnography initially focused on visually identifiable patterns of brain activity during NREM sleep. Continuous periods of brain waveform patterns such as alpha and delta activity, as well as isolated waveforms including K complexes, spindles, vertex waves, and posterior occipital sharp transients were identified during this period. Rapid eye movements (REM) associated with respiratory and cardiac effects were identified in 1953 by Aserinsky and Kleitman and later more formally incorporated into the stage of REM sleep.

Although there were several early efforts to characterize the patterns of sleep, demonstration of rather poor reliability in scoring these patterns provided the needed rationale for a standardized scoring manual. After several exploratory meetings in the early 1960s and lively consensus meetings in April 1967, an enduring standardized scoring manual for normal sleep was developed and published under the direction of Allan Rechtschaffen and Anthony Kales. There have been several subsequent initiatives to develop rules for scoring sleep since 1968 including an effort by the Sleep Disorders Atlas Task Force of the American Sleep Disorder Association in 1992 and preliminary studies of automatic methods by the SIESTA group. The recognition of qualitative differences in sleep in newborns resulted in publication of a separate manual for this age group in 1971. Since the publication of the scoring manual by Rechtschaffen and Kales 38 years ago, there has been a rich evolution in our understanding of sleep.

The evolving science of sleep and the clinical field of sleep medicine are employing novel metrics to characterize sleep. Developmental changes are recognized that affect the characterization of sleep throughout the lifespan. The nature and importance of sleep-related phenomena such as arousal, cardiac dyshisthmias, respiratory patterns, movements, and behaviors are now areas of both clinical practice and scientific discovery. A more comprehensive scoring manual has been needed that would incorporate these evolutionary changes as well as newer technical methods and capabilities.

SCORING MANUAL DEVELOPMENT

The development of this new scoring manual was designed to encourage a visible and standardized decision-making process that would broadly represent expertise in the field. The goal was to create a manual that reflected current knowledge and that would provide more comprehensive standardized specifications and scoring rules for characterizing natural sleep as commonly performed in polysomnography. Potential rules that were drafted reflected evidence for reliability and validity as assessed by content experts performing structured evidence review or convening for a standardized consensus when evidence was lacking. Visibility of the process and unstructured feedback was encouraged by open discussions at meetings of the Associated Professional Sleep Societies in 2004-2006. Structured feedback on drafted rules was provided by a panel of sleep technologists and a panel of industry experts prior to finalization by content experts and approval or adjudication by a steering committee. The key for the recommendation terminology and the terminology that was used for the decision-making process may be found in Section I, Key. An outline of the details of the procedural processes in decision-making may be found in the procedural notes on pages 51-57 (Section IX). For the details of the rationale and bases of the decisions, the reader is referred to the review papers of the respective task forces published as an issue of the Journal of Clinical Sleep Medicine.

The principal participants in the scoring manual development process included a) a supervising steering committee of 4 individuals appointed by the AASM Board of Directors, b) 8 task forces leaders with content expertise selected by the steering committee, c) 8-12 task force members for each task force who were chosen by consensual agreement of the task force leaders and steering committee and d) the extremely able administrative staff of the AASM. Steering committee members also attended task force activities as liaisons to help guide the evidence review and consensus processes. Task forces used an evidence-based process to do literature searches, grade evidence and create evidence-based tables on their topics, which summarized the accumulated evidence. Using this material, they wrote review papers on the topics of their task force assignments. The evidence review papers were periodically reviewed by the steering committee for format and progress.

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Review papers were sent for independent outside review, and the reviewers' comments were addressed. Upon completion, review papers were approved by the Scoring Manual Steering Committee and subsequently by the AASM Board of Directors.

Following construction of the review papers and based on their literature review, task forces identified a list of potential specifications and principles for which rules might be appropriate. Task force leaders, in conjunction with the steering committee, constructed ballots for potential scoring rules, technical specifications, and reporting parameters. Utilizing the RAND/UCLA Appropriateness Method\textsuperscript{21} and the evidence gathered in the review paper process, these considerations were subjected to a formal series of ballots to determine the soundness of principles upon which to develop final rules. Using the final ballot data, preliminary scoring rules were then drafted by the steering committee. The task force chairs, and industry and technical panels reviewed the draft rules to provide comments regarding feasibility and appropriateness. Final modifications were made by the steering committee. The scoring rules were then reviewed by the AASM Board of Directors who approved the rules following final modifications by the steering committee.

The task force meetings commenced in July 2004; the final rules, terminology and specifications were drafted in May 2006 and approved by the Board of Directors in December 2006.

All scoring manual committee members completed AASM conflict of interest statements. Steering Committee members did not have any Level 1 conflicts of interest with any monitoring device that might be affected by the development of any recommendation. Potential conflicts of task force members were reviewed by the steering committee for decision regarding inclusion or exclusion of participants in task force activities. No approved task force members had Level 1 conflicts in the scope of their respective tasks.

**TASK FORCES**

Six task forces were developed to review evidence for the scoring manual. The 6 task forces covered each of the major areas: visual scoring, digital scoring, arousal, movement, respiratory issues, and cardiac issues.

Two additional special population task forces were created for pediatrics and geriatrics. In addition to task force liaisons from each of the other areas, the geriatric and pediatric task forces each included 5 sleep medicine specialists with expertise in the age range under consideration.

Each of the 6 topical task forces was made up of at least 5 experts in the specific content area of sleep medicine, along with an advisor who represented expertise in evidence review, and liaisons from the pediatric and aging task forces and the steering committee, for a total of 8-13 task force members. Task forces spent 8-20 hours in either phone or face-to-face conferences over the 18 months of evidence review and consensus activity.

As described above, each task force was charged with the task of identifying papers relevant to their topics, reviewing the papers and extracting evidence information, writing a review paper and, in conjunction with the steering committee, developing a RAND ballot and voting on it.

As evidence papers were identified within the topical task forces, those portions of the review process that were relevant to either pediatric or geriatric populations were assigned to the appropriate liaison member for consideration and modification. RAND ballots that were constructed by the topical task forces were reviewed by the Pediatric and Geriatric Task Forces and items were identified for modification and balloting to develop separate age-appropriate scoring rules.

Within pediatrics, separate scoring rules were developed in areas of visual scoring, respiratory events, and cardiac events. These differences are outlined within their respective sections of the scoring manual.

Within geriatrics, the only rule that needed to be voted upon by the Geriatric Task Force was the question of whether amplitude criteria for SWS should be different in older adults than in younger adults. The result of the final vote was the same in both the Geriatric Task Force and the Visual Task Force, and therefore no adjudication was needed.

**EVIDENCE REVIEW**

Task forces were charged with developing review papers that addressed evidence supporting reliability and validity of technical specifications and the related components of scoring in each of 6 content areas: visual, digital, arousal, respiratory, cardiac, and movements. The specific details of each task force evidence review and search focus can be found in the methods section of the individual review papers.

In all evidence review papers, a computer-based PubMed literature search was performed for all human studies, in English, published between 1968 and September 2004, using key words identified by the task forces. For the assignments, the respective task forces selected between 91 and 372 articles as appropriate for formal evidence review. Evidence was then extracted by task force members under the direction of a task force liaison with previous experience in evidence grading.

The criteria for evidence levels generally followed Sackett,\textsuperscript{22} although in some instances appropriate modifications were made to complement the nature of the content area. In the case of digital signal analysis, where sampling methods were critical to evidence review, comparison of identical epochs or events was mandated, and a minimum sample size was required for each level of evidence.

**CONSENSUS**

When there was insufficient Level 1 or Level 2 evidence for clear evidence-based rule development, terminology or specifications, a consensus process based on considerations in the appropriate review paper was employed. This consensus process followed the standardized RAND/UCLA Appropriateness Method.\textsuperscript{23} RAND ballots were constructed to formally
assess consensus opinion regarding terminology, technical specifications, and the components of scoring rules. The ballots were developed by the task forces and submitted to the steering committee for approval. In compliance with RAND methods, 9 to 11 participants completed each series of ballots. Task force members and liaisons participated in balloting. If less than 9 voting members were available, additional experts were selected by the steering committee to assist with the balloting process.

In order to encourage single recommendations, consensus ballots were constructed when possible to address mutually exclusive options. In order to encourage a progressive decision-making process, participants were directed, when felt appropriate by the steering committee, to achieve agreement on the validity, reliability and final preference for any of the optional choices.

At least 2 rounds of consensus were convened for each task force: round 1 was completed individually without discussion by task force members, whereas round 2 was completed following a face-to-face or conference call discussion of the RAND items and the results of the first vote. In 2 task forces, selected items from round 1 were approved by the task force because of agreement during round 1 voting.

For balloting, items were rated on a 0-point to 4-point scale for appropriateness and a 4-letter rank for specifying a judgment regarding whether the decision was being made on evidence vs. opinion. The "classic" definition of agreement was assessed using definitions from the RAND manual:

- Agreement for or against: No more than 2 panelists rate the indication outside the 3-point region (1-3; 4-6; 7-9) containing the median.
- Disagreement: At least 3 panelists rate the indication in the 1-3 region, and at least 3 panelists rate it in the 7-9 region.
- Indeterminate: Criteria are not met for agreement or disagreement.

In order to ensure that consensus rested as much as possible within the content expertise of the task force, an additional round with discussion was employed for initially indeterminate decisions within a series of mutually exclusive options. In instances when there was indeterminate agreement from the RAND process after the series of ballots and there was insufficient evidence for recommendation from the task force among 2 options used in practice, the steering committee adjudicated a recommended and an alternative acceptable rule or specification. Any items that did not achieve consensus during round 3 or additional rounds were adjudicated by the steering committee. Only 9 items required adjudication by the steering committee.

Following the decisions regarding standardized rules by the task forces, the geriatric and pediatric task forces reviewed results of balloting to determine what items required modification or revision for age and pediatric considerations. A separate evidence review was then conducted and a single round of RAND balloting was completed with interaction to conclude the pediatric and age modifications for items with limited evidence.

INDUSTRY AND TECHNICAL REVIEW

Technical and industry panels were constituted for the purpose of obtaining structured input on preliminary rules drafted after evidence review and consensus. These panels were asked to evaluate the appropriateness of proposed rules and to comment on any perceived impediments to implementation. Technical panels met by conference call to allow interaction prior to drafting their input. The structured input from the industry and technical panels then were provided to task force leaders who developed a rationale for either modifying the rule(s) or for retaining the original language. The structured input from panels and responses from task force leaders were used by the steering committee in crafting the final rules and in the final adjudication when there were substantial differences.

Industry input was also solicited during a face-to-face meeting with task force chairs, members of the steering committee, and AASM staff on July 16, 2004. Representatives from several software and hardware companies involved in polysomnography data acquisition or scoring were invited to discuss and provide materials regarding potential reporting parameters, the current state of digital acquisition of polysomnographic data, and automated scoring. Information exchanged at this meeting was used to focus the assignments of the scoring manual task forces.

SUMMARY AND FUTURE EDITIONS

The reader will find that this edition of the "AASM Manual for the Scoring of Sleep and Associated Events" has a comprehensive scope which incorporates events, technical specifications, pediatric scoring, as well as modified staging terminology and rules. Arousal, movements, respiratory events, and cardiac events are now folded into the standardized scoring system using both new and existing evidence as well as consensus. The design of decision-making encouraged both the retention of existing valid and reliable methods when appropriate and the development of new terminology, specifications, and rules when supported. The rules and specifications in the visual scoring of sleep retain much of the framework of Rechtschaffen and Kales, based on the accumulated validity and reliability of this scoring system, with some new definitions and rule modifications as well as with new rules for pediatric visual scoring. A visible format is provided for identifying evidence and/or consensus-driven recommendations as well as optional specifications or rules for scoring. While rules and definitions are the product of evidence review and consensus, explanatory notes have been added following each rule to provide additional clarifications that were not derived from consensus. Readers are referred to the review papers for more detailed analysis of the rationale underpinning the recommendations in the manual.

The expanded choice of analytical tools used in this edition reflects the evidence review and consensus processes. The use of digital interfaces has required extensive specifications that were not necessary in the previous standardized scoring manual. The scope and methods characterizing respiratory events.
has been extended from earlier practices to address new evidence. Based on current evidence and consensus, certain areas of active investigation have not been utilized for digital rules in this edition. Quantitative electroencephalography, cyclic alternating pattern, and methods characterizing autonomic events have not been incorporated although a process for revision has been created to incorporate techniques if accumulating evidence supports their utility.

Though schematics are used to assist in demonstrating visual and respiratory rules, readers will note that reproductions of sleep recordings do not accompany the rules. This scoring manual does not incorporate an atlas of visually presented examples and emphasizes instead an articulation of rules and specifications based on a standardized decision-making process and designed to encourage the objective basis for implementation of staging and event rules. The rules are crafted as a platform to support the evolution of both non-visual and visual methods for the future.

The science of sleep and the specialty of sleep medicine have evolved rapidly since the initial attempts in the 1930s to develop a consistent framework to describe the complexity of sleep. Although the first generally accepted scoring manual by Rechtschaffen and Kales has served the field well, the need for modification and additions has been apparent to sleep scientists and clinicians for a number of years. This new scoring manual represents an attempt to combine the best available evidence with the opinion of experts in sleep science and medicine. However, just as the field of sleep is not a static doctrine, this manual is not intended to remain immutable. It is the intention of the steering committee that this scoring manual should be reviewed on a periodic basis with additions, modifications, and deletions made based on new scientific data accumulated over interim periods. In this manner, the scoring manual will become a “living” document that incorporates new information as it becomes available.

REFERENCES:


5. Waller A. A demonstration on man of electromotive changes accompanying the heart's beat. J Physiol 1887;8:229-34.


7. Ancoli-Israel S. “Sleep is not tangible” or what the Hebrew tradition has to say about sleep. Psychosomatic Medicine 2001;63:778-87.


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1. RULES

[RECOMMENDED] These rules are recommended for the routine scoring of polysomnography.

[ALTERNATIVE] These are rules that may be used as alternatives to the recommended rules at the discretion of the clinician or investigator.

[OPTIONAL] These are suggested rules for uncommonly encountered events, events not known to have physiologic significance or events for which there was no consensus decision. Scoring may be performed at the discretion of the clinician or investigator.

2. PROCEDURAL NOTES

[STANDARD] Recommendation based on level 1 evidence or overwhelming level 2 evidence.

[GUIDELINE] Recommendation based on level 2 evidence or a consensus of level 3 evidence.

[CONSENSUS] Recommendation with less evidence than guideline for which agreement was reached in a standardized consensus process based on available information.

[ADJUDICATION] Recommendation from the steering committee based on all available information. Adjudication was only performed a) when there was insufficient evidence and no consensus agreement or b) in conjunction with task force leaders on issues regarding minor clarifications and additions to rules.
II. PARAMETERS TO BE REPORTED FOR POLYSOMNOGRAPHY

1. POLYSOMNOGRAPHY

A. Parameters

1) EEG derivations [RECOMMENDED]
2) EOG derivations [RECOMMENDED]
3) Chin EMG [RECOMMENDED]
4) Leg EMG derivations [RECOMMENDED]
5) Airflow parameters [RECOMMENDED]
6) Effort parameters [RECOMMENDED]
7) Oxygen saturation [RECOMMENDED]
8) Body position [RECOMMENDED]

B. Sleep Scoring Data

1) Lights out clock time (hr:min) [RECOMMENDED]
2) Lights on clock time (hr:min) [RECOMMENDED]
3) Total sleep time (TST; in min) [RECOMMENDED]
4) Total recording time ("lights out" to "lights on" in min) [RECOMMENDED]
5) Sleep latency (SL; lights out to first epoch of any sleep in min) [RECOMMENDED]
6) Stage R latency (sleep onset to first epoch of Stage R in min) [RECOMMENDED]
7) Wake after sleep onset (WASO; Stage W during B4, minus B5, in min). [RECOMMENDED]
8) Percent sleep efficiency (B3/B4)x100 [RECOMMENDED]
9) Time in each stage (min) [RECOMMENDED]
10) Percent of TST in each stage (B9 values/B3)x100 [RECOMMENDED]

Note: Wake after sleep onset includes all wake activity, including wake out of bed.

C. Arousal Events

1) The number of arousals [RECOMMENDED]
2) The arousal index (ArI; C1x60/B3) [RECOMMENDED]

D. Respiratory Events

1) Number of obstructive apneas [RECOMMENDED]
2) Number of mixed apneas [RECOMMENDED]
3) Number of central apneas [RECOMMENDED]
4) Number of hypopneas [RECOMMENDED]
5) Number of apneas + hypopneas [RECOMMENDED]
6) Apnea index (AI; (D1+D2+D3)x60/B3) [RECOMMENDED]
7) Hypopnea index (HI; D4x60/B3) [RECOMMENDED]
8) Apnea + Hypopnea index (AHI; D5x60/B3) [RECOMMENDED]
9) Respiratory effort related arousals, total number [OPTIONAL]
10) Respiratory effort related arousal index (D9x60/B3) [OPTIONAL]
11) Oxygen desaturations ≥3% or ≥4%, total number [OPTIONAL]
12) Oxygen desaturation index ≥3% or ≥4% (D1; D11x60/B3) [OPTIONAL]
13) Continuous oxygen saturation, mean value [RECOMMENDED]
14) Minimum oxygen saturation during sleep [RECOMMENDED]
15) Occurrence of hypoventilation (yes/no) [OPTIONAL]
16) Occurrence of Cheyne Stokes breathing (yes/no) [RECOMMENDED]

Notes:
1. For oxygen desaturation, percent time spent below a given threshold may be reported at the discretion of the investigator.
2. In adults, the choice of hypopnea definition (recommended, VII.4A or alternative, VII.4B) should be specified in D4, D5, D7, D8.

E. Cardiac Events

1) Average heart rate during sleep [RECOMMENDED]
2) Highest heart rate during sleep [RECOMMENDED]
3) Highest heart rate during recording [RECOMMENDED]

Occurrence of the following arrhythmias (yes/no). If present, list arrhythmia and heart rate or duration of pause.

4) Bradycardia; report lowest heart rate observed [RECOMMENDED]
5) Asystole; report longest pause observed [RECOMMENDED]
6) Sinus tachycardia during sleep; report highest heart rate observed [RECOMMENDED]
7) Narrow complex tachycardia; report highest heart rate observed [RECOMMENDED]
8) Wide complex tachycardia; report highest heart rate observed [RECOMMENDED]
9) Atrial fibrillation [RECOMMENDED]

Occurrence of the other arrhythmias (yes/no).

10) If present, list arrhythmia [RECOMMENDED]

F. Movement Events

1) Number of periodic limb movements of sleep (PLMS) [RECOMMENDED]
2) Number of periodic limb movements of sleep (PLMS) with arousals [RECOMMENDED]
3) PLMS index (PLMSI; F1x60/B3) [RECOMMENDED]
4) PLMS arousal index (PLMSAri; F2x60/B3) [RECOMMENDED]

G. Summary Statements

1. Findings related to sleep diagnoses [RECOMMENDED]
2. EEG abnormalities [RECOMMENDED]
3. ECG abnormalities [RECOMMENDED]
4. Behavioral observations [RECOMMENDED]
5. Sleep hypnogram [OPTIONAL]
### III. TECHNICAL AND DIGITAL SPECIFICATIONS

#### 1. SPECIFICATIONS

**A. Digital Specifications for Routine PSG Recordings (Notes)**

<table>
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<tr>
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<tr>
<td>EEG</td>
<td>500 Hz&lt;sup&gt;2&lt;/sup&gt;</td>
<td>200 Hz&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>EOG</td>
<td>500 Hz&lt;sup&gt;4&lt;/sup&gt;</td>
<td>200 Hz</td>
</tr>
<tr>
<td>EMG</td>
<td>500 Hz&lt;sup&gt;5&lt;/sup&gt;</td>
<td>200 Hz</td>
</tr>
<tr>
<td>ECG</td>
<td>500 Hz&lt;sup&gt;6&lt;/sup&gt;</td>
<td>200 Hz</td>
</tr>
<tr>
<td>Airflow</td>
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<td>25 Hz</td>
</tr>
<tr>
<td>Oximetry</td>
<td>25 Hz&lt;sup&gt;7&lt;/sup&gt;</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Nasal Pressure</td>
<td>100 Hz&lt;sup&gt;8&lt;/sup&gt;</td>
<td>25 Hz</td>
</tr>
<tr>
<td>Esophageal Pressure</td>
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</tr>
<tr>
<td>Body Position</td>
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<td>1 Hz</td>
</tr>
<tr>
<td>Snoring Sounds</td>
<td>500 Hz&lt;sup&gt;9&lt;/sup&gt;</td>
<td>200 Hz</td>
</tr>
<tr>
<td>Rib Cage and Abdominal Movements</td>
<td>100 Hz&lt;sup&gt;10&lt;/sup&gt;</td>
<td>25 Hz</td>
</tr>
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</table>

**Low Frequency Filter**

<table>
<thead>
<tr>
<th>Routinely Recorded Filter Settings</th>
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<td>EEG</td>
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<td>35 Hz&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>EOG</td>
<td>0.3 Hz</td>
<td>35 Hz</td>
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<tr>
<td>EMG</td>
<td>10 Hz&lt;sup&gt;5&lt;/sup&gt;</td>
<td>100 Hz&lt;sup&gt;6&lt;/sup&gt;</td>
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<tr>
<td>ECG</td>
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<td>70 Hz</td>
</tr>
<tr>
<td>Respiration</td>
<td>0.1 Hz</td>
<td>15 Hz</td>
</tr>
<tr>
<td>Snoring</td>
<td>10 Hz</td>
<td>100 Hz</td>
</tr>
</tbody>
</table>

**Notes:**

1. This applies to measured EEG and EOG electrode impedances. Electrode impedances should be rechecked during a recording when any pattern that might be artifactual appears.

2. For EEG, 500 Hz could improve resolution of spikes in the EEG and better maintain details of the waveform.

3. For more detailed EEG analysis, sampling rate and high frequency filter settings may be increased. In these circumstances, the sampling rate should be at least 3 times the high frequency filter settings.

4. For EOG, using the 500 Hz desirable EEG sampling rate also allows the reflection of the EEG in this lead as an EEG backup and may better define some artifacts in these leads.

5. This applies to submental and leg EMG. Higher sampling rates better define waveforms; while the waveform itself is not an issue, a better-defined waveform can help avoid amplitude attenuation as the envelope of the rapidly oscillating signal is read and interpreted.

6. For ECG, 500 Hz can better define pacemaker spikes and ECG waveforms, however pacemaker spikes can be seen at 200 Hz and the evaluation of cardiac ischemia by ECG waveform is not a usual PSG issue. Higher frequencies may be required for complex waveform analysis and research applications.

7. For oximetry, 25 Hz is desirable to assist with artifact rejection.

8. For nasal pressure transducer technology (especially with settings which identify snoring occurring on top of the airflow wave form), this higher frequency may be of benefit for better definition of flattening, plateauing, and/or fluctuating in the wave airflow form.

9. For snoring sound, 500 Hz can better define amplitude variation by clearer waveforms with more accurate amplitude determination as the envelope of the rapidly oscillating signal is interpreted, (as for EMG). If a preprocessing of snoring results in a continuous sound loudness level or in a sound intensity level, then a much lower sampling rate is acceptable. That sampling rate is not specified because it depends on the preprocessing of the sound in order to produce loudness.

10. For rib cage and abdominal movements using inductance plethysmography, cardiogenic oscillations can be better seen and may result in better artifact assessment.

11. To accommodate older equipment, filter settings in the range of 30-35 Hz may be used to comply with the above recommendations of 35 Hz. This applies most specifically in the context of EEG and EOG high filter settings.

12. For ECG, low frequency settings and wide bandwidth minimizes distortion in a 12 lead ECG; however in PSG recording for single-channel modified lead II used for identifying basic heart rates and dysrhythmias, it may not be as necessary. Advanced cardiac assessment may be more optimal using an LFF of 0.3 Hz for slower parts of the cardiac cycle. The channel is susceptible to artifacts at this setting due to patient movement, perspiration, muscle activity and electrode displacement with more sweat artifact, which is a common problem in the laboratory. It is less likely a problem using standard ECG leads with good contact and stability of application than using EEG leads for cardiac monitoring.

General note: in the absence of clear preferences, there is consensus to use similar settings among leads to simplify technical implementation.
B. Digital PSG Recording Features

Digital systems must include the following features:

1) A toggle switch permitting visual (on-screen) standard negative 50 μV DC calibration signal for all channels to demonstrate polarity, amplitude and time constant settings for each recorded parameter

2) A separate 50/60 Hz filter control for each channel

3) The capability of selecting sampling rates for each channel

4) A method of measuring actual individual electrode impedance against a reference (the latter may be the sum of all other applied electrodes)

5) The capability of retaining and viewing the data in the exact manner in which it was recorded by the attending technologist (i.e., retain and display all derivation changes, sensitivity adjustments, filter settings, temporal resolution)

6) The capability of retaining and viewing the data in the exact manner it appeared when it was scored by the scoring technologist (i.e., retain and display all derivation changes, sensitivity adjustments, filter settings, temporal resolution)

7) A filter design for data collection which functionally simulates or replicates conventional (analog-style) frequency response curves rather than removing all activity and harmonics within the specified bandwidth

Digital systems should include the following features:

8) An electrode selector process with the flexibility for choosing and/or changing electrode input signal derivations without relying on a common reference electrode

[OPTIONAL]

C. Rules for PSG Display and Display Manipulation

Systems must include the following PSG features:

1) Resolution of a digital screen and video card must be at least 1600 x 1200 for display and scoring of raw PSG data

2) Histogram with stage, respiratory events, leg movement events, O₂ saturation, and arousals, with cursor positioning on histogram and ability to jump to the page

3) Ability to view a screen on a time scale ranging from the entire night to windows as small as 5 seconds

4) Recorded video data must be synchronized with PSG data and have an accuracy of at least one video frame per second

Systems should include the following PSG features:

5) Page automatic turning and automatic scrolling

[OPTIONAL]

6) Channel off control key or toggle

[OPTIONAL]

7) Channel invert control key or toggle

[OPTIONAL]

8) Change order of channel by click and drag

[OPTIONAL]

9) Display setup profiles (including colors) which may be activated at any time

[OPTIONAL]

10) Fast Fourier Transformation or spectral analysis on specifiable interval (omitting segments marked as data artifact)

[OPTIONAL]
D. Digital Analysis of PSG

Digital sleep systems must include the ability to:

1) Identify whether sleep stage scoring was performed visually or computed by the system [RECOMMENDATION]

Digital sleep systems should include the capability to turn off and on, as demanded, highlighting for:

2) Patterns identifying sleep stage decisions (for example sleep spindle, K complex, alpha, delta) [OPTIONAL]

3) Patterns identifying the respiratory analysis (for example apneas, hypopneas, desaturations) [OPTIONAL]

4) Patterns identifying the movement analysis (for example PLMs) [OPTIONAL]
1. TECHNICAL SPECIFICATIONS

A. Electroencephalogram (EEG)

1) The recommended derivations are:
   a. Fz-M1
   b. C3-M1
   c. O1-M1

[RECOMMENDED]

Backup electrodes should be placed at F3, C3, O1, and M2 to allow display of F3-M2, C3-M2, and O1-M2 if electrodes malfunction during the study.

2) Alternative acceptable derivations are:
   a. Fz-Cz
   b. Cz-Oz
   c. C4-M1

[ALTERNATIVE]

Backup electrodes should be placed at Fp1, Cz, Oz, and M2 to allow substitution of Fp1 for Fz, C3 for Cz, or C4, O1 for Oz, and M2 for M1 if electrodes malfunction during the study.
3) EEG electrode position is determined by International 10-20 System
   [RECOMMENDED]
   Note:
   1. A minimum of 3 EEG derivations are required in order to sample activity from the frontal, central, and occipital regions.
   2. M₁ and M₂ refer to the left and right mastoid processes.

B. Electrooculogram (EOG)

1) The recommended EOG derivations are:
   [RECOMMENDED]
   a. E₁-M₁ (E₁ is placed 1 cm below the left outer canthus)
   b. E₂-M₂ (E₂ is placed 1 cm above the right outer canthus)

   ![Diagram of EOG derivations]

2) Alternative acceptable derivations are:
   [ALTERNATIVE]
   a. E₁-Fₚ (E₁ is placed 1 cm below and 1 cm lateral to the outer canthus of the left eye)
   b. E₂-Fₚ (E₂ is placed 1 cm below and 1 cm lateral to the outer canthus of the right eye)

   ![Diagram of alternative EOG derivations]

   Note: The alternative derivations record the direction of eye movements, i.e. vertical movements will show in-phase deflections and horizontal eye movements out-of-phase deflections.

C. Electromyogram (EMG)
   [RECOMMENDED]
   1) Three electrodes should be placed to record chin EMG:
      a. One in the midline 1 cm above the inferior edge of the mandible
      b. One 2 cm below the inferior edge of the mandible and 2 cm to the right of the midline
      c. One 2 cm below the inferior edge of the mandible and 2 cm to the left of the midline
   2) The standard chin EMG derivation consists of either of the electrodes below the mandible referred to the electrode above the mandible. The other inferior electrode is a backup electrode to allow for continued display of EMG activity if 1 of the primary electrodes malfunctions.

2. SCORING OF SLEEP STAGES
   [RECOMMENDED]

A. Stages of Sleep
   1) The following terminology is recommended for the stages of sleep:
      a. Stage W (Wakefulness)
      b. Stage N1 (NREM 1)
      c. Stage N2 (NREM 2)
      d. Stage N3 (NREM 3)
      e. Stage R (REM)

   Note: Stage N3 represents slow wave sleep and replaces the R & K nomenclature of stage 3 and stage 4 sleep.

B. Scoring by Epochs
   [RECOMMENDED]
   1) Score sleep stages in 30 second sequential epochs commencing at the start of the study.
   2) Assign a stage to each epoch.
   3) If 2 or more stages coexist during a single epoch, assign the stage comprising the greatest portion of the epoch.
3. STAGE W

**Definitions**

**Alpha rhythm**: Trains of sinusoidal 8-13 Hz activity recorded over the occipital region with eye closure, attenuating with eye opening.

**Eye blinks**: Conjugate vertical eye movements at a frequency of 0.5-2 Hz present in wakefulness with the eyes open or closed.

**Reading eye movements**: Trains of conjugate eye movements consisting of a slow phase followed by a rapid phase in the opposite direction as the subject reads.

**Rapid eye movements (REM)**: Conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500 msec. While rapid eye movements are characteristic of stage R sleep, they may also be seen in wakefulness with eyes open when subjects scan the environment.

**Rules**

A. Score epochs as stage W when more than 50% of the epoch has alpha rhythm over the occipital region.

B. Score epochs without visually discernable alpha rhythm as stage W if any of the following are present:

1. Eye blinks at a frequency of 0.5-2 Hz
2. Reading eye movements
3. Irregular conjugate rapid eye movements associated with normal or high chin muscle tone

**Notes**:

1. Stage W represents the waking state, ranging from full alertness through early stages of drowsiness. Electrophysiological and psychophysiological markers of drowsiness may be present during stage W and may persist into stage N1.

2. In stage W, the majority of individuals with eyes closed will demonstrate alpha rhythm. The EEG pattern with eyes open consists of low amplitude activity (chiefly beta and alpha frequencies) without the rhythmicity of alpha rhythm. About 10% of subjects do not generate alpha rhythm on eye closure, and a further 10% may generate limited alpha rhythm. In these subjects, the occipital EEG activity is similar during eye opening and eye closure.

3. The EEG during wakefulness may demonstrate rapid eye blinks at a frequency of about 0.5-2 Hz. As drowsiness develops, the frequency of blinking slows, and eye blinks may be replaced by slow eye movements, even in the presence of continued alpha rhythm. If the eyes are open, voluntary rapid eye movements or reading eye movements may be seen.

4. The chin EMG during stage W is of variable amplitude, but is usually higher than during sleep stages.

4. STAGE N1

**Definitions**

**Slow eye movements (SEM)**: Conjugate, reasonably regular, sinusoidal eye movements with an initial deflection usually lasting >500 msec.

**Low amplitude, mixed frequency activity**: Low amplitude, predominantly 4-7 Hz activity.

**Vertex sharp waves (V waves)**: Sharply contoured waves with duration <0.5 seconds maximal over the central region and distinguishable from the background activity.

**Sleep onset**: The start of the first epoch scored as any stage other than stage W. (In most subjects this will usually be the first epoch of stage N1.)

**Rules**

A. In subjects who generate alpha rhythm, score stage N1 if alpha rhythm is attenuated and replaced by low amplitude, mixed frequency activity for more than 50% of the epoch.

B. In subjects who do not generate alpha rhythm, score stage N1 commencing with the earliest of any of the following phenomena:

1. Activity in range of 4-7 Hz with slowing of background frequencies by ≥1 Hz from those of stage W.
2. Vertex sharp waves.
3. Slow eye movements.

**Notes**:

1. Vertex sharp waves may be present but are not required for scoring stage N1.
2. The EEG will often show slow eye movement in stage N1, but these are not required for scoring.
3. During stage N1, the chin EMG amplitude is variable, but often lower than in stage W.
4. As slow eye movements often commence before attenuation of alpha rhythm, sleep latency may be slightly shorter for some individuals who do not generate alpha rhythm compared to those who do.
5. STAGE N2

Definitions
K complex: A well-delineated negative sharp wave immediately followed by a positive component standing out from the background EEG, with total duration ≥0.5 seconds, usually maximal in amplitude when recorded using frontal derivations. For an arousal to be associated with a K complex, it must commence no more than 1 second after termination of the K complex.
Sleep spindle: A train of distinct waves with frequency 11-16 Hz (most commonly 12-14 Hz) with a duration ≥0.5 seconds, usually maximal in amplitude using central derivations.

Rules
A. The following rule defines the start of a period of stage N2 sleep:

1) Begin scoring stage N2 (in absence of criteria for N3) if 1 or both of the following occur during the first half of that epoch or the last half of the previous epoch:
   a. One or more K complexes unassociated with arousals
   b. One or more trains of sleep spindles

Note:
1. Continue to score stage N1 for epochs with arousal-associated K complexes but no spontaneous K complexes or sleep spindles.
2. For the purposes of scoring N2 sleep, arousals are defined according to arousal rule V1.

B. The following rule defines continuation of a period of stage N2 sleep:

1) Continue to score epochs with low amplitude, mixed frequency EEG activity without K complexes or sleep spindles as stage N2 if they are preceded by a) K complexes unassociated with arousals or b) sleep spindles.

C. The following rule defines the end of a period of stage N2 sleep:

1) End stage N2 sleep when 1 of the following events occurs:
   a. Transition to stage W
   b. An arousal (change to stage N1 until a K complex unassociated with an arousal or a sleep spindle occurs) (See Figure 1)
   c. A major body movement followed by slow eye movements and low amplitude mixed frequency EEG without non-arousal associated K complexes or sleep spindles (score the epoch following the major body movement as stage N1; score the epoch as stage N2 if there are no slow eye movements; the epoch containing the body movement is scored using criteria in Section 8) (See Figure 2)
   d. Transition to stage N3
   e. Transition to stage R

![Figure 1](image-url)
Notes:
1. The EOG usually shows no eye movement activity during stage N2 sleep, but slow eye movements may persist in some subjects.
2. In stage N2, the chin EMG is of variable amplitude, but is usually lower than in stage W, and may be as low as in stage R sleep.

6. STAGE N3

Definition
Slow wave activity: Waves of frequency 0.5 Hz-2 Hz and peak-to-peak amplitude >75 μV, measured over the frontal regions.

Rule
A. Score stage N3 when 20% or more of an epoch consists of slow wave activity, irrespective of age.

Notes:
1. Sleep spindles may persist in stage N3 sleep.
2. Eye movements are not typically seen during stage N3 sleep.
3. In stage N3, the chin EMG is of variable amplitude, often lower than in stage N2 sleep and sometimes as low as in stage R sleep.

7. STAGE R

Definitions
Rapid eye movements (REM): Conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500 msec.
Low chin EMG tone: Baseline EMG activity in the chin derivation no higher than in any other sleep stage and usually at the lowest level of the entire recording.
Sawtooth waves: Trains of sharply contoured or triangular, often serrated, 2-6 Hz waves maximal in amplitude over the central head regions and often, but not always, preceding a burst of rapid eye movements.
Transient muscle activity: Short irregular bursts of EMG activity usually with duration <0.25 seconds superimposed on low EMG tone. The activity may be seen in the chin or anterior tibial EMG derivations, as well as in EEG or EOG deviations, the latter indicating activity of cranial nerve innervated muscles. The activity is maximal in association with rapid eye movements.

Rules
A. Score stage R sleep in epochs with all the following phenomena:
   a. Low amplitude, mixed frequency EEG
   b. Low chin EMG tone
   c. Rapid eye movements
B. The following rule defines the continuation of a period of stage R sleep:

Continue to score stage R sleep, even in the absence of rapid eye movements, for epochs following 1 or more epochs of stage R as defined in A above, if the EEG continues to show low amplitude, mixed frequency activity without K complexes or sleep spindles and the chin EMG tone remains low. (Figure 3)

![Figure 3](image)

C. The following rule defines the end of a period of stage R sleep:

1) Stop scoring stage R sleep when 1 or more of the following occur:
   a. There is a transition to stage W or N3
   b. An increase in chin EMG tone above the level of stage R is seen and criteria for stage N1 are met (Figure 4)
   c. An arousal occurs followed by low amplitude, mixed frequency EEG and slow eye movements (score as stage N1; if no slow eye movements and chin EMG tone remains low, continue to score as stage R) (Figure 5)
   d. A major body movement followed by slow eye movements and low amplitude mixed frequency EEG without non- arousal associated K complexes or sleep spindles (score the epoch following the major body movement as stage N1; if no slow eye movements and the EMG tone remains low, continue to score as stage R; the epoch containing the body movement is scored using criteria in Section 8) (Figure 6)
   e. One or more non-arousal associated K complexes or sleep spindles are present in the first half of the epoch in the absence of rapid eye movements, even if chin EMG tone remains low (score as stage N2) (Figure 7)

![Figure 4](image)
D. Score epochs at the transition between stage N2 and stage R as follows:

1) In between epochs of definite stage N2 and definite stage R, score an epoch with a distinct drop in chin EMG in the first half of the epoch to the level seen in stage R as stage R if all of the following criteria are met, even in the absence of rapid eye movements (Figure 8):
   a. Absence of non-arousal associated K complexes
   b. Absence of sleep spindles

2) In between epochs of definite stage N2 and definite stage R, score an epoch with a distinct drop in chin EMG in the first half of the epoch to the level seen in stage R as stage N2 if all of the following criteria are met (Figure 9A):
   a. Presence of non-arousal associated K complexes or sleep spindles
   b. Absence of rapid eye movements

3) In between epochs of definite stage N2 with minimal chin EMG tone and definite stage R without further drop in chin EMG tone, score epochs as stage R if all of the following are met, even in the absence of rapid eye movements (Figure 9B):
   a. Absence of non-arousal associated K complexes
   b. Absence of sleep spindles

---

Figure 8

Figure 9

AASM Manual for Scoring Sleep, 2007
Notes:
1. Low amplitude, mixed frequency activity in stage R resembles that seen in stage N1. In some individuals, a greater amount of alpha activity can be seen in stage R than in stage N1. The alpha frequency in stage R often is 1-2 Hz slower than during wakefulness.
2. The following phenomena are strongly supportive of the presence of stage R sleep and may be helpful when the stage is in doubt:
   a. Sawtooth waves
   b. Transient muscle activity (Sawtooth waves and transient muscle activity may be present but are not required for scoring stage R.)
3. At times, especially in the first REM sleep period of the night, K complexes or sleep spindles may be interspersed among epochs of what otherwise appears to be stage R sleep. The above rules indicate that epochs with rapid eye movements should be scored as stage R even in the presence of K complexes or spindles. However, if rapid eye movements are absent, subsequent epochs with K complexes or spindles should be scored as stage N2, even if chin muscle tone remains low.

8. MAJOR BODY MOVEMENTS

<table>
<thead>
<tr>
<th>Definition</th>
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<tbody>
<tr>
<td>Major body movement: Movement and muscle artifact obscuring the EEG for more than half an epoch to the extent that the sleep stage cannot be determined</td>
</tr>
</tbody>
</table>

**Rules**

Score an epoch with a major body movement as follows:

A. If alpha rhythm is present for part of the epoch (even <15 seconds duration), score as stage W.

B. If no alpha rhythm is discernable, but an epoch scorably as stage W either precedes or follows the epoch with a major body movement, score as stage W.

C. Otherwise, score the epoch as the same stage as the epoch that follows it.
VISUAL RULES FOR CHILDREN

1. AGES FOR WHICH PEDIATRIC SLEEP SCORING APPLY: [RECOMMENDED]

A. Pediatric sleep scoring rules can be used to score sleep and wakefulness in children 2 months post-term or older.

Notes:
1. For children less than 2 months post-term, refer to discussion in the Pediatric Task Force review paper.
2. There is no precise upper age boundary for pediatric visual rules, refer to discussion in the Pediatric Task Force review paper.

2. TERMINOLOGY OF SLEEP STAGES [RECOMMENDED]

A. The following terminology should be used when scoring sleep in children 2 months post-term or older:

1) Stage W (Wakefulness)
2) Stage N1 (NREM 1)
3) Stage N2 (NREM 2)
4) Stage N3 (NREM 3)
5) Stage N (NREM)
6) Stage R (REM)

3. TECHNICAL CONSIDERATIONS

See adult sleep scoring rules and digital PSG section for technical considerations other than those in the notes below.

Notes:
1. Adult electrode derivations for EEG, EOG and chin EMG are acceptable for recording sleep except that the distance between the chin EMG electrodes often needs to be reduced from 2 cm to 1 cm and the distance from the eyes in EOG electrodes often need to be reduced from 1 cm to 0.5 cm in children and infants with small head size.
2. An initial EEG sensitivity of 7 µV/mm (vertical scaling) is appropriate for routine PSG recordings but the sensitivity often needs to be adjusted in infants and younger children typically to 10 or even 15 µV/mm. If sensitivities of 10 or 15 µV/mm are used, portions of the sleep recording should be reviewed using 7 µV/mm in order to display and recognize low voltage faster frequencies (including spindle frequencies).

4. SCORING SLEEP STAGES [RECOMMENDED]

Because of the variability of sleep in infants, 4 possible scenarios are described below:

A. If all epochs of NREM sleep contain no recognizable sleep spindles, K complexes or high-amplitude 0.5 to 2 Hz slow wave activity, score all epochs of NREM sleep as stage N (NREM).

B. If some epochs of NREM sleep contain sleep spindles or K complexes, score those as stage N2 (NREM 2). If in the remaining NREM epochs, there is no slow wave activity comprising more than 20% of the duration of epochs, score as stage N (NREM).

C. If some epochs of NREM sleep contain greater than 20% slow wave activity, score these as stage N3 (NREM 3). If in the remaining NREM epochs, there are no K complexes or spindles then score as stage N (NREM).

D. If NREM is sufficiently developed that some epochs contain sleep spindles or K complexes and other epochs contain sufficient amounts of slow wave activity, then score NREM sleep in this infant as either stage N1, N2 or N3 as in an older child or adult.

Notes:
1. Sleep spindles usually are present in NREM sleep of infants 2 to 3 months post-term or older.
2. K complexes are usually present in NREM sleep in infants 4 to 6 months post-term or older.
3. Slow wave activity (>75 µV, 0.3-2 Hz typically in the frontal regions) is usually present 4 to 5 months post-term.
4. NREM sleep can be scored as stage N1, N2 or N3 in most infants 5-6 months post-term or older, occasionally in infants as young as 4 to 5 months post-term.
5. Non-EEG correlates are very helpful in recognizing NREM and REM sleep in infants 6 months post-term or younger. These correlates in REM sleep include the presence of irregular respiration, chin EMG atonia, transient muscle activity, and rapid eye movements. In NREM sleep, correlates include regular respiration, no or rare vertical eye movements, and preserved chin EMG tone.

AASM Manual for Scoring Sleep, 2007
5. STAGE W  [RECOMMENDED]

Definitions

**Alpha rhythm:** Trains of sinusoidal 8-13 Hz activity recorded over the occipital region present with eye closure and which is reactive (attenuates with eye opening).

**Eye blinks:** Conjugate vertical eye movements at a frequency of 0.5-2 Hz present in wakefulness with eyes open or closed.

**Reading eye movements:** Trains of conjugate eye movements consisting of a slow phase followed by a rapid phase in the opposite direction as the child reads or visually scans the environment.

**Rapid eye movements (REM):** Conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500 msec. While rapid eye movements are characteristic of stage R sleep, they may also be seen in wakefulness with eyes open when subjects visually scan the environment.

**Dominant posterior rhythm (DPR):** The dominant reactive EEG rhythm over the occipital regions in relaxed wakefulness with eyes closed which is slower in infants and young children and attenuates with eye opening or attention. Frequency is 3.5-4.5 Hz when first seen in infants 3-4 months post-term, 5-6 Hz by 5-6 months, and 7.5 to 9.5 Hz by 3 years of age and amplitude is usually >50 μV.

Rules

A. In children the dominant posterior rhythm replaces the term alpha rhythm for the purposes of scoring wakefulness and NREM stages.

B. Score epochs as stage W when more than 50% of the epoch has either reactive alpha or age-appropriate dominant posterior rhythm over the occipital region.

C. If there is no discernable reactive alpha or no age-appropriate dominant posterior rhythm, score epochs as stage W if any of the following are present:

1) Eye blinks at a frequency of 0.5-2 Hz
2) Reading eye movements
3) Irregular conjugate rapid eye movements associated with normal or high chin muscle tone

Notes:

1. The dominant posterior rhythm (DPR) over the occipital derivations in adults has amplitude of <50 μV, a frequency of 8.5 to 13 Hz, and is reactive to eye opening. The frequency and amplitude of the dominant posterior rhythm over the occipital derivations in children changes with age.
   a. Only slow irregular potential changes are seen over the occipital scalp regions in infants before 3 to 4 months post-term.
   b. The majority (75%) of infants by 3 to 4 months post-term have an irregular 50-100 μV, 3.5 to 4.5 Hz activity over the occipital regions which is reactive (i.e., blocks or attenuates with eye opening and appears with passive eye closure).
   c. By 5-6 months of age, many children have 50 to 110 μV, 5-6 Hz activity over the occipital regions, and this rhythm is present in 70% of normal children by age 12 months.
   d. By 3 years of age, 82% of children who were normal post-term infants show a mean occipital frequency of >8 Hz (range 7.5 to 9.5 Hz).
   e. A mean alpha frequency of 9 Hz is found in 65% of 9 year olds and increases to 10 Hz in 65% by age 15.
   f. The average amplitude of the dominant posterior rhythm in children is 50-60 μV; 9% of children have >100 μV (especially between 6-9 years); children rarely have alpha activity <30 μV.

2. The highest amplitude and sharpest component of reading eye movements in children is usually surface-negative in the occipital derivations, typically last 150 to 250 msec, and have amplitudes up to 65 μV.

3. Occipital sharp waves with eye blinks are typically single monophasic or biphasic <200 μV sharp waves over the occipital derivations which usually last 200 to 400 msec and occur 100 to 500 msec following an eye blink or eye movement. In children, the initial component of the occipital sharp wave is surface-positive; the ascending phase of next surface-negative component has a steep wave front; and the descending phase of the second component less steep.

4. The dominant posterior rhythm (DPR) in infants and children typically contains intermixed slower EEG rhythms including:
   a. Posterior slow waves of youth (PSW) which are intermittent runs of bilateral but often asymmetric 2.5-4.5 Hz slow waves superimposed, riding upon, or fused with the dominant posterior rhythm, are usually <120% of dominant posterior rhythm voltage, block with eye opening and disappear with drowsiness and sleep. PSW are uncommon in children <2 years of age, have a maximal incidence between ages 8 to 14 years, and are uncommon after age 21 years.
   b. Random or semi-rhythmic occipital slowing: <100 μV, 2.5 to 4.5 Hz rhythmic or arrhythmic activity lasting <3 seconds; a normal finding in EEGs of children ages 1 to 15 years, especially prominent ages 5 to 7 years; the amount of intermixed slowing decreases and its frequency increases with increasing age.
   c. Spontaneous eye closure in an infant signals drowsiness.

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6. STAGE N1

Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow eye movements (SEM)</td>
<td>Conjugate, reasonably regular, sinusoidal eye movements with an initial deflection which usually last &gt;500 msec.</td>
</tr>
<tr>
<td>Low amplitude, mixed frequency activity</td>
<td>Low amplitude, predominantly 4-7 Hz activity.</td>
</tr>
<tr>
<td>Vertex sharp waves (V waves)</td>
<td>Sharply contoured waves with duration &lt;0.5 seconds maximal over the central region and distinguishable from the background activity.</td>
</tr>
<tr>
<td>Sleep onset</td>
<td>The start of the first epoch scored as any stage other than stage W.</td>
</tr>
<tr>
<td>Rhythmic anterior theta activity</td>
<td>Runs of 5-7 Hz rhythmic theta activity maximal over the frontal or frontocentral regions.</td>
</tr>
<tr>
<td>Hypnagogic hypersynchrony</td>
<td>Paroxysmal bursts or runs of diffuse high amplitude sinusoidal 75 to 350 µV, 3-4.5 Hz waves which begin abruptly, are usually widely distributed but often maximal over the central, frontal, or frontocentral scalp regions.</td>
</tr>
</tbody>
</table>

Rules

A. In subjects who generate a dominant posterior rhythm, score stage N1 if the posterior rhythm is attenuated or replaced by low amplitude mixed frequency activity for more than 50% of the epoch.

B. In subjects who do not generate a dominant posterior rhythm, score stage N1 commencing with the earliest of any of the following phenomena:

1. Activity in the range of 4-7 Hz with slowing of background frequencies by ≥1-2 Hz from those of stage W
2. Slow eye movements
3. Vertex sharp waves
4. Rhythmic anterior theta activity (RAT)
5. Hypnagogic hypersynchrony
6. Diffuse or occipital predominant high amplitude rhythmic 3-5 Hz activity

Notes:

1. Drowsiness in infants up to age 6 to 8 months is characterized by the gradual appearance of diffuse high amplitude (often 75 to 200 µV) 3-5 Hz activity which is typically of higher amplitude, more diffuse, and 1-2 Hz slower than the waking EEG background activity.
2. Drowsiness in children 8 months to 3 years is characterized by either diffuse runs or bursts of rhythmic or semi-rhythmic biventricular 75 to 200 µV, 3-4 Hz activity often maximal over the central regions and/or higher amplitude (>200 µV) 4-6 Hz theta activity maximal over the frontocentral or central regions.
3. Sleep onset from 3 years on is often characterized by a 1-2 Hz slowing of the dominant posterior rhythm frequency and/or the dominant posterior rhythm often becomes diffusely distributed then is gradually replaced by relatively low voltage mixed frequency EEG activity.
4. In most subjects sleep onset will be the first epoch of stage N1 but in infants younger than 3 months post-term, this is often stage R.
5. Rhythmic anterior theta activity (RAT) are runs of moderate voltage 5-7 Hz theta activity over the frontal regions is commonly seen in adolescents and young adults when drowsy, may first appear around 5 years of age.
6. Vertex sharp waves are monophasic, surface-negative sharp waves maximal over the central regions which last <0.5 second (usually <200 msec), can occur in bursts or runs, most often seen during transition to stage N1 sleep but can occur in either stage N1 or N2 sleep. By 6 months post-term, a few broad vertex sharp waves can be seen over the central regions but vertex sharp waves which resemble those seen in older children and adults typically first appear 16 months post-term.
7. Hypnagogic hypersynchrony (HH) is a distinctive EEG pattern of drowsiness and stage N1 characterized by paroxysmal runs or bursts of diffuse biventricular 75 to 350 µV, 3-4.5 Hz waves often maximal over the central, frontal or frontocentral or derivations. HH often disappears with deeper stages of NREM sleep. HH is seen in approximately 30% of infants 3 months post-term, 95% of all normal children ages 6 to 8 months, and is less prevalent after age 4 to 5 years, seen in only 10% of healthy children age 11, rarely seen after age 12 years.

7. STAGE N2

Same as adult rules as noted in section IV. 5.

Notes:

1. Sleep spindles (SS) are usually are first seen in infants 4 to 6 weeks post-term as brief bursts of low amplitude less sinusoidal 12-14 Hz activity maximal over the vertex (C) region, are usually well-developed and are present in all normal infants 8 to 9 weeks.
2. Eighty percent of children <13 years of age have 2 independent scalp locations and frequency ranges for sleep spindles: 10.0 to 12.75 Hz over the frontal and 12.5 to 14.75 Hz maximal over the central or centrotemporal region.
3. Frontal sleep spindles are more prominent than centrotemporal spindles in young children but abruptly decrease in EEG power and presence beginning at age 13 whereas centrotemporal spindles persist unchanged in presence or location.
4. K complexes are usually present 3 to 6 months post-term and are maximal over the pre-frontal and frontal regions, as they are in adults. For definition, see IV.
8. STAGE N3

Same as adult rules in section IV. 6.

Note: Slow wave activity (SWA) in pediatric populations often 100 to 400 µV, 0.5 to 2.0 Hz activity maximal over the recommended derivations in the frontal scalp regions (F4, F3) first appears as early as 2 months, more often about 3 to 4.5 months post-term.

9. STAGE R

Same as adult rules section IV. 7.

Note: The continuous low voltage, mixed frequency EEG activity of stage R in infants and children resembles adults though the dominant frequencies increase with age: approximately 3 Hz activity at 7 weeks post-term; 4-5 Hz activity with bursts of saw tooth waves at 5 months; 4-6 Hz at 9 months; and prolonged runs or bursts of notched 5- to 7-Hz theta activity at 1 to 5 years age. By 5 to 10 years of age, the low voltage mixed frequency activity in stage R resembles that of adults.
1. SCORING AROUSALS

A. Score arousal during sleep stages N1, N2, N3, or R if there is an abrupt shift of EEG frequency including alpha, theta and/or frequencies greater than 16 Hz (but not spindles) that lasts at least 3 seconds, with at least 10 seconds of stable sleep preceding the change. Scoring of arousal during REM requires a concurrent increase in submental EMG lasting at least 1 second.

Notes:
1. Arousal scoring should incorporate information from both the occipital and central derivations.
2. Arousal scoring can be improved by the use of additional information in the recording such as respiratory events and/or additional EEG channels. Scoring of arousals, however, cannot be based on this additional information alone and such information does not modify any of the arousal scoring rules.
VI. CARDIAC RULES

1. TECHNICAL SPECIFICATIONS

A. A single modified electrocardiograph Lead II using torso electrode placement is recommended.

Notes:
1. Additional leads may be placed if clinically indicated at the discretion of the practitioner.
2. Increasing image size on display may improve detection of arrhythmias.
3. While classically Lead II is derived from electrodes placed on the right arm and left leg, the electrodes may be placed on the torso aligned in parallel to the right shoulder and left hip.
4. Standard ECG electrode applications are superior to EEG electrodes in minimizing artifact.

2. SCORING RULES

A. Score sinus tachycardia during sleep for a sustained sinus heart rate of greater than 90 beats per minute for adults.

B. Score bradycardia during sleep for a sustained heart rate of less than 40/minute for ages 6 years through adult.

C. Score asystole for cardiac pauses greater than 3 seconds for ages 6 years through adult.

D. Score wide complex tachycardia for a rhythm lasting a minimum of 3 consecutive beats at a rate greater than 100 per minute with QRS duration of greater than or equal to 120 msec.

E. Score narrow complex tachycardia for a rhythm lasting a minimum of 3 consecutive beats at a rate of greater than 100 per minute with QRS duration of less than 120 msec.

F. Score atrial fibrillation if there is an irregularly irregular ventricular rhythm associated with replacement of consistent P waves by rapid oscillations that vary in size, shape, and timing.

Notes:
1. Significant arrhythmias such as heart block should be reported if the quality of the single lead is sufficient for accurate scoring.
2. Ectopic beats should be reported if felt to be clinically significant.
3. Sinus rates vary according to age in children, with faster rates in young children as compared to adults. For typical sinus rates in children, refer to the Cardiac Task Force review paper.
VII. MOVEMENT RULES

1. SCORING PERIODIC LIMB MOVEMENTS IN SLEEP (PLMS)

A. The following rules define a significant leg movement (LM) event:

1) The minimum duration of a LM event is 0.5 seconds
2) The maximum duration of a LM event is 10 seconds.
3) The minimum amplitude of a LM event is an 8 μV-increase in EMG voltage above resting EMG.
4) The timing of the onset of a LM event is defined as the point at which there is an 8 μV-increase in EMG voltage above resting EMG.
5) The timing of the ending of a LM event is defined as the start of a period lasting at least 0.5 seconds during which the EMG does not exceed 2 μV above resting EMG.

B. The following rules define a PLM series:

1) The minimum number of consecutive LM events needed to define a PLM series is 4 LMs.
2) The minimum period length between LMs (defined as the time between onsets of consecutive LMs) to include them as part of a PLM series is 5 seconds.
3) The maximum period length between LMs (defined as the time between onsets of consecutive LMs) to include them as part of a PLM series is 90 sec.
4) Leg movements on 2 different legs separated by less than 5 seconds between movement onsets are counted as a single leg movement.

Notes:
1. An LM should not be scored if it occurs during a period from 0.5 seconds preceding an apnea or hypopnea to 0.5 seconds following an apnea or hypopnea.
2. An arousal and a PLM should be considered associated with each other when there is <0.5 seconds between the end of one event and the onset of the other event regardless of which is first.
3. Surface electrodes should be placed longitudinally and symmetrically around the middle of the muscle so that they are 2 to 3 cm apart or 1/3 of the length of the anterior tibialis muscle, whichever is shorter. Both legs should be monitored for the presence of the leg movements. Separate channels for each leg are strongly preferred. Combining electrodes from the 2 legs to give 1 recorded channel may suffice for some clinical settings, though it should be recognized that this strategy may reduce the number of detected LMs. Movements of the upper limbs may be sampled if clinically indicated.
4. The rules in “A” above define a significant leg movement event by absolute increase in μV above resting baseline for the anterior tibialis EMG. This requires a stable resting EMG for the relaxed anterior tibialis whose absolute signal should be no greater than +10 μV between negative and positive deflection (±5 μV) or +5 μV for rectified signals.
5. Use of 60 Hz (notch) filters should be avoided. Impedances need to be less than 10,000 Ω. Less than 5,000 Ω is preferred but may be difficult to obtain. Sensitivity limits of -100 and 100 μV (upper/lower) are preferred.

2. SCORING ALTERNATING LEG MUSCLE ACTIVATION (ALMA)

A. The following rules define ALMA:

1) The minimum number of discrete and alternating bursts of leg muscle activity needed to score an ALMA series is 4 ALMAs.
2) The minimum frequency of the alternating EMG bursts in ALMA is 0.5 Hz.
3) The maximum frequency of the alternating EMG bursts in ALMA is 3.0 Hz.

Notes:
1. ALMAs alternate between legs.
2. The usual range for duration of ALMA is 100-500 msec.
3. ALMA may simply be a benign movement phenomenon associated with characteristic EMG patterns as there have been no reported clinical consequences.
3. SCORING HYPNAGOGIC FOOT TREMOR (HFT)

A. The following rules define HFT:

1) The minimum number of bursts needed to make a train of bursts in hypnagogic foot tremor is 4 bursts.
2) The minimum frequency of the EMG bursts in hypnagogic foot tremor is 0.3 Hz.
3) The maximum frequency of the EMG bursts in hypnagogic foot tremor is 4.0 Hz.

Notes:
1. The usual range for duration of hypnagogic foot tremor is 250-1000 msec.
2. HFT may simply be benign movement phenomenon associated with characteristic EMG patterns as there have been no reported clinical consequences.

4. SCORING EXCESSIVE FRAGMENTARY MYOCLONUS (EFM)

A. The following rules define EFM:

1) The usual maximum EMG burst duration seen in fragmentary myoclonus is 150 msec
2) At least 20 minutes of NREM sleep with EFM must be recorded
3) At least 5 EMG potentials per minute must be recorded

Notes:
1. EFM may be a benign movement phenomenon associated with a characteristic EMG pattern as there have been no reported clinical consequences.
2. In many cases no visible movements are present. Gross jerk-like movements across the joint spaces are not observed. When minor movement across a joint space is present, the movement resembles the small twitch-like movements of the fingers, toes, and the corner of the mouth intermittently seen in REM sleep in normal individuals.
3. In some cases when visible movement is present, the EMG burst duration may be >150 msec.

5. SCORING BRUXISM

A. The following rules define bruxism:

1) Bruxism may consist of brief (phasic) or sustained (tonic) elevations of chin EMG activity that are at least twice the amplitude of background EMG.
2) Brief elevations of chin EMG activity are scored as bruxism if they are 0.25-2 seconds in duration and if at least 3 such elevations occur in a regular sequence.
3) Sustained elevations of chin EMG activity are scored as bruxism if the duration is more than 2 seconds.
4) A period of at least 3 seconds of stable background chin EMG must occur before a new episode of bruxism can be scored.
5) Bruxism can be scored reliably by audio in combination with polysomnography by a minimum of 2 audible tooth grinding episodes/night of polysomnography in the absence of epilepsy.

Notes:
1. In sleep, jaw contraction frequently occurs. This contraction can take 2 forms: a) sustained (tonic) jaw clenching tonic contractions or b) a series of repetitive brief (phasic) muscle contractions termed rhythmic masticatory muscle activity (RMM).
2. In addition to the recommended placement of chin EMG electrodes as noted in section IV.A.1.c, additional masseter electrodes may be placed at the discretion of the investigator or clinician.

6. SCORING PSG FEATURES OF REM SLEEP BEHAVIOR DISORDER (RBD):

Definitions

Sustained muscle activity (tonic activity) in REM sleep: An epoch of REM sleep with at least 50% of the duration of the epoch having a chin EMG amplitude greater than the minimum amplitude than in NREM.

Excessive transient muscle activity (phasic activity) in REM sleep: In a 30-second epoch of REM sleep divided into 10 sequential 3 second mini-epochs, at least 5 (50%) of the mini-epochs contain bursts of transient muscle activity. In RBD, excessive transient muscle activity bursts are 0.1 – 5.0 seconds in duration and at least 4 times as high in amplitude as the background EMG activity.

Rule:

1) The polysomnographic characteristics of RBD are characterized by either or both of the following features:
   a. Sustained muscle activity in REM sleep in the chin EMG
   b. Excessive transient muscle activity during REM in the chin or limb EMG

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Notes:
1. Time synchronized video PSG audio or a characteristic clinical history are necessary to make the diagnosis of RBD in addition to polysomnographic evidence of REM without atonia or excessive transient muscle activity in REM.
2. Transient muscle activity and occasional accompanying visible twitching of small muscle groups are a normal phenomenon seen in REM sleep (see IV. Adult. 7). When larger muscle groups are involved, this activity is not associated with large, overt muscular activity acting across large joints. When smaller muscle groups are involved, the movement often involves the distal muscles of the hands and face or the corners of the mouth. Transient muscle activity may be excessive in RBD.
3. The sustained muscle activity or the excessive transient muscle activity observed in REM sleep may be interrupted by superimposed (usually dream-enacting) behaviors of RBD.
4. In normal individuals there is an atonia seen in REM sleep in the chin and anterior tibialis EMG. In this state the baseline amplitude of the EMG signal decreases markedly. This atonia of REM sleep is lost to a considerable extent in RBD, with variable frequency, and as a result, the EMG baseline amplitude is often higher. In this situation, the EMG can be said to be in a tonic rather than atonic state.

7. SCORING THE PSG FEATURES OF RHYTHMIC MOVEMENT DISORDER

A. The following rule defines the polysomnographic characteristics of rhythmic movement disorder:

1) The minimum frequency for scoring rhythmic movements is 0.5 Hz
2) The maximum frequency for scoring rhythmic movements is 2.0 Hz
3) The minimum number of individual movements required to make a cluster of rhythmic movements is 4 movements
4) The minimum amplitude of an individual rhythmic burst is 2 times the background EMG activity

Notes:
1. Bipolar surface electrodes should be placed to record electrical activity of the large muscle groups involved.
2. Time synchronized video PSG, in addition to polysomnographic criteria, is necessary to make the diagnosis of rhythmic movement disorder.
VIII. RESPIRATORY RULES

RESPIRATORY RULES FOR ADULTS

1. TECHNICAL CONSIDERATIONS

A. The sensor to detect absence of airflow for identification of an apnea is an oronasal thermal sensor.

B. The sensor for detection of airflow for identification of a hypopnea is a nasal air pressure transducer with or without square root transformation of the signal.

C. The sensor for detection of respiratory effort is either esophageal manometry, or calibrated or uncalibrated inductance plethysmography.

D. The sensor for detection of blood oxygen is pulse oximetry with a maximum acceptable signal averaging time of 3 seconds.

Notes:
1. Alternative sensors are to be used when the signal from the recommended sensor is not reliable.
2. The alternative signal to detect absence of airflow for identification of an apnea when the thermistor signal is unreliable is a nasal air pressure transducer.
3. An alternative sensor for detection of effort is diaphragmatic/intercostal EMG.
4. For scoring of hypopnea when the nasal pressure device is not functioning, alternative sensory including uncalibrated or calibrated inductance plethysmography or an oronasal thermal sensor may be used.
5. A small bias i.e., more events in reporting hypopneas at the flow threshold recommended for scoring hypopneas (≤50% of baseline), may be corrected by square root transformation.

2. EVENT DURATION RULES

A. For scoring either an apnea or a hypopnea, the event duration is measured from the nadir preceding the first breath that is clearly reduced to the beginning of the first breath that approximates the baseline breathing amplitude (see horizontal brackets, Figures 1 and 2).

B. When baseline breathing amplitude cannot be easily determined (and when underlying breathing variability is large), events can also be terminated when either there is a clear and sustained increase in breathing amplitude, or in the case where a desaturation has occurred, there is event-associated resaturation of at least 2%.

3. SCORING OF APNEAS

A. Score an apnea when all of the following criteria are met (Figure 1):

1) There is a drop in the peak thermal sensor excursion by ≥90% of baseline
2) The duration of the event lasts at least 10 seconds. (see Section 2 above)
3) At least 90% of the event’s duration meets the amplitude reduction criteria for apnea

B. Classify an apnea in an adult based upon inspiratory effort:

1) Score a respiratory event as an obstructive apnea if it meets apnea criteria and is associated with continued or increased inspiratory effort throughout the entire period of absent airflow.
2) Score a respiratory event as a central apnea if it meets apnea criteria and is associated with absent inspiratory effort throughout the entire period of absent airflow.
3) Score a respiratory event as a mixed apnea if it meets apnea criteria and is associated with absent inspiratory effort in the initial portion of the event, followed by resumption of inspiratory effort in the second portion of the event.

Notes:
1. Identification of an apnea does not require a minimum desaturation criterion.
2. The criteria for determination of the length of an apnea are specified in Section 2.
4. HYPOPNEA RULES

A. Score a hypopnea if all of the following criteria are met (See Figure 2):

1) The nasal pressure signal excursions (or those of the alternative hypopnea sensor) drop by $\geq 30\%$ of baseline
2) The duration of this drop occurs for a period lasting at least 10 seconds
3) There is a $\geq 4\%$ desaturation from pre-event baseline
4) At least $90\%$ of the event’s duration must meet the amplitude reduction of criteria for hypopnea

B. Score a hypopnea if all of the following criteria are met:

1) The nasal pressure signal excursions (or those of the alternative hypopnea sensor) drop by $\geq 50\%$ of baseline
2) The duration of this drop occurs for a period lasting at least 10 seconds
3) There is a $\geq 3\%$ desaturation from pre-event baseline or the event is associated with arousal
4) At least $90\%$ of the event’s duration must meet the amplitude reduction of criteria for hypopnea

Note:
1. The definition of hypopnea used (VIII.4.A or VIII.4.B) should be specified in the PSG report.
2. Classification of a hypopnea as obstructive, central, or mixed should not be performed without a quantitative assessment of ventilatory effort (esophageal manometry, calibrated respiratory inductance plethysmography, or diaphragmatic/intercostal EMG).

5. RESPIRATORY EFFORT-RELATED AROUSAL RULE

A. Score a respiratory effort-related arousal (RERA) (Figure 3):

1) If there is a sequence of breaths lasting at least 10 seconds characterized by increasing respiratory effort or flattening of the nasal pressure waveform leading to an arousal from sleep when the sequence of breaths does not meet criteria for an apnea or hypopnea.

Notes:
1. With respect to scoring a RERA, use of esophageal pressure is the preferred method of assessing change in respiratory effort, although nasal pressure and inductance plethysmography can be used.

6. HYPOVENTILATION RULE

A. Score hypventilation during sleep as present if there is a $\geq 10$ mm Hg increase in PaCO$_2$ during sleep in comparison to an awake supine value.

Notes:
1. Persistent oxygen desaturation is not sufficient to document hypventilation.
2. An increased PaCO$_2$ value obtained immediately upon awakening from sleep is suggestive of sleep hypventilation.
3. At this time, there is insufficient evidence to allow specification of sensors for direct or surrogate measures of PaCO$_2$. Both end-tidal
4. At this time, there is insufficient evidence to allow specification of a duration of hyperventilation though the duration should be sufficient to account for the effects of response time of the sensor used and to exclude brief changes that reflect sensor artifact.

7. CHEYNE STOKES BREATHING RULE

A. Score Cheyne Stokes breathing if there are at least 3 consecutive cycles of cyclical crescendo and decrescendo change in breathing amplitude (Figure 4) and at least 1 of the following:

   1) Five or more central apneas or hypopneas per hour of sleep
   2) The cyclic crescendo and decrescendo change in breathing amplitude has duration of at least 10 consecutive minutes.

Note: Cheyne Stokes breathing has variable cycle length that is most commonly in the range of 60 seconds.
RESPIRATORY RULES FOR CHILDREN

1. TECHNICAL CONSIDERATIONS

A. The sensor used to detect absence of airflow for identification of an apnea is an oronasal thermal sensor.

B. The sensor for detection of airflow for identification of a hypopnea is a nasal air pressure transducer without square root transformation of the signal.

C. Acceptable sensors for detection of respiratory effort are either esophageal manometry, or calibrated or uncalibrated inductance plethysmography.

D. The sensor for detection of blood oxygen is pulse oximetry with a maximum acceptable signal averaging time of 3 seconds.

E. Acceptable methods for assessing alveolar hypoventilation are either transcutaneous or end-tidal PCO₂ monitoring.

Note:
1. Alternative sensors are to be used when the signal from the recommended sensor is not reliable.
2. The alternative signal to detect absence of airflow for identification of an apnea is a nasal air pressure transducer.
3. Alternative signals for identification of apnea are end-tidal PCO₂ and summed calibrated inductance plethysmography.
4. The alternative sensor for detection of airflow for identification of a hypopnea is an oronasal thermal sensor.

2. AGES FOR WHICH PEDIATRIC SCORING RULES SHOULD BE USED

A. Criteria for respiratory events during sleep for infants and children can be used for children <18 years, but an individual sleep specialist can choose to score children ≥13 years using adult criteria.

Note: Several studies have published data using pediatric criteria in children up to 18 years of age. However, there have been no studies comparing adult and pediatric criteria in adolescents, particularly those approaching adulthood. Empiric observations would suggest that adult criteria could be used in some older children.

3. APNEA RULES

A. Score a respiratory event as an obstructive apnea if it meets all of the following criteria:

1) The event lasts for at least 2 missed breaths (or the duration of 2 breaths as determined by baseline breathing pattern)
2) The event is associated with a >90% fall in the signal amplitude for ≥90% of the entire respiratory event compared to the pre-event baseline amplitude
3) The event is associated with continued or increased inspiratory effort throughout the entire period of decreased airflow
4) The duration of the apnea is measured from the end of the last normal breath to the beginning of the first breath that achieves the pre-event baseline inspiratory excursions

B. Score a respiratory event as a mixed apnea if it meets both 3.A.1, and 3.A.2, and it is associated with associated with absent inspiratory effort in the initial portion of the event, followed by resumption of inspiratory effort before the end of the event.

C. Score a respiratory event as a central apnea if it is associated with absent inspiratory effort throughout the entire duration of the event and 1 of the following is met:

1) The event lasts 20 seconds or longer
2) The event lasts at least 2 missed breaths (or the duration of 2 breaths as determined by baseline breathing pattern) and is associated with an arousal, an awakening or a ≥3% desaturation

Notes:
1. An apnea during sleep in an infant or child does not need to cause an arousal, awakening or an arterial oxygen desaturation to be scored.
2. A central apnea which lasts at least 2 missed breaths (or the duration of 2 breaths as determined by baseline breathing pattern), but is less than 20 seconds and immediately follows a snore, sigh, respiratory event or arousal is not scored unless it causes either an arousal, an awakening or a ≥3% desaturation.
4. PEDIATRIC HYPOPNEA RULES

A. Score a respiratory event as a hypopnea if it meets all of the following criteria:

1) The event is associated with a $\geq 50\%$ fall in the amplitude of the nasal pressure or alternative signal compared to the pre-event baseline excursion
2) The event lasts at least 2 missed breaths (or the duration of 2 breaths as determined by baseline breathing pattern) from the end of the last normal breathing amplitude
3) The fall in the nasal pressure signal amplitude must last for $\geq 90\%$ of the entire respiratory event compared to the signal amplitude preceding the event
4) The event is associated with an arousal, awakening, or $\geq 3\%$ desaturation

B. Score a respiratory effort related arousal (RERA) event if the conditions in either 1 or 2 are met:

1) When using a nasal pressure sensor all of the following must be met:
   a. There is a discernible fall in the amplitude of signal from a nasal pressure sensor, but it is less than 50% in comparison to the baseline level
   b. There is flattening of the nasal pressure waveform
   c. The event is accompanied by snoring, noisy breathing, elevation in the end-tidal PCO$_2$, transcutaneous PCO$_2$ or visual evidence of increased work of breathing
   d. The duration of the event is at least 2 breath cycles (or the duration of 2 breaths as determined by baseline breathing pattern)

2) When using an esophageal pressure sensor all of the following must be met:
   a. There is a progressive increase in inspiratory effort during the event
   b. The event is accompanied by snoring, noisy breathing, elevation in the end-tidal PCO$_2$, transcutaneous PCO$_2$ or visual evidence of increased work of breathing
   c. The duration of the event is at least 2 breath cycles (or the duration of 2 breaths as determined by baseline breathing pattern)

Notes:
1. Removal or malfunction of the nasal pressure sensor occurs more commonly in infants and children than in adults. If this occurs during a recording, hypopneas may be scored using a thermal sensor if the signal quality is adequate, following the same criteria used for scoring hypopneas with a nasal pressure sensor.
2. A RERA (or flow limitation event) cannot be scored without an adequate nasal pressure or esophageal pressure signal.
3. Classification of a hypopnea as obstructive, central or mixed should not be performed without a quantitative assessment of ventilatory effort (esophageal manometry or calibrated respiratory inductance plethysmography).

5. HYPOVENTILATION RULE

A. Score the presence of sleep-related hypoventilation when $\geq 25\%$ of the total sleep time as measured by either the transcutaneous PCO$_2$ and/or end-tidal CO$_2$ sensor(s) is spent with a CO$_2$ $\geq 50$ mm Hg.

Notes:
1. The end-tidal PCO$_2$ often malfunctions or provides falsely low values in patients who have marked nasal obstruction, profuse nasal secretions, are obligate mouth breathers, or who are receiving supplemental oxygen or CPAP during the PSG. It is crucial to obtain a plateau in the end-tidal waveform for the signal to be considered valid.
2. Transcutaneous PCO$_2$ monitoring provides only a semi-quantitative index of trends in alveolar ventilation, and varies unpredictably from the PaCO$_2$, typically logging after the event.

6. PERIODIC BREATHING RULE

A. Score periodic breathing if there are $\geq 3$ episodes of central apnea lasting $\geq 3$ seconds separated by no more than 20 seconds of normal breathing.
IX. PROCEDURAL NOTES

PARAMETERS TO BE REPORTED PROCEDURE NOTES


1.B.1-10. Sleep scoring data. No evidence. Adopted and modified from previous AASM practice parameter. Consensus of Task Force with approval by Steering Committee. [CONSENSUS]


1.E.1-10. Cardiac events. No evidence. Compliant with rules of Cardiac Task Force. Consensus of Cardiac Task Force with approval by Steering Committee. [CONSENSUS]


TECHNICAL AND DIGITAL SPECIFICATIONS PROCEDURE NOTES

1.A. Sampling frequency and filter specifications for routine PSG recordings. No evidence. Non-systematic review on ECG sampling rates and commonly applied principles in practice. Consensus of Digital Task Force with approval by Steering Committee. [CONSENSUS]


1.C.1-10. PSG display and display manipulation. No evidence. Consensus of Digital Task Force with approval by Steering Committee. [CONSENSUS]


VISUAL RULES FOR ADULTS PROCEDURE NOTES


1.A.3. Ten-twenty application map. No evidence. Consensus vote was not felt necessary, Steering Committee approved as a standardized and universally accepted procedure. [ADJUDICATION]


1.C.1-2. EMG derivation. No evidence. Consensus agreement with clarification of specific distances and back-up electrode requested by industry and technical review panel and provided by Visual Task Force chair with Steering Committee approval. [CONSENSUS AND ADJUDICATION]


2.B.3. Assignment of epoch with multiple stages. No evidence. Clarification was provided by agreement of Visual Task Force chair and Steering Committee.


5.A. Stage N2 based on K complexes and spindles. Consistent level 1 and 2 evidence. Decision by Steering Committee and consensus agreement of Visual Task Force.


7.A. Stage R based on rapid eye movements, low EMG and EEG. Consistent level 1 and 2 evidence. Decision by Steering Committee and consensus agreement of Visual Task Force.


VISUAL RULES FOR CHILDREN PROCEDURE NOTES


3. Technical considerations. Adult rules accepted by Pediatric Task Force with pediatric caveats provided in notes.


7. Stage N2 rules. Adult rules accepted by Pediatric Task Force.


9. Stage R. Adult rules accepted by Pediatric Task Force.

AROUSAL RULE PROCEDURE NOTE

1. Arousal Rule.
   • Duration and EEG change. Level 1 and 2 evidence. Decision by Steering Committee and consensus of Arousal Task Force.
   • Specification for duration of EMG increase was requested by technical/industry and recommended by task force chair. This decision was then adjudicated by Steering Committee.

CARDIAC RULES PROCEDURE NOTES


2.A. Tachycardia. Level 3 and 4 evidence. Consensus agreement by Cardiac Task Force approved by Steering Committee.

2.B. Bradycardia. Level 3 and 4 evidence. Consensus agreement by Cardiac Task Force approved by Steering Committee.

2.C. Asystole. Limited evidence. Consensus agreement by Cardiac Task Force approved by Steering Committee.


2.F. Atrial fibrillation. American Heart Association consensus modified by consensus of Cardiac Task Force and approved by Steering Committee.
MOBMENT RULES PROCEDURE NOTES


1.A.2. Leg movements. Evidence level 5. Rule states 10 seconds instead of the previous 5 second rule based on consensus agreement by Movements Task Force; approved by Steering Committee. [CONSENSUS]


1.B.2. PLM series. Evidence level 5 based on ICSD Consensus. Consensus agreement by Movements Task Force, approved by Steering Committee. [CONSENSUS]

2.A. The minimum duration of the muscle bursts for ALMA was removed due to concerns by the technical panel and Movements Task Force leader and adjudication by steering committee. [CONSENSUS]


3.A.1-4. Hypnagogic Foot Tremor (HFT). Evidence level 2 Consensus agreement by Movements Task Force; approved by Steering Committee [GUIDELINE]


5.A.7. Bruxism amplitude of individual burst. No evidence. Consensus agreement by Movements Task Force plus adjudication by Steering Committee based on technical panel input and discussions of the Movements Task Force. [ADJUDICATION]


- REM without atonia and duration of bursts of transient muscle activity. Consensus agreement by Movements Task Force, approved by Steering Committee. [CONSENSUS]

- Amplitude criterion and 3 second sequences of transient muscle activity recommended by task force chair and approved by Steering Committee. [ADJUDICATION]


RESPIRATORY RULES FOR ADULTS PROCEDURE NOTES

1.A. Preferred primary airflow sensor for apnea detection. Limited evidence. Consensus agreement by Respiratory Task Force approved by Steering Committee. [CONSENSUS]


1.E. Preferred sensor for detection of blood oxygen.
   • Use of pulse oximetry. No evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Pulse oximetry averaging times. Level 3-4 evidence. No agreement by Respiratory Task Force, adjudicated by Steering Committee.

2. Event duration rules.


3.A. Scoring apnea.
   • Amplitude criterion. Level 3-5 evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Duration of event criterion. Level 3-5 evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Minimal event amplitude duration criterion. No evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.


4.A. Scoring hypopnea.
   • Amplitude criterion. Level 3-5 evidence. Recommendation by AASM Board of Directors to meet current practice.
   • Duration criterion. Level 3-5 evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Desaturation criterion. Level 2-5 evidence. Recommendation by AASM Board of Directors to meet current practice.
   • No arousal criterion. Limited level 2 and 5 evidence. Recommendation by AASM Board of Directors to meet current practice.
   • Minimal event amplitude and duration criterion. No evidence. No agreement by Respiratory Task Force, adjudicated by Steering Committee.

4.B. Scoring hypopnea.
   • Amplitude criterion. Level 3-5 evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Duration criterion. Level 3-5 evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Desaturation criterion. Level 2-5 evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Arousal criterion. Limited level 2 and 5 evidence. Consensus agreement by Respiratory Task Force, approved by Steering Committee.
   • Minimal event amplitude and duration criterion. No evidence. No agreement by Respiratory Task Force, adjudicated by Steering Committee.


RESPIRATORY RULES FOR CHILDREN PROCEDURE NOTES


1.B. Preferred airflow sensor for detection of a hypopnea. Limited level 3 evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.

1.C. Acceptable sensors for detection of respiratory effort. Consistent limited level 3 evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.

1.D. Preferred sensor for detection of blood oxygen. Level 3-4 evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.


2.A. Age criterion. Limited level 3 evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.

3.A. Scoring obstructive apnea.
   - Length criterion. Level 3 evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.
   - Amplitude criterion. No evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.
   - Effort criterion. Level 3-5 evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.
   - Minimal event amplitude duration criterion. Level 3 evidence. Consensus agreement by the Pediatric Task Force approved by Steering Committee.


4.A. Scoring hypopnea.
   - Amplitude criterion: Conflicting level 2-5 evidence. Consensus agreement by Pediatric Task Force approved by Steering Committee.
   - Length criterion. Level 3-5 evidence. Consensus agreement by Pediatric Task Force approved by Steering Committee.
   - Minimal event amplitude duration criterion. No evidence. Consensus agreement by Pediatric Task Force approved by Steering Committee.
   - Associated event criteria. Limited level 3-5 evidence. Consensus agreement by Pediatric Task Force approved by Steering Committee.

4.B. RERA scoring.
   - Nasal pressure sensor criteria. Limited level 3-5 evidence. Consensus agreement by Pediatric Task Force approved by Steering Committee.
• Esophageal catheter criteria. Limited level 2 evidence. Consensus agreement by Pediatric Task Force approved by Steering Committee.

5.A. Sleep related hypoventilation. Level 3 evidence. Consensus agreement by Pediatric Task Force approved by Steering Committee.

X. GLOSSARY OF TERMS

Apnea: An interruption of airflow lasting at least 10 seconds in adults or the equivalent of 2 breaths in children.

Alpha rhythm: An EEG pattern consisting of trains of sinusoidal 8-13 Hz activity recorded over the occipital region with eye closure and attenuation with eye opening.

Asystole: An interruption of cardiac rhythm lasting more than 3 seconds.

Atrial fibrillation: An irregularly irregular ventricular rhythm associated with replacement of consistent P waves by rapid electrical oscillations.

Beta rhythm: An EEG rhythm consisting of 13-30 Hz activity.

Bradygait: A sustained heart rate less than 40 beats per minute.

Bruxism: Grinding or clenching of the teeth during sleep that is often associated with movement.

Cheyne Stokes breathing: A breathing rhythm with a specified crescendo and decrescendo change in breathing amplitude.

Consensus: A specified agreement of appropriateness amongst a minimum of 7 individuals using RAND/UCLA methods.

Delta rhythm: An EEG rhythm consisting of 1-4 Hz activity.

Dominant posterior rhythm: An EEG pattern with frequency appropriate to age which is observed over the occipital regions during relaxed wakefulness with eyes closed and attenuates with eye opening or attention.

Excessive fragmentary myoclonus: Limb EMG activity of a specified frequency and duration often unassociated with visible movement, not a defined disorder.

Eye blinks: EOG events consisting of conjugate vertical eye movements at a frequency of 0.5-2 Hz present in wakefulness with the eyes open or closed.

Guideline: A recommendation based on level 2 evidence or a consensus of level 3 evidence.

Hypnagogic foot tremor: Trains of activity of the lower limb with a specified frequency, not a defined disorder.

Hypnagogic hypersynchrony: An EEG pattern consisting of paroxysmal runs or bursts of diffuse high amplitude sinusoidal 75 to 350 µV, 3-4.5 Hz waves which begin abruptly, are usually widely distributed but often maximal over the central, frontal, or frontocentral scalp regions.

Hypopnea: A specified reduction in airflow lasting at least 10 seconds in adults or the equivalent of 2 breaths in children.

Hyperventilation: A specified period of increased PCO₂ of >50 mm Hg in children or a rise of PaCO₂ during sleep of 10 mm Hg in adults.

K complex: An EEG event consisting of a well delineated negative sharp wave immediately followed by a positive component standing out from the background EEG with total duration ≥0.5 seconds, usually maximal in amplitude over the frontal regions.

Low amplitude, mixed frequency activity: An EEG pattern consisting of low amplitude, predominantly 4-7 Hz activity.

Low chin EMG tone: Baseline EMG activity in the chin derivation no higher than in any other sleep stage and usually at the lowest level of the entire recording.

Narrow complex tachycardia: A sustained cardiac rhythm lasting a minimum of 3 consecutive beats with QRS duration of less than 120 msec and a rate of greater than 100 per minute.

Periodic Limb Movements of Sleep: Movements of the limbs during sleep and occurring with a specified frequency, duration, and amplitude.

Rapid eye movements: EOG events consisting conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500 msec.

Reading eye movements: EOG events consisting of trains of conjugate eye movements consisting of a slow phase followed by a rapid phase in the opposite direction as the subject reads.

REM Behavior Disorder: A parasomnia characterized by relative atonia during REM and associated with potentially harmful dream-enacting behaviors.

Respiratory effort related arousal: A sequence of breaths lasting at least 10 seconds which does not meet criteria for an apnea or hypopnea and is characterized by increasing respiratory effort leading to an arousal from sleep.

Rhythmic Movement Disorder: Repetitive, stereotyped and rhythmic motor behaviors that occur predominantly during drowsiness or sleep and involve large muscle groups.

Rhythmic theta activity: An EEG pattern consisting of runs of 6-7 Hz rhythmic theta activity maximal over the frontal or frontocentral regions.

Sawtooth waves: An EEG pattern consisting of trains of sharply contoured or triangular, often serrated, 2-6 Hz waves maximal in amplitude over the central head regions and often, but not always, preceding a burst of rapid eye movements.

Sleep spindle: An EEG event consisting of a train of distinct waves with frequency 11-16 Hz (most commonly 12-14 Hz) with a duration ≥0.5 seconds, usually maximal in amplitude over the central regions.

Slow eye movements: EOG events consisting of conjugate, reasonably regular, sinusoidal eye movements with an initial deflection usually lasting <500 msec.

Standard: A recommendation based on level 1 evidence or overwhelming level 2 evidence.

Theta rhythm: An EEG rhythm consisting of 4-8 Hz activity.

Transitory muscle activity: Short irregular bursts of EMG activity usually with duration <0.25 seconds superimposed on low EMG tone. The activity may be seen in the chin or anterior tibial EMG derivations, as well as in EEG or EOG deviations, the latter indicating activity of cranial nerve innervated muscles. The activity is maximal in association with rapid eye movements.

Vertex sharp waves (V waves): An EEG pattern consisting of sharply contoured waves with duration <0.5 seconds maximal over the central region and distinguishable from the background activity.

Wide complex tachycardia: A sustained cardiac rhythm lasting a minimum of 3 consecutive beats with QRS duration of greater than or equal to 120 msec and a rate of greater than 100 per minute.