

The AASM Manual for the Scoring of Sleep and Associated Events

RULES, TERMINOLOGY AND TECHNICAL SPECIFICATIONS

Manual Revisions

1968 – R & K Manual

2007 – AASM Manual – First Edition

2012 – v2.0.0

2013 – v2.0.1

2013 – v2.0.2

2014 – v2.0.3

2014 – v2.1.0

2015 – v2.2.0

2016 – v2.3.0

2017 – v2.4.0 CURRENT

The Morphing Manual

User Guide

FOR POLYSOMNOGRAPHY

User Guide

Appeared in Manual:
2012 – v2.0

Designed to be a GUIDE

1. Technical Aspects of routine PSG
2. Analytic Scoring and Interpretation

User Guide

Appeared in Manual:

2012 – v2.0

2015 – v2.2

- Added an entirely new chapter for HSAT

Organization of the Manual

Chapters

1. 2012 - 11 Original Chapters v2.0
 1. User Guide
 2. Parameters to Be Reported
 3. Technical and Digital Specifications
 4. Visual Rules (Sleep Staging Rules v2.0.1)
 5. Arousals
 6. Cardiac
 7. Movement
 8. Respiratory
 9. Development Process
 10. Procedural Notes
 11. Glossary of Terms

2. 2015 – HSAT inserted as “Chapter 9” v2.2

Parameters to be Reported

FOR POLYSOMNOGRAPHY



Parameters to Be Reported

✓ Adult & Pediatric

Appeared in Manual:
2012 – v2.0
▪ No Changes

A. General Parameters

Reporting Parameters Recommended

1. General Parameters
2. Sleep Scoring Data
3. Arousal Events
4. Cardiac Events
5. Movement Events
6. Respiratory Events
7. Summary Statements

These are items that should be on the final report!

Parameters to Be Reported

✓ Adult & Pediatric

Appeared in Manual:

2012 – v2.0

2014 – v2.0.3

- Added Notes 1 and 2

A. General Parameters

Recording Parameters

1. Recommended vs Optional
 - a. Recommended (MUST)
 - b. Optional (Discretion of Clinician)

2. Virtually Unchanged Since v2.0 in 2012
 - a. 2014 – v2.0.3
 - b. Added Notes 1 and 2 of current manual

Note 1. Using supplemental oxygen may cause an underestimation of respiratory events which should be taken into consideration by the interpreting physician.

Note 2. The criteria used to score a respiratory event as a hypopnea (either rule 1A or 1B) should be specified in the PSG report.

Note 3. Percent time spent below a given threshold of oxygen desaturation may be reported at the discretion of the clinician.

Note 4. If electing to measure the arterial PCO_2 or surrogate during sleep in cases where it is optional to do so, the occurrence/absence of hypoventilation must be included in the PSG report.

Note 5. Reporting the occurrence of Cheyne-Stokes breathing in the PSG report is required only if central apneas and/or central hypopneas are present.

Technical & Digital Specifications

FOR POLYSOMNOGRAPHY

Technical & Digital Specifications

✓ Adult & Pediatric

Appeared in Manual:
2012 – v2.0
▪ No Changes

A. Technical & Digital Specifications

Technical and Digital Specifications Recommended

1. Digital Specifications for Routine PSG
 1. Electrode Impedances (5000 Ohms)
 2. Minimum Digital Resolution (12 bits per sample)
 3. Sampling Rates
 4. Filter Settings
2. PSG Recording Features
3. PSG Display and Display Manipulation Features
4. Perform Digital Analyses of PSG

3. Sampling Rates

	Desirable	Minimal	
EEG ^{N3,N4}	500 Hz	200 Hz	RECOMMENDED
EOG ^{N5}	500 Hz	200 Hz	RECOMMENDED
EMG ^{N6}	500 Hz	200 Hz	RECOMMENDED
ECG ^{N7}	500 Hz	200 Hz	RECOMMENDED
Airflow	100 Hz	25 Hz	RECOMMENDED
Oximetry, Transcutaneous PCO ₂ ^{N8}	25 Hz	10 Hz	RECOMMENDED
Nasal Pressure, End-Tidal PCO ₂ , PAP Device Flow ^{N9}	100 Hz	25 Hz	RECOMMENDED
Esophageal Pressure	100 Hz	25 Hz	RECOMMENDED
Body Position ^{N10}	1 Hz	1 Hz	RECOMMENDED
Snoring Sounds ^{N11}	500 Hz	200 Hz	RECOMMENDED
Rib Cage and Abdominal Movements ^{N12}	100 Hz	25 Hz	RECOMMENDED

4. Routinely Recorded Filter Settings

	Low-Frequency Filter	High-Frequency Filter	
EEG ^{N4,N13}	0.3 Hz	35 Hz	RECOMMENDED
EOG ^{N13}	0.3 Hz	35 Hz	RECOMMENDED
EMG ^{N6}	10 Hz	100 Hz	RECOMMENDED
ECG ^{N14}	0.3 Hz	70 Hz	RECOMMENDED
Oronasal Thermal Flow, Thoracoabdominal Belt Signals	0.1 Hz	15 Hz	RECOMMENDED
Nasal Pressure	Direct current (DC) or ≤ 0.03 Hz	100 Hz	RECOMMENDED
PAP Device Flow	DC	DC	RECOMMENDED
Snoring	10 Hz	100 Hz	RECOMMENDED

- Note 1. In the absence of clear preferences, use similar settings among leads to simplify technical implementation.
- Note 2. This applies to measured EEG and EOG electrode impedance. Electrode impedances should be rechecked during a recording when any pattern that might be artifactual appears.
- Note 3. For EEG, 500 Hz sampling rate could improve resolution of spikes in the EEG and better maintain details of the waveform.
- Note 4. 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.
- Note 5. 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.
- Note 6. 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 interpreted.
- Note 7. For ECG, 500 Hz sampling rate 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 common PSG issue. Higher frequencies may be required for complex waveform analysis and research applications.
- Note 8. For oximetry, 25 Hz sampling is desirable to assist with artifact evaluation.

- Note 9. For nasal pressure transducer technology (especially with settings which identify snoring occurring on top of the airflow waveform), this higher frequency may be of benefit for better definition of flattening, plateauing, and/or fluttering in the airflow waveform.
- Note 10. The body position channel is exempt from the digital resolution standard. However, the recommended sampling rate of 1 Hz remains in effect.
- Note 11. For snoring sound, 500 Hz sampling rate 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.
- Note 12. For rib cage and abdominal movements using inductance plethysmography, cardiogenic oscillations can be better seen and may result in better artifact assessment at a higher sampling rate.
- Note 13. To accommodate older equipment, filter settings in the range of 30–35 Hz may be used to comply with the recommendations of 35 Hz. This applies most specifically in the context of EEG and EOG high filter settings.
- Note 14. For ECG, low-frequency settings and wide bandwidth minimizes distortion in a 12 lead ECG; however in PSG recording with 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 a low-frequency filter 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. Artifact is less likely at these settings when standard ECG leads are used for cardiac monitoring.

Technical & Digital Specifications

✓ Adult & Pediatric

Appeared in Manual:

2012 – v2.0

2017 – v2.4

- Entire section for calibration and system response

A. Technical & Digital Specifications

Technical and Digital Specifications Recommended

1. Virtually Unchanged Since v2.0 in 2012
2. 2017 – v2.4
 - a. Entire section added for Calibration and System Response
 - b. Established a Standardization for “BioCals”
3. Notable Updates
 - a. Confirm polarity of respiratory flow
 - b. Deep breath and Exhale slowly for 10 seconds
 - c. Upper extremities
 - d. Confirm impedance and perform BioCals at end of study

- Note 1. Perform physiological calibrations for all patients to the extent that the patient is able to cooperate and complete the requested maneuvers.
- Note 2. Document all calibrations. Verify that the signal appropriately responds to the requested patient maneuvers. Repeat calibrations as needed to document a working signal for all recording parameters.
- Note 3. Measured EEG, EOG and EMG channel impedances should be 5 K Ω or less and relatively equal. Limb EMG impedances of 10 K Ω or less are acceptable, but impedances of 5 K Ω or less are preferred. Recheck impedances during the recording when any pattern that might be artifact appears.
- Note 4. Check EEG channels for blocking, 60 Hz, EKG, and sweat or respiratory artifact and make any necessary adjustments to assure a readable EEG recording.
- Note 5. Adjust chin EMG to an adequate sensitivity while patient is awake. In an awake relaxed patient the chin EMG signal should be visible (at least 1–2 mm amplitude). During chewing or teeth gritting maneuvers the chin EMG signal should be at least double the size of the baseline signal.
- Note 6. Check the integrity of the snore microphone or sensor by asking the patient to simulate a snore and hum. Adjust as necessary to provide a clear signal with activity. Activity should be negligible with quiet breathing.
- Note 7. Adjust all respiratory channels to provide a large clean signal with each respiration. Observe and document the signal direction during inhalation and exhalation. Airflow and effort and signals should be in phase with respect to each other. Adjust belt position to attain a readable signal on all airflow and effort channels. Assure that airflow and effort signals respond appropriately to a 10 second breath hold.
- Note 8. Adjust limb EMG signal to reflect a low background; check signal with bilateral limb movements to verify a noticeable deflection with movement.
- Note 9. If recording the flexor digitorum superficialis, the patient should flex the fingers at the base (avoid bending at the distal two joints). If recording the extensor digitorum communis, the patient should extend their fingers back without moving their wrist.
- Note 10. Compare heart rate (HR) to EKG signal (heart rate is collected from pulse oximetry) to assure HR accuracy.
- Note 11. Repeat the impedance check and physiological calibrations after lights on in the morning.

PSG Recording Features

TECHNICAL & DIGITAL SPECIFICATIONS

B. PSG **Recording 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	RECOMMENDED
2. A separate 50/60 Hz filter control for each channel	RECOMMENDED
3. The capability of selecting sampling rates for each channel	RECOMMENDED
4. A method of measuring actual individual electrode impedance against a reference (the latter may be the sum of all other applied electrodes)	RECOMMENDED
5. The capability of retaining and viewing the data in the exact manner in which it was <u>recorded</u> by the attending technologist (i.e., retain and display all derivation changes, sensitivity adjustments, filter settings, temporal resolution)	RECOMMENDED
6. The capability of retaining and viewing the data in the exact manner it appeared when it was <u>scored by the scoring technologist</u> (i.e., retain and display all derivation changes, sensitivity adjustments, filter settings, temporal resolution)	RECOMMENDED
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	RECOMMENDED
8. An electrode selector process with the flexibility for choosing and/or changing electrode input signal derivations without relying on a common reference electrode	RECOMMENDED

C. Use Systems with the Following **PSG Display and Display Manipulation** Features

1. The display for scoring and review of sleep study data must meet or exceed the following criteria: <u>15 inch screen size, 1,600 pixels horizontal and 1,050 pixels vertical</u>	RECOMMENDED
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	RECOMMENDED
3. Ability to view a screen on a time scale ranging from the entire night to windows as small as 5 seconds	RECOMMENDED
4. Recorded video data must be synchronized with PSG data and have an accuracy of at least one video frame per second	RECOMMENDED
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. Perform the Following **Digital Analyses of PSG**

1. Ability to display whether sleep stage <u>scoring was performed visually or computed</u> by the system	RECOMMENDED
2. Ability to turn off and on, as demanded, highlighting of EEG patterns used to make sleep stage decisions (for example sleep spindle, K complex, alpha activity)	OPTIONAL
3. Ability to turn off and on, as demanded, highlighting of patterns identifying respiratory events (for example apneas, hypopneas, desaturations)	OPTIONAL
4. Ability to turn off and on, as demanded, highlighting of patterns identifying identifying the movement analysis (for example PLMs)	OPTIONAL

Technical Specifications

SLEEP STAGING RULES FOR ADULTS

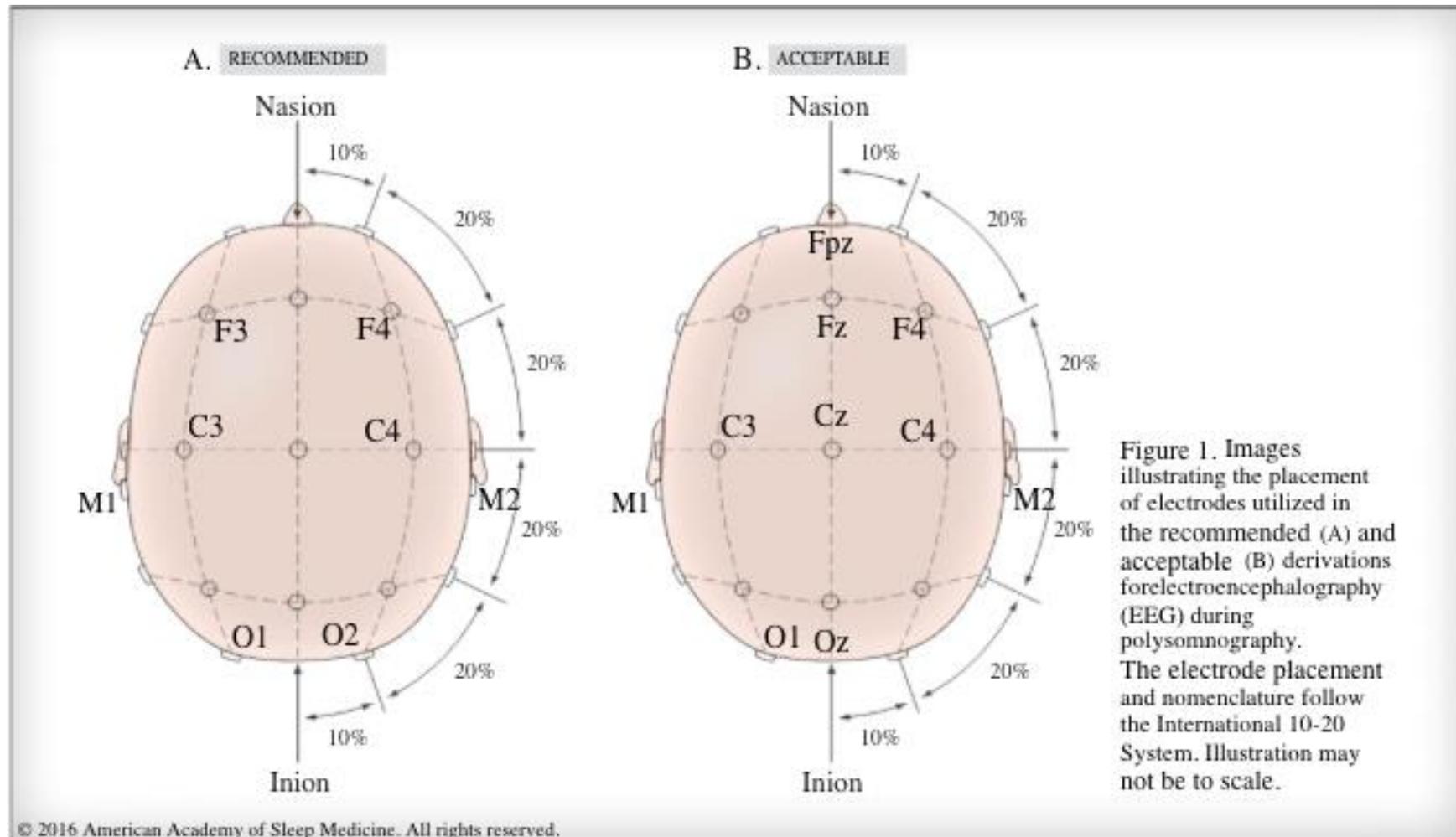
Sleep Staging Rules – Part 1

✓ Scoring for Adults

Appeared in Manual:
2012 – v2.0.0

A. Technical Specifications for EEG

1. Recommended EEG Derivations
 - a. F4-M1
 - b. C4-M1
 - c. O2-M1
 - d. Backups: F3, C3, O1 and M2
2. Acceptable EEG Derivations
 - a. Fz-Cz
 - b. Cz-Oz
 - c. C4-M1
 - d. Backups: Fpz, C3, O1 and M2
3. EEG Electrode Position
 - a. 10-20 System



Technical Specifications for EEG: Notes

Note 1. At a minimum, frontal, central, and occipital derivations (3 EEG channels) are required to stage sleep.

Note 2. M1 and M2 refer to the left and right mastoid processes. M1 is the standard reference electrode for recording EEG. If M1 fails during the recording, backup electrodes should be used and referenced to M2.

Note 3. Fz-Cz is not appropriate for measuring the amplitude of frontal activity for determination of slow wave activity. When using the **acceptable** EEG derivations and the **acceptable** EOG derivations (Figure 2), the **E1-Fpz** derivation should be used to measure frontal slow wave amplitude. Used in this way, Fpz will be the active electrode recording frontal activity and E1 the reference electrode in a referential derivation. When using the **acceptable** EEG derivations and the **recommended** EOG derivations, EEG amplitude to determine slow wave activity should be measured using the **C4-M1** derivation (C3-M2 if either C4 or M1 electrodes malfunction). When using the **recommended** EEG derivations and **recommended** EOG derivations, the EEG amplitude is measured using the derivation **F4-M1**.

Sleep Staging Rules – Part 1

✓ Scoring for Adults

Appeared in Manual:

2012 – v2.0.0

2013 – v2.0.1

- Added Note #2

2017 – v2.4

- Added the lateral to the Recommended Derivation

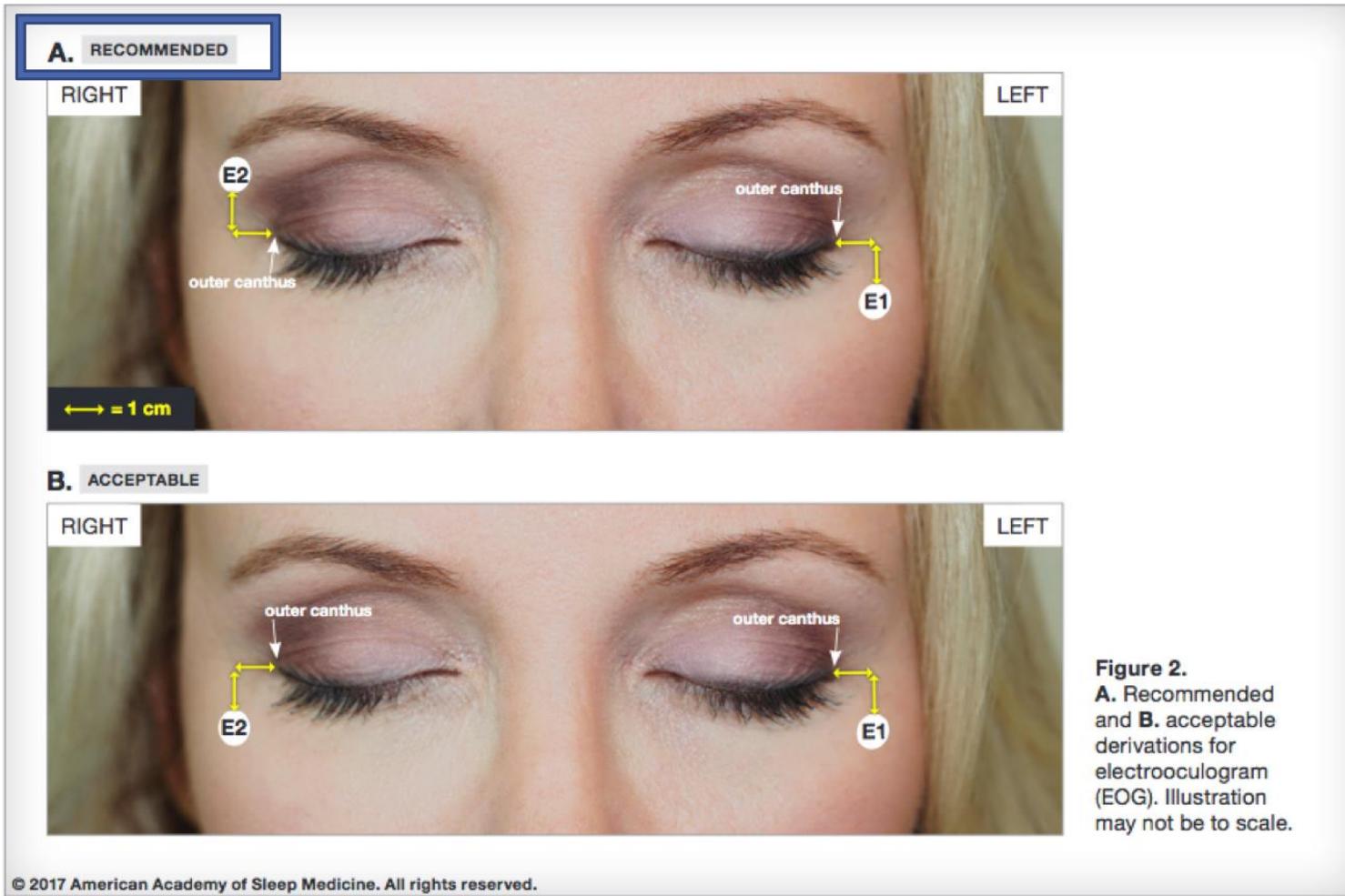
B. Technical Specifications for EOG

1. Recommended EOG Derivations & Placement

- a. E1-M2
- b. E2-M2
- c. E1 is placed 1cm below / 1cm lateral left outer canthus
- d. E2 is placed 1cm above / 1 cm lateral right outer canthus

2. Acceptable EOG Derivations & Placement

- a. E1-Fpz
- b. E2-Fpz
- c. E1 is placed 1cm below / 1cm lateral of left outer canthus
- d. E2 is placed 1cm above / 1 cm lateral of right outer canthus



Note:
Conjugate = Out of Phase

Note:
Directional Eye Movements

Vertical = In-Phase
Horizontal – Out of Phase

Technical Specifications for EOG: Notes

Note 1. When using the recommended EOG derivations, if the M2 reference electrode fails, E1 and E2 should be referenced to M1.

Note 2. When using the recommended electrode derivations, conjugate eye movements result in out-of-phase deflections. The acceptable derivations allow determination of the direction of eye movements, i.e. vertical movements will show in-phase deflections and horizontal eye movements, out-of-phase deflections.

Sleep Staging Rules – Part 1

✓ Scoring for Adults

Appeared in Manual:

2012 – v2.0.0

2013 – v2.0.1

- Added Note #1

2014 – v2.1

- ChinZ, Chin1, Chin,

C. Technical Specifications for EMG

1. Three electrodes to record chin EMG
 - a. One in midline 1cm above the inferior edge of mandible
 - b. One 2cm below the inferior edge of the mandible AND 2cm right of the midline
 - c. One 2cm below the inferior edge of the mandible AND 2cm left of the midline
2. Standard chin EMG Derivation
 - a. Electrode below mandible to electrode above the mandible
 - b. Other inferior electrode used as a backup

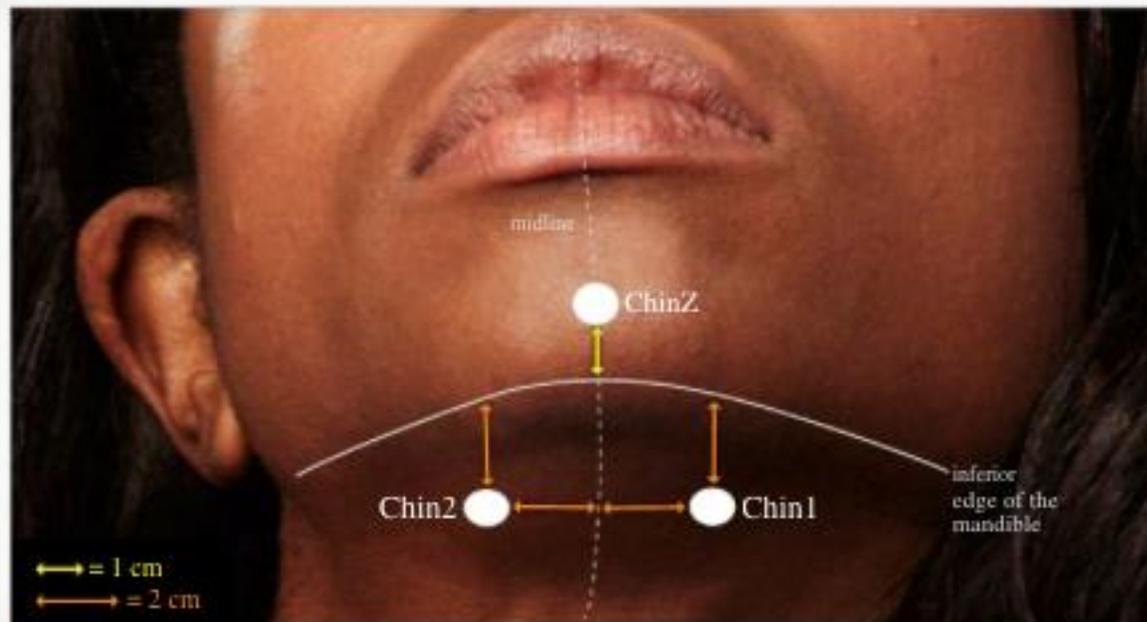


Figure 3. Placement of electrodes on the chin for electromyogram (EMG) recording. Illustration may not be to scale.

Technical Specifications for EMG: Notes

Note 1. If EMG electrode ChinZ (above the mandible) fails during the recording, it should be replaced, if possible.
Otherwise, reference electrodes Chin2 and Chin1 (below the mandible) to each other.

General Staging Rules

SLEEP STAGING RULES FOR ADULTS

Sleep Staging Rules – Part 1

✓ Scoring for Adults

Appeared in Manual:

2012 – v2.0.0

- Original note about how N3 replaces Stage 3 and Stage 4

2014 – v2.1

- Added #3 Frequencies
- Dropped Original note about N3

2016 – v2.3

- Added illustration for majority rule

2017 – v2.4

- Stage R vs REM Sleep

D. General Scoring of Sleep Stages

1. Terminology

- a. Stage W;
- b. Stage N1; Stage N2; Stage N3;
- c. Stage R

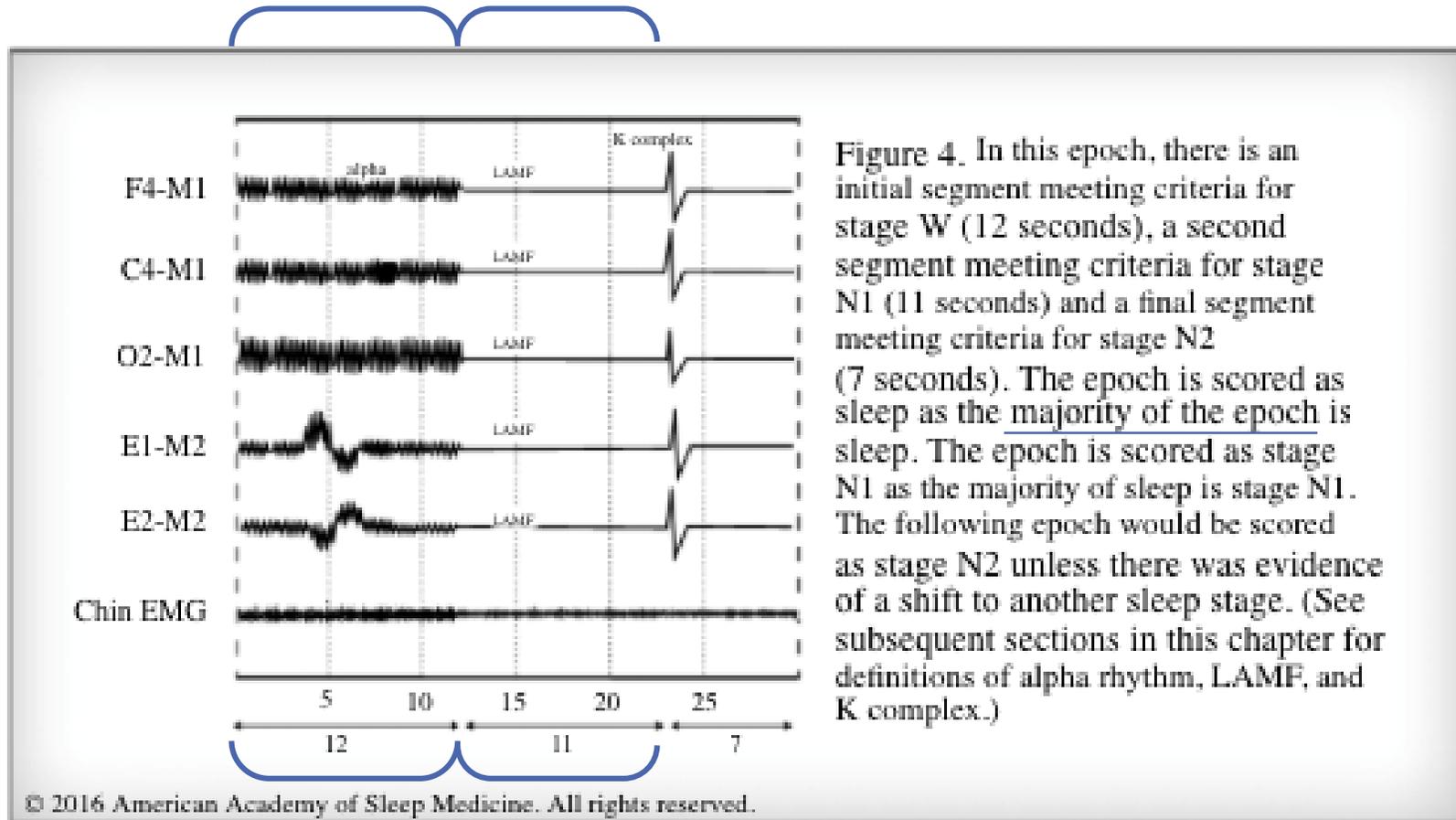
2. Epochs

- a. 30-Seconds; Sequential from start of study
- b. If two or more stages coexist, assign stage of greatest portion

3. EEG Frequencies

- a. Slow waves – 0.5-2.0 Hz AND min amplitude 75uV in Frontals
- b. Delta waves are 0-3.99 Hz
- c. Theta waves are 4-7.99 Hz
- d. Alpha waves are 8-13 Hz
- e. Beta waves are greater than 13 Hz

General Approach of Scoring of an EPOCH



Stage W

SLEEP STAGING RULES FOR ADULTS

Sleep Staging Rules – Part 1

✓ Scoring for Adults

Appeared in Manual:

2012 – v2.0.0

2014 – v2.1

- And / Or of 2a and 2b
- Added illustration
- Conjugate replaced with Rapid Eye Movements

2016 – v2.3

- Added illustration for majority rule

E. Scoring Stage W

1. Definitions

1. Alpha Rhythm (posterior dominant rhythm); occipital region with eye closure, attenuating with eye opening
2. Eye Blinks - vertical eye movements at 0.5-2 Hz
3. Reading eye movements – slow phase followed by rapid phase
4. Rapid eye movements (REM) – irregular; lasting <500 msec
5. Slow eye movements (SEM) – more regular; lasting >500 msec

2. Scoring W

- a) More than 50% of epoch is Alpha (PDR) in occipital region
- b) And /OR any of the following
 1. Eye blinks (0.5-2.0 Hz)
 2. Rapid eye movements with normal /high chin muscle tone
 3. Reading eye movements

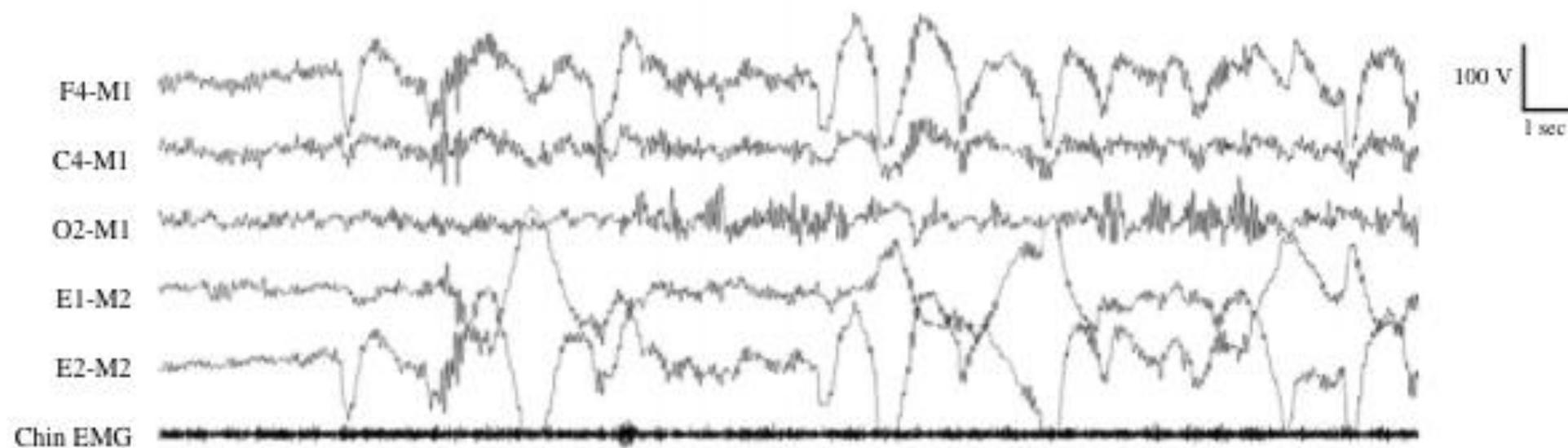


Figure 5. An epoch of stage W with both alpha rhythm (posterior dominant rhythm) and REMs. Note the EMG activity in the chin channel.

Scoring Wake: Notes

Note	Comments
EEG	Stage W represents waking state, from full alertness to early stages of drowsiness. Markers of drowsiness may be present during Stage W and may persist into Stage N1
EEG	Majority will show alpha rhythm (PDR) with eyes closed; 10% do not generate alpha; another 10% show limited alpha with eyes closed
EOG	EOG demonstrates rapid eye blinks; earliest sign of drowsiness is absence of eye blinks; SEM will develop with drowsiness
cEMG	Chin EMG is variable amplitude but usually higher than during sleep stages
	Score <u>time away from recording equipment as Wake</u> ; any sleep during this time not considered significant

Stage N1

SLEEP STAGING RULES FOR ADULTS

Sleep Staging Rules – Part 1

✓ Scoring for Adults

Appeared in Manual:

2012 – v2.0.0

2014 – v2.0.3

- Note 5 added about pathological Theta

2014 – v2.1

- Added illustration

F. Scoring Stage N1

1. Definitions

- a. Slow eye movements (SEM) – more regular; lasting >500 msec
- b. Low-amplitude, mixed frequency (LAMF) – 4-7 Hz (theta)
- c. Vertex Sharpe waves (V waves) - 0.5 sec in Central region
- d. Sleep Onset – first epoch of any stage other than W, usual N1

Sleep Staging Rules – Part 1

✓ Scoring for Adults

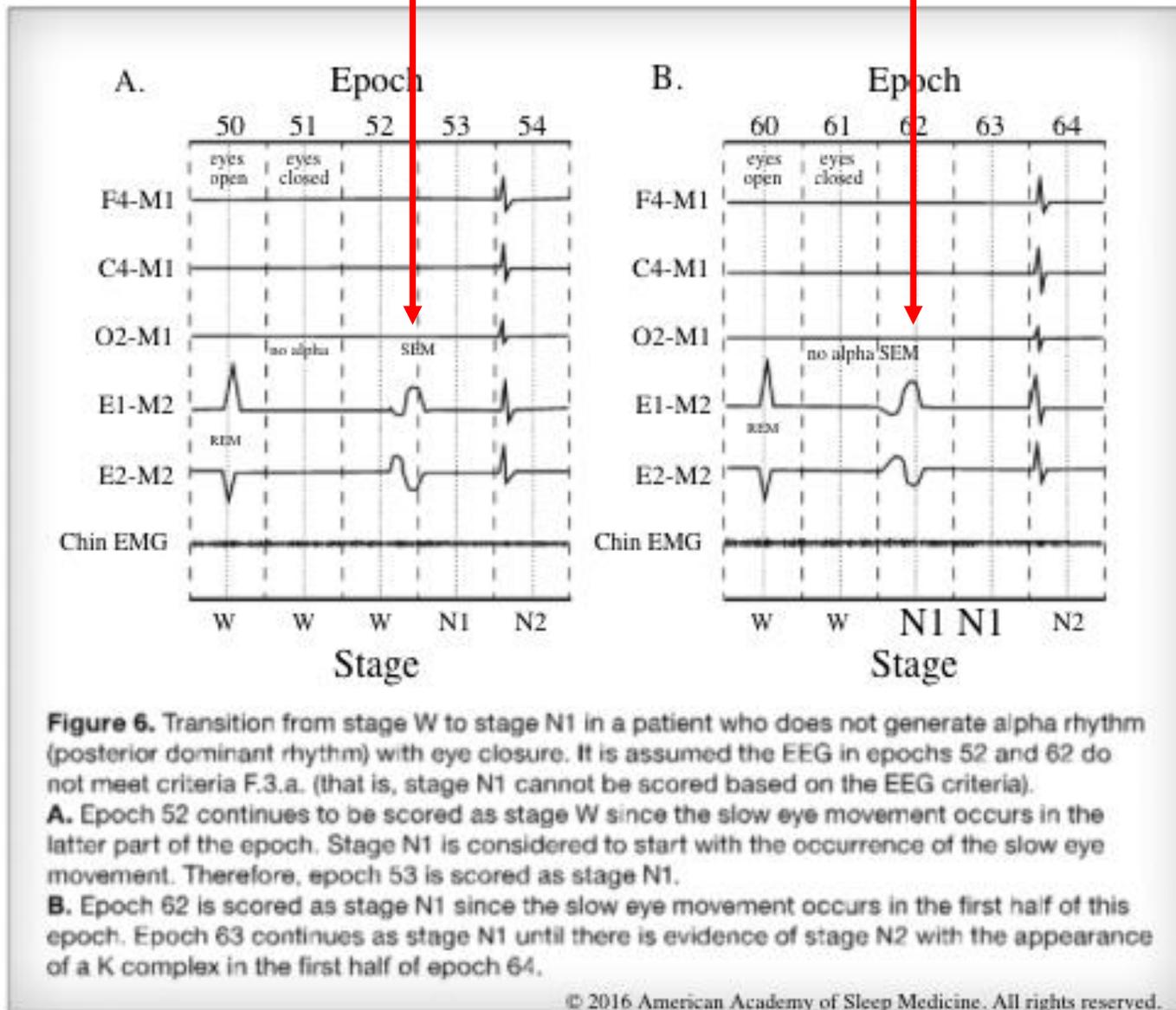
Appeared in Manual:
2014 – v2.1

- Added illustration
- Clarified Majority and Does Not Meet another rule criteria
- Added Arousal rules for N2 and Stage R
- Added “Continue” rule

F. Scoring Stage N1

Scoring Stage N1

1. Scoring N1
 - A. If Alpha (PDR) present,
 1. when attenuated by 50% of LAMF
 - B. If No Alpha present,
 1. LAMF and when slows by 1 Hz from W, V waves, SEM
 - C. If majority of epoch meets criteria and absence of evidence of any other stage of sleep
 - D. Continue N1 until evidence for another stage of sleep
 - E. When Arousal in N2, score N1 if EEG LAMF without K/Spindles or evidence for another stage of sleep
 - F. When Arousal in REM, score N1 if LAMF has no alpha but SEM **even if chin levels remains** at Stage R level
 - G. Continue N1 until evidence for another stage of sleep



Scoring with
“No Alpha”

Use SEMs in “first
Half” of EPOCH

Scoring N1: Notes

Note	Comments
EEG	Vertex sharp waves may be present but are <u>not</u> required for scoring N1
EOG	Will often show SEM but <u>not required</u> for scoring N1
cEMG	Chin amplitude is variable but often lower than stage W
	A SEM commence before attenuation of alpha, sleep latency may be slightly shorter for some individuals who do not generate alpha rhythm
	Theta waveforms from pathological origin, like epilepsy, should not be considered for determining stage N1; it must include more than 1 Hz slowing from background activity during stage W

Stage N2

SLEEP STAGING RULES FOR ADULTS

Sleep Staging Rules – Part 1

✓ Rules for Adults

Appeared in Manual:

2012 – v2.0.0

2014 – v2.1

- Inserted Note 5, to clarify rules when there are Ks/Spindles as well as R.E.M. activity

2017 – v2.4

- Removed Note 4 regarding the use of Spindle in central or frontal regions

G. Scoring Stage 2

1. Definitions

- a. K complex – well-delineated, negative sharp wave immediately followed by a positive component standing out from the background EEG; duration >0.5 secs; maximal in the frontal region
- a. Arousal – only associated if concurrent with the K complex or commence no more than 1 sec after termination of K complex
- b. Sleep Spindle – train of distinct sinusoidal waves 11-16 Hz and duration >0.5 secs; maximal in the Central region

Scoring N2: Notes

Note	Comments
1	Definite stage N2 if K complex or sleep spindle observed (“last half or first half” rule). <u>If conflict between N2 and R, R rule takes precedence</u>
2	<u>Continue N1 for epochs with arousal-associated K complex</u> unless they contain sleep spindles or K complexes NOT associated with an arousals
3	For scoring N2, arousals are defined according to arousal rule
4	Although spindles more common in Central region, can use if seen in Frontal region
5	<u>K complex can be seen in stage R</u> and there are scenarios to keep as stage R or change to score N2. Depends on chin tone changes as well as if REM outside of back-to-back K complexes
6	Usually shows no eye movements but SEM may persist in some individuals
7	Chin EMG is of variable amplitude, but usually lower than stage W and may be as low as stage R

Sleep Staging Rules – Part 1

✓ Rules for Adults

Appeared in Manual:

2012 – v2.0.0

2014 – v2.1

- Added arousal rule and illustration to support

G. Scoring Stage 2

1. Scoring N2

- a. If does not meet N3 criteria
- b. BEGIN staging N2;**
 - i. If last half of previous epoch or first half of current epoch has one or more K complex or sleep spindles
- c. CONTINUE stage N2 if:**
 - i. Majority of the epoch meets criteria for N2
 - ii. If same or subsequent epoch has arousal, the segment of the recording preceding the arousal is considered stage N2
 - iii. If epochs have LAMF without K complex or sleep spindles if they are preceded by epochs with either K complex or sleep spindle AND there is no arousal
 - iv. If epochs following N3 (that do not meet N3) if no arousal and does not meet criteria for stage W or stage R

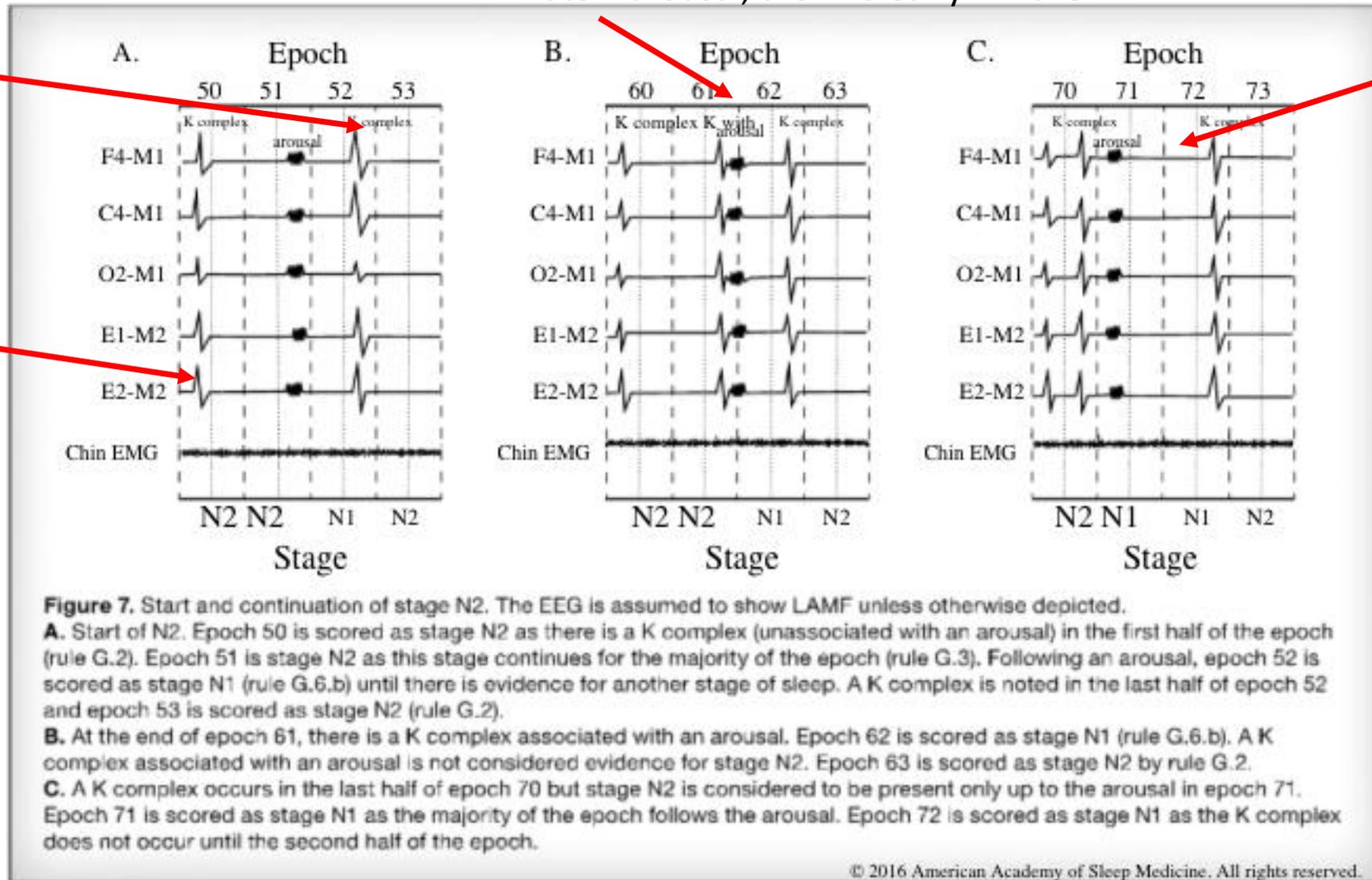
Late K arousal, then no early K make N1

K in last half after arousal makes N1

K in first half make N2

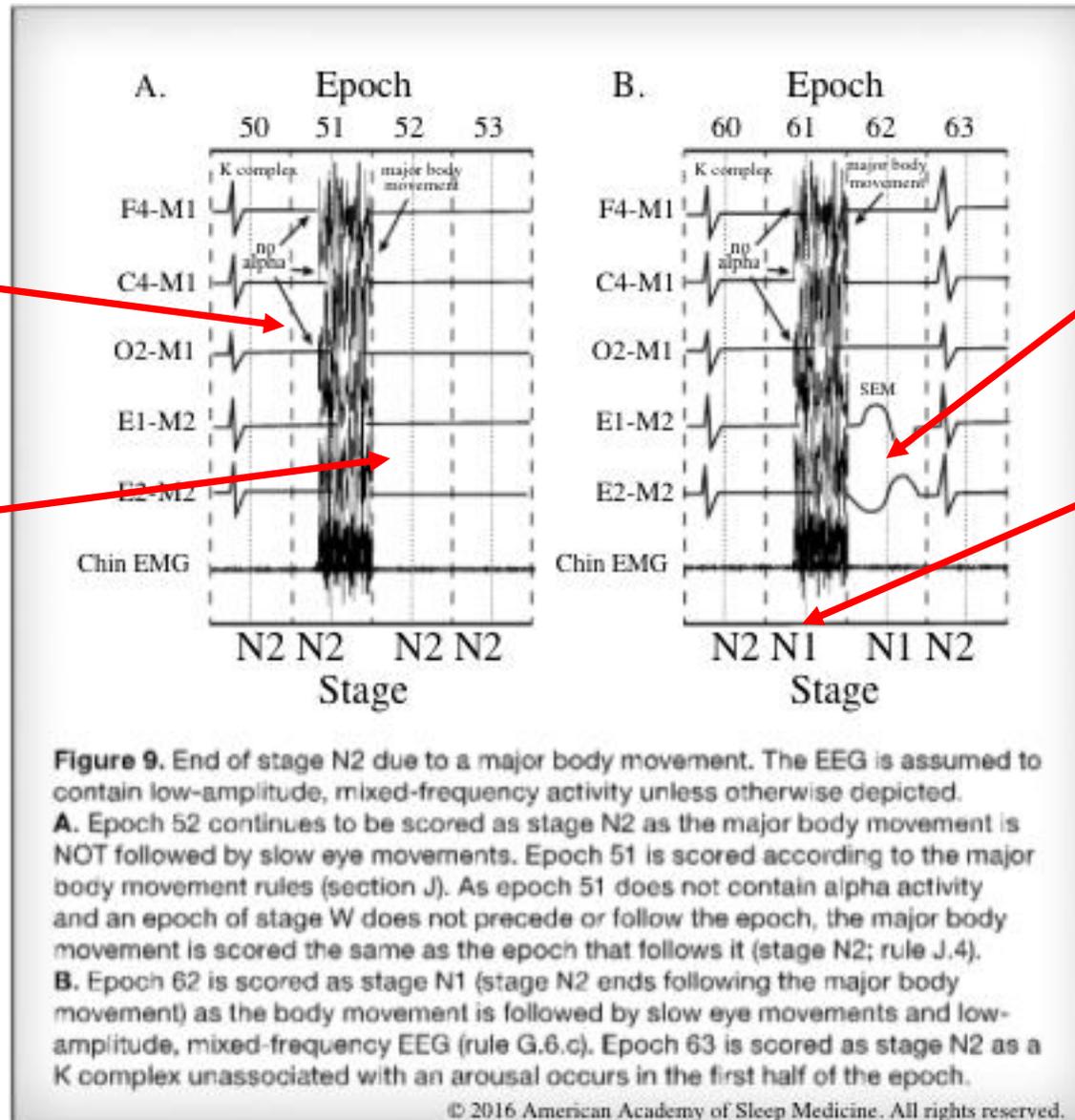
Arousal in 71 With no early K in 72 makes N1

K in first half make N2



51 remains N2 because of no alpha before major body movements

52 remains N2 because of no SEM after major body movement



62 changes to N1 because of SEM after major body movement,

61, therefore, changes to N1 even though no alpha was observed before the major body movement

Sleep Staging Rules – Part 1

✓ Rules for Adults

Appeared in Manual:

2012 – v2.0.0

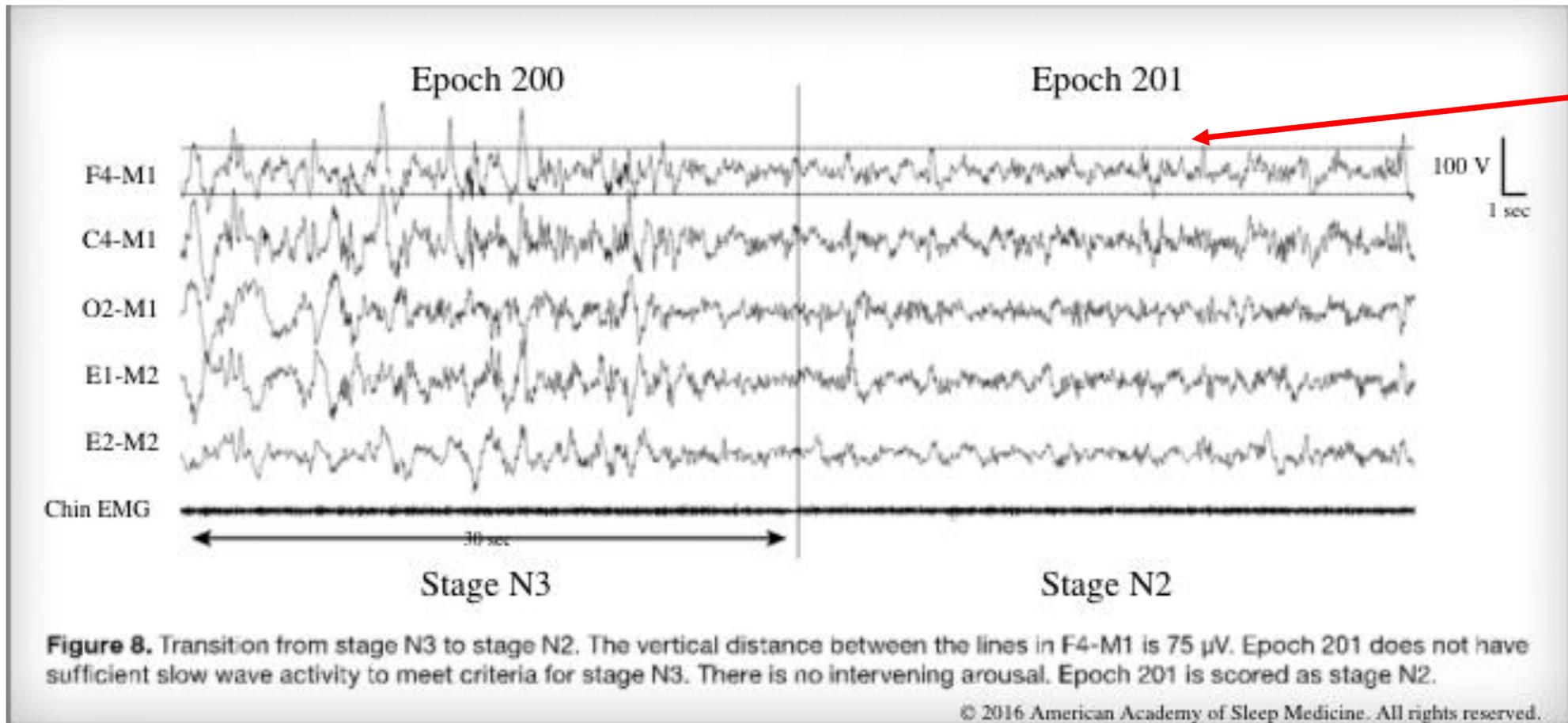
2014 – v2.1

- Added illustration to clarify transition from N3 back to N2
- Clarified “Ending” N2 due to arousal... (2a)

G. Scoring Stage 2

Scoring Stage N2

1. End Scoring N2 when ONE of the following occurs:
 1. Transition to stage W
 2. Arousal followed by LAMF EEG; Score N1 until K complex or sleep spindle observed
 - a. Assumes that Stage R criteria not met
 3. Major body movement followed by SEM and LAMF without the presence of K complex or sleep spindle; Score the following epoch as N1,
 - a. but keep as N2 if no SEM observed
 4. Transition to stage N3
 5. Transition to stage R



Note the amplitude did not remain at 75uVs

Stage N3

SLEEP STAGING RULES FOR ADULTS

Sleep Staging Rules – Part 1

✓ Rules for Adults

Appeared in Manual:

2012 – v2.0.0

2013 – v2.0.1

- Added Note 2 about pathological waves not used for scoring N3

2014 – v2.1.0

- Added Note 1 about N3 replacing old R&K rules for stages 3 and 4

H. Scoring Stage 3

Scoring Stage N3

1. Definitions

1. Slow wave activity...
 1. 0.5 – 2 Hz AND
 2. >75 uV;
 3. Frontal region

2. Scoring N3

1. When >20% of the epoch consists of slow wave activity, irrespective of age

Scoring N3: Notes

Note	Comments
1	N3 represents slow wave sleep and replaces the R&K nomenclature for stage 3 and stage 4 sleep
2	<u>K complexes would be considered slow waves</u> if they meet the definition of slow wave activity
3	<u>Pathological wave forms</u> that meet slow wave activity, such as epileptiform, are not counted as slow wave activity of sleep. Same applies to artifact or non-cerebral origin
4	<u>Sleep spindles may persist</u> during stage N3 sleep
5	Usually shows no eye movements
6	Chin EMG is of variable amplitude, but usually lower than stage N2 and may be as low as stage R

Stage REM

SLEEP STAGING RULES FOR ADULTS

Sleep Staging Rules – Part 1

✓ Rules for Adults

Appeared in Manual:

2012 – v2.0.0 to v2.0.3

- Had the same 6 Notes

2014 – v2.1.0

- Dropped Notes:
 - Definite stage N2
 - No Rules for N1-R transitions
- Added Notes:
 - Scoring with mixture of REM and Ks/SS
 - SEM with and without arousals

I. Scoring Stage R

Scoring Stage R

1. Definitions

1. Rapid eye movements (REM) – irregular; lasting <500 msec
2. Low chin EMG tone – baseline no higher than any other sleep stage and usually lowest level of the entire recording
3. Sawtooth waves – trains of sharply contoured or triangular, often serrated, 2-6 Hz waves, maximal over Central region; may precede a burst of REM
4. Transient muscle activity – short, irregular burst of EMG <0.25 seconds; superimposed on low EMG chin or leg tone
 - a. May also be seen in the EEG and EOG derivations, indicating activity of the cranial nerve innervated (facial/scalp) muscles

Sleep Staging Rules – Part 1

✓ Rules for Adults

Appeared in Manual:

2012 – v2.0.0

2014 – v2.1.0

- Added Concurrent with REMs
- Greater clarification to rules in absence of REMs
- Added many more illustrations to help clarify staging rules

I. Scoring Stage R

Scoring Stage R

1. Scoring R

1. Must include ALL of the following:

- a. LAMF EEG activity without K complexes or sleep spindles
- b. Low chin EMG tone for the majority of the epoch
 - i. concurrent with REMs
- c. REMs at any position within the epoch

2. CONTINUE Score R, in the absences of REMs, if ALL:

- a. LAMF without K complexes or sleep spindles
- b. Chin EMG tone is low, as in definite stage R
- c. No intervening arousal

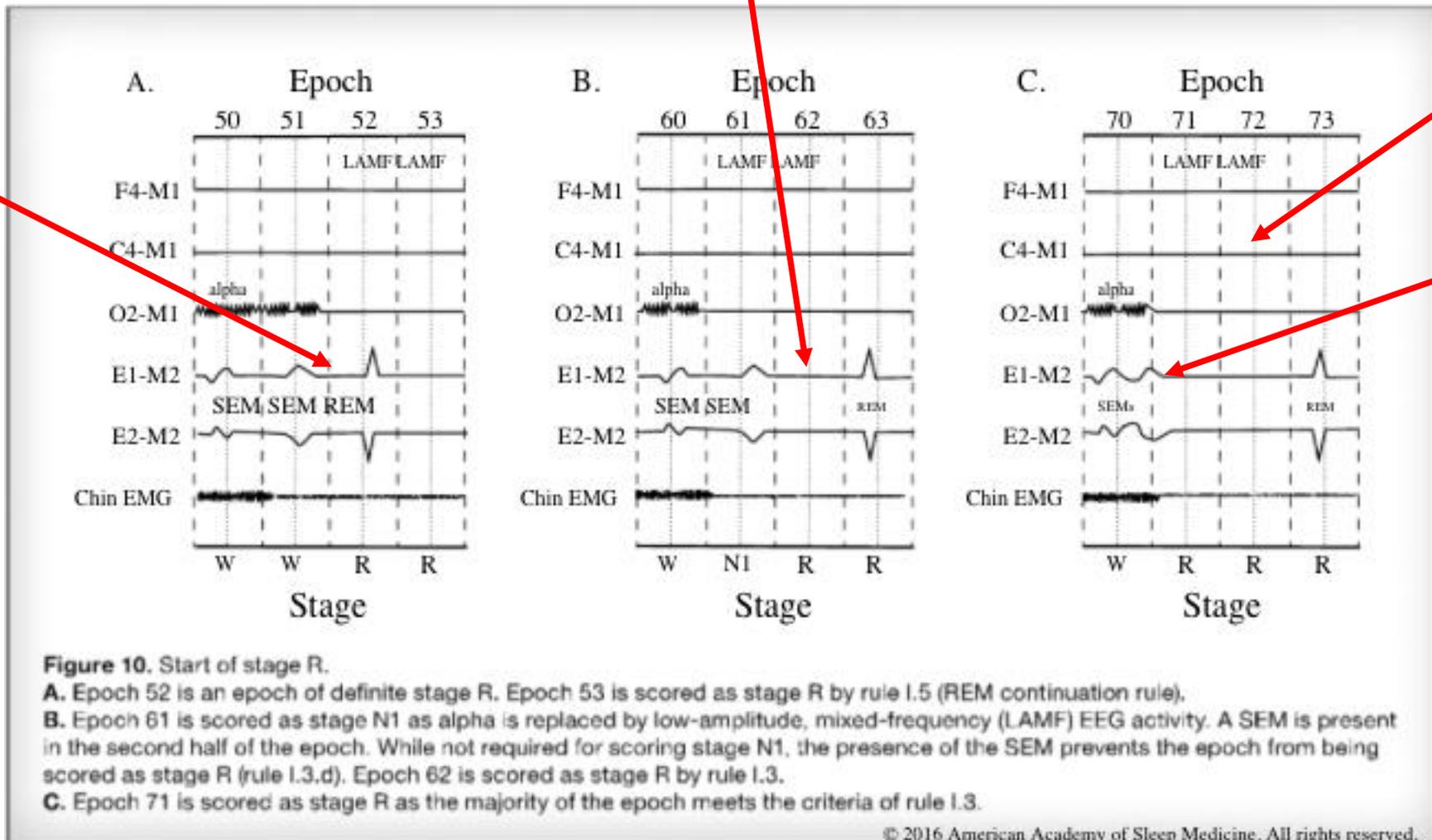
3. Continue R, If majority of an epoch contains a segment that meets R;

1. It takes precedence over stage N2 rules

Once 63 scored a REM, then 62 can be because of “contiguous rule”

Transition to R

- chin drop
- loss of alpha
- rapid eye



Once 73 scored as REM...

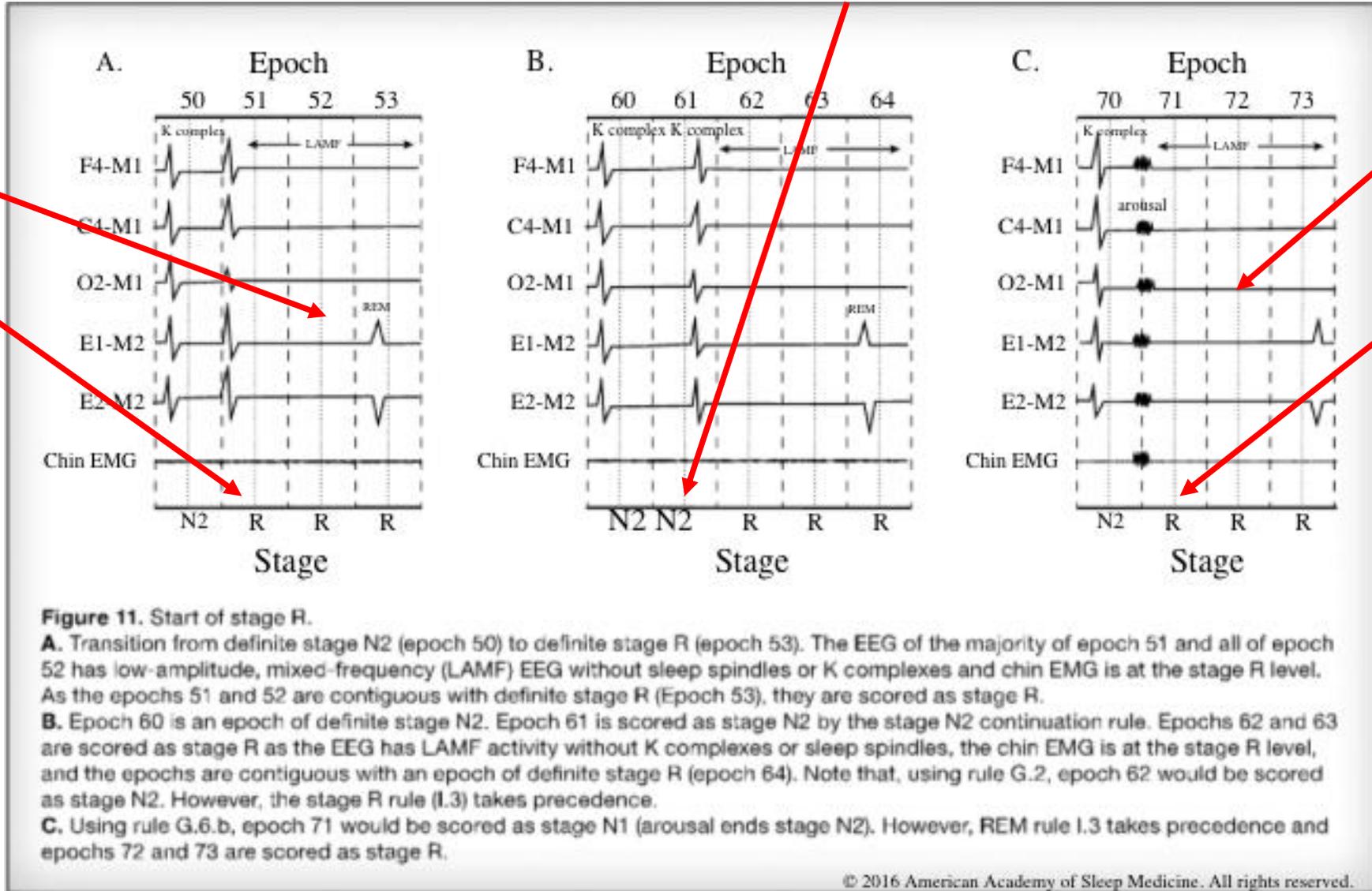
- 72 can be because of “contiguous rule”
- 71 can be because of the “majority rule”

Once 64 scored as REM, then 63 and 62 can be; 61 can not because of "majority rule"

Once 53 scored as REM...

-52 can be because of "contiguous rule"

-51 can be because of the "majority rule"



Once 73 scored as REM...

-72 can be because of "contiguous rule"

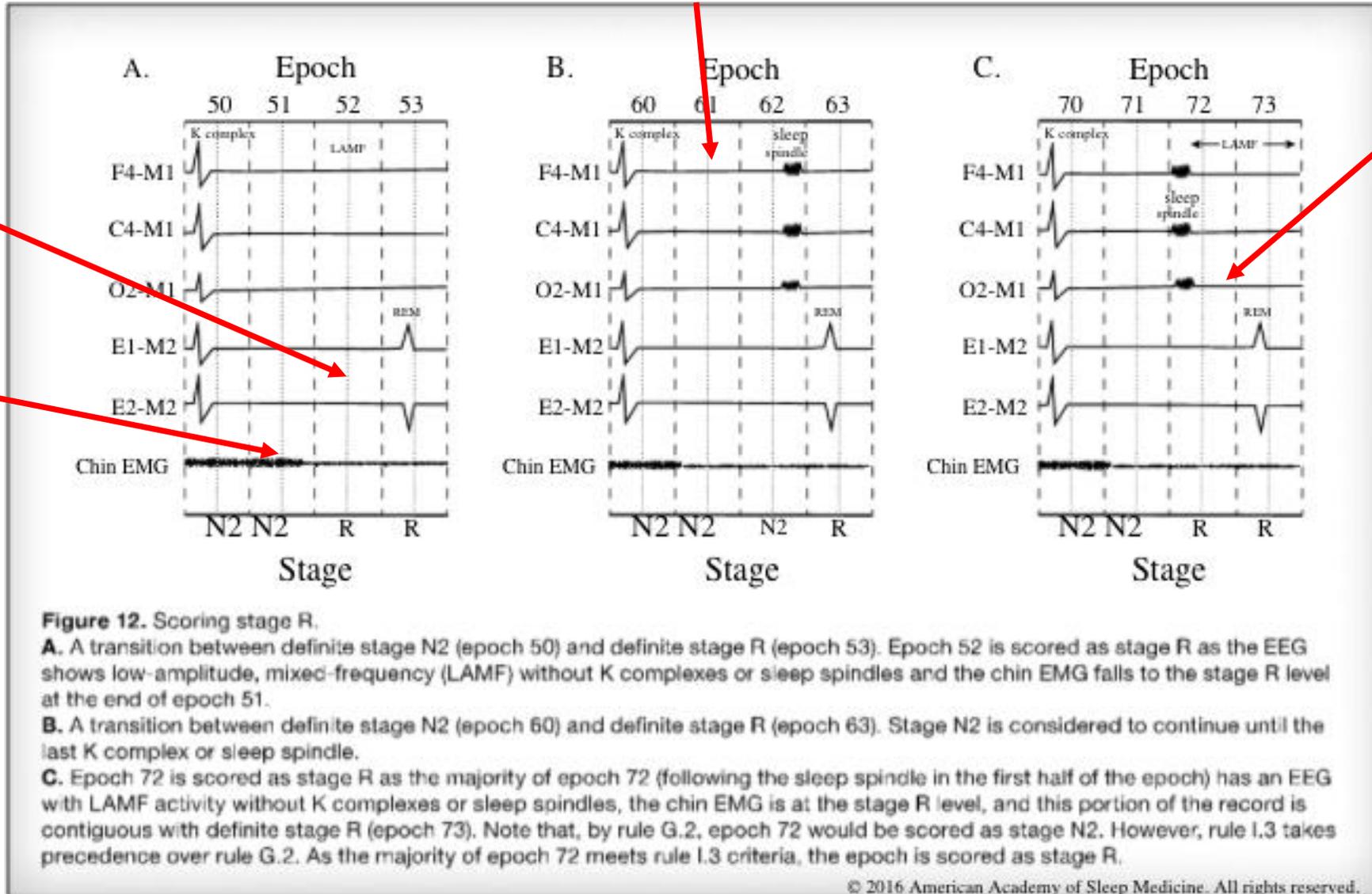
-71 can be because of the "precedence rule", normally be N1 due to arousal

Once 62 scored as N2 due to late spindle, 61 is N2 by “contiguous rule”, even though chin has dropped

Once 53 scored as REM...

-52 can be because of the “contiguous rule”

-51 can NOT be REM because of the chinEMG elevated, stays N2



Once 73 scored as REM...

-72 can be because of “majority rule” since early spindle

-71 stays N2 due to “contiguous rule”; early spindle of next epoch

Sleep Staging Rules – Part 1

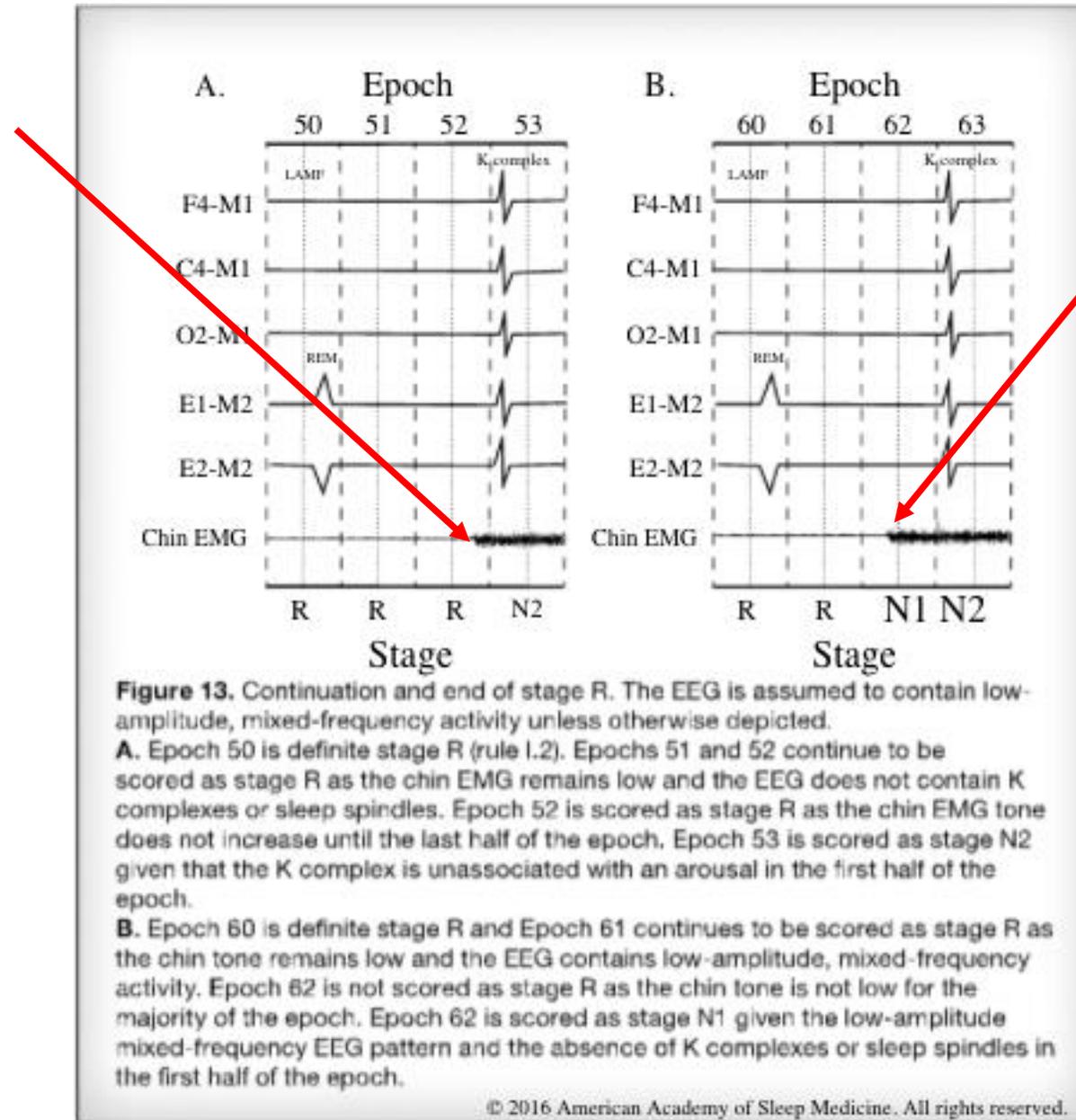
✓ Rules for Adults

I. Scoring Stage R

Scoring Stage R

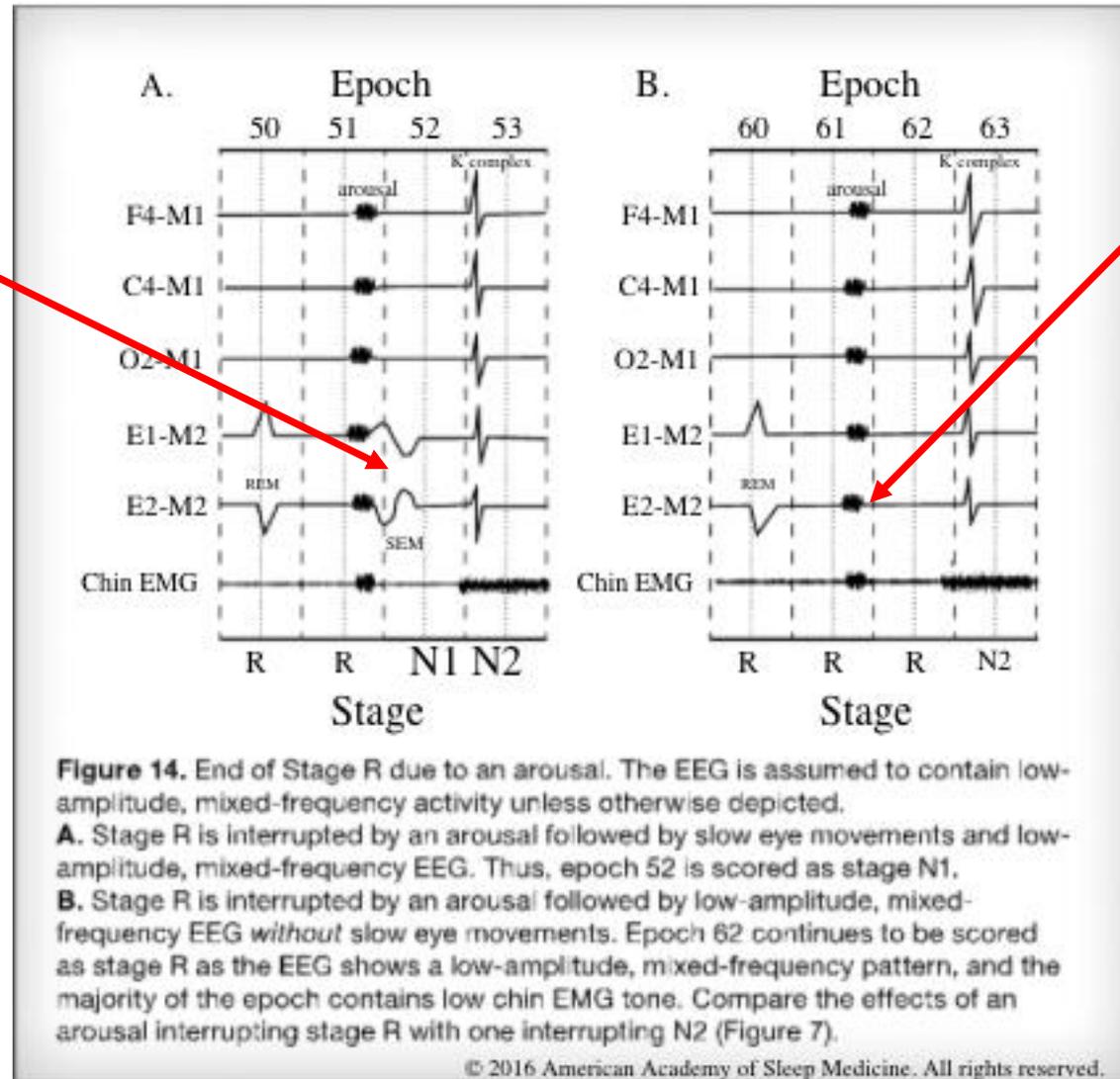
1. END Scoring R when **ONE or MORE** of the following occurs:
 1. Transition to stage W or N3
 2. Increase in chin EMG tone above the level of stage R AND stage N1 criteria is met
 3. Arousal followed by LAMF EEG AND SEM; continue R if no SEMs or increase in chin EMG tone
 4. Major body movement followed by SEM and LAMF without the presence of K complex or sleep spindle; Score the following epoch as N1, but keep as R if no SEMs or increase in chin EMG tone
 5. One or more non-arousal associated K complexes or sleep spindles are present in the first half of the epoch in the ABSENCE of REMs, even if chin EMG tone remains low; Score as N2

52 scored as R due to
late chin increase
-Nothing to make it
N2 is present...



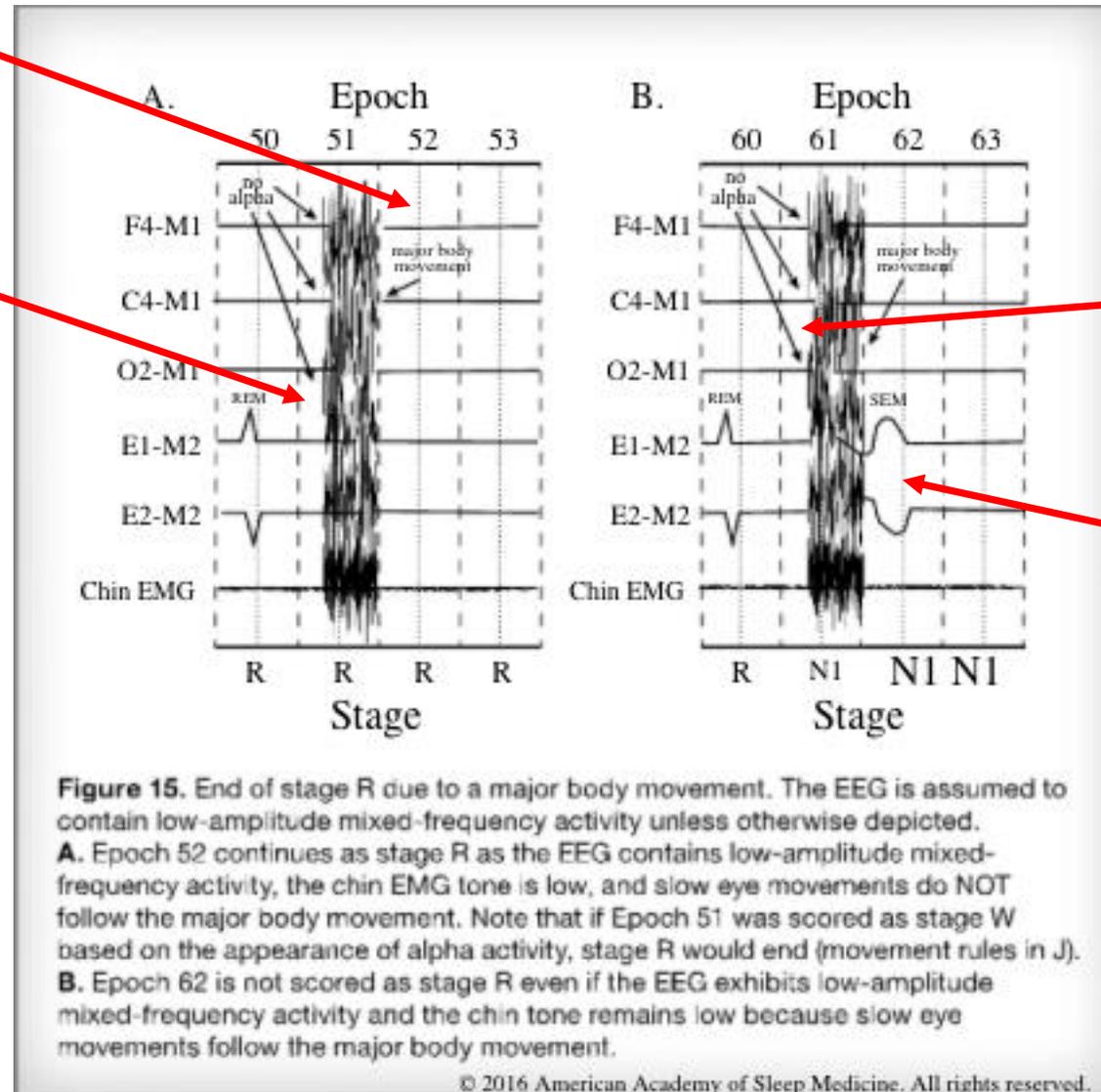
62 scored as N1 due to
early chin increase
-Nothing to make it
N2 is present...

52 scored as N1 due to SEM after arousal -even though chin remained low



62 scored as R due to No SEM after arousal -all other criteria for REM still met

Once 52 scored as R,
then 51 also scored as R
even though majority is
major body movement.
-also since no alpha
before major body
movement, so not W

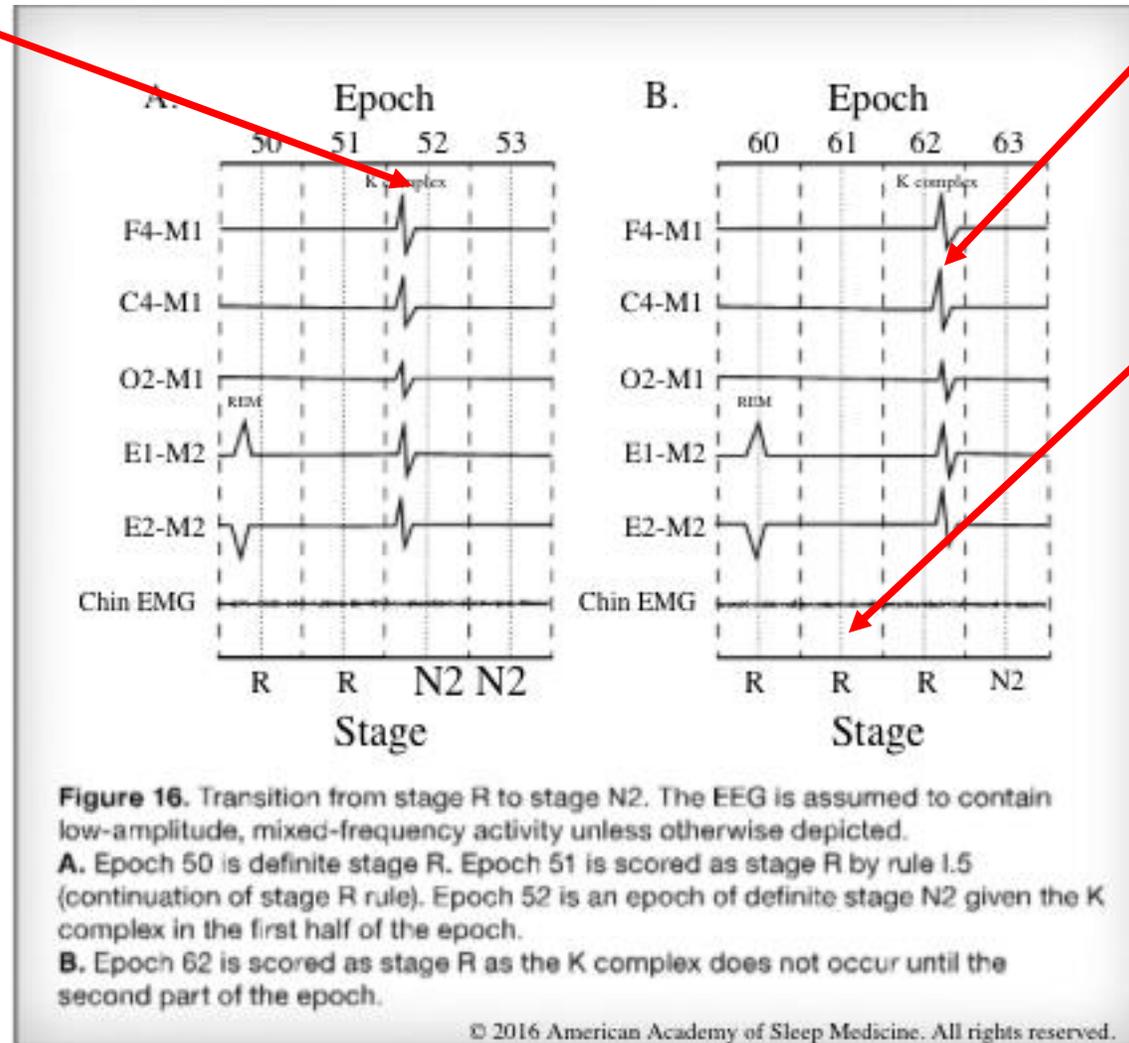


Once 62 scored as N1,
then 61 also scored as
N1 even though
majority is major body
movement.

-also since no alpha
before major body
movement, so not W

-SEM really defined the
stage as N1

Once 52 scored as N2,
and 50 was a definite
stage R, then 51 scored
as R due to
“Continuation of Stage R
Rule”.
-early K in 52 makes N2



62 remains stage R due
to the late K
-61 scored as R due to
“Contiguous Rule”

Sleep Staging Rules – Part 1

✓ Rules for Adults

I. Scoring Stage R

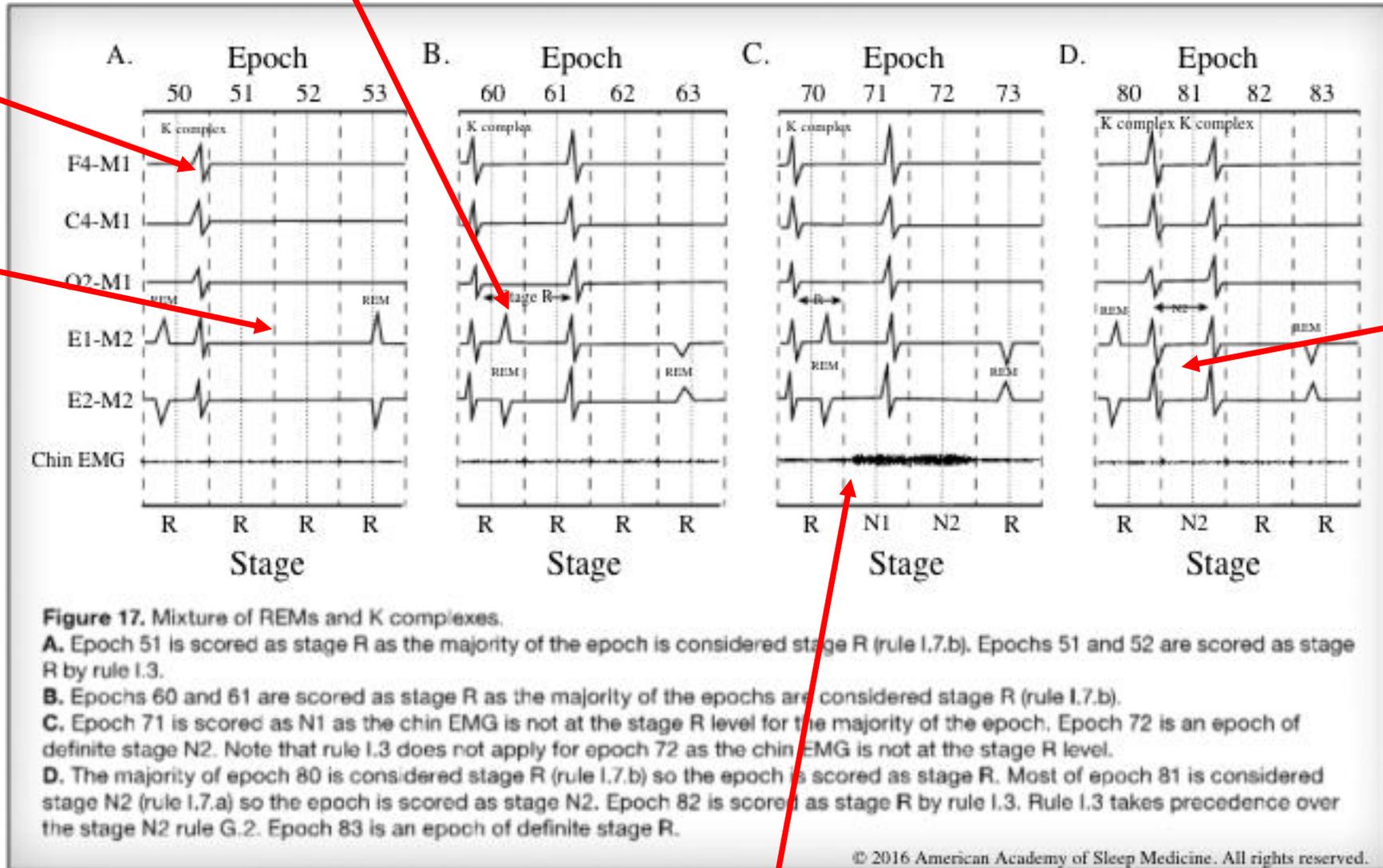
Scoring Stage R

1. Scoring R with low chin EMG and mixture of REMs and sleep spindles and/or K complexes:
 1. Segments between two K complexes, two spindles or a K complex and a spindle without intervening REMs should be scored as stage N2
 2. Segments containing REMs without K complexes or sleep spindles and chin tone at the REM levels are considered to be stage R
 3. If majority of epoch contains a segment considered to be stage N2, it is scored as stage N2.
 4. If majority of epoch contains a segment considered to be stage R, it is scored as stage R.

Early K in 60 and late K in 61; REM “in-between” makes stage R

50 scored as R since late K.

Once 53 scored as R, then 51 & 52 scored as R due to “Continuation of Stage R Rule”.



81 scored as N2 because back to back K's -no REM activity between the Ks

Early & sustained, chin increase in 71 makes N1 due to “Majority Rule”

Scoring R: Notes

Note	Comments
1	Definite stage R includes LAMF, low chin tone and REMs
2	LAMF in R resembles N1; <u>Some individuals have more alpha in R than in N1</u> , alpha frequency is 1-2 Hz slower than during wakefulness
3	Sawtooth waves or transient muscle activity are <u>strongly supportive of stage R sleep</u> and can be helpful when stage is in doubt, but NOT required for scoring stage R
4	There are times to score stage R with low chin tone and the presence of K complexes or sleep spindles
5	<u>SEM can occur during stage R but SEMs following an arousal while LAMF remains suggests a transition to stage N1 even if chin tone remains low</u>
6	Segments with low chin EMG activity and a mixture of REM and sleep spindles and/or K complexes usually occur during the first REM period of the night

Sleep Staging Rules – Part 1

✓ Rules for Adults

Appeared in Manual:
2012 – v2.0.0
No changes....

J. Scoring Epochs with Major Body Movements

Scoring Epochs with Major Body Movements

1. Definitions
 - a. Major body movements – movement or muscle artifact obscuring the EEG for more than half an epoch to the extent that the sleep stage cannot be determined
2. If alpha rhythm is present, even <15 sec, score Wake
3. If no alpha rhythm is discernable, but the epochs before or after is scored as W with major body movements, score as stage W
4. Otherwise, score the epoch as the same stage as the epoch that **follows it**.

Arousals

ADULT & PEDIATRIC RULES

Arousal Rules

✓ Adult & Pediatric

Appeared in Manual:

2012 – v2.0.0

2013 – v2.1.0

- Added Note 4, clarifying 10 secs can carry over from previous epoch

2016 – v2.3.0

- Added Note 5, arousals with transition to wake are BOTH scored

A. Scoring Arousals

Scoring Arousals

1. Abrupt shift of EEG frequency including alpha, theta and/or frequencies above 16 Hz
2. At least 3 seconds long
3. Must have 10 seconds of stable sleep preceding the change
4. During REM requires a concurrent increase in submental EMG for at least 1 second

Arousal Rule: Notes

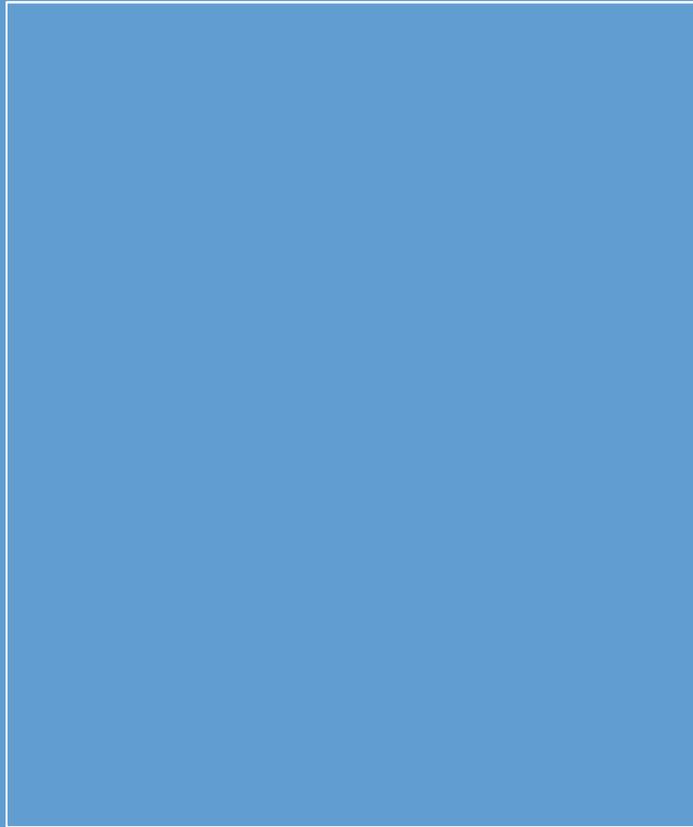
Note	Comments
1	Should use information <u>from central and occipital</u> derivations
2	Scoring can be supported with information from respiratory events and/or other EEG channels; but not ONLY from other channels
3	If criteria for scoring arousal occurs in an awake epoch, <u>then it should be scored</u> so it can be included in the arousal index
4	10 seconds of stable sleep <u>may begin in the preceding epoch</u> , even if that epoch is stage W
5	Arousals can still be scored if it immediately precedes the transition to W. <u>Both are scored.</u>

Cardiac

ADULT & PEDIATRIC RULES

Cardiac Rules

✓ Adult & Pediatric



A. Technical Specification

Cardiac Rules – Technical Specifications

1. Single Modified ECG Lead II and Torso Placement
 - a. “Think Passenger Seatbelt”

Cardiac Technical: Notes

Note	Comments
1	Additional leads may be placed if clinically indicated by practitioner
2	Increasing the image size on display may improve detection of arrhythmias
3	Classically Lead II is derived from electrodes placed on 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 in minimizing artifact

Cardiac - Scoring

ADULT & PEDIATRIC RULES

Cardiac Rules

✓ Adult & Pediatric

Appeared in Manual:
No changes

B. Scoring Cardiac Events

Cardiac Rules – Scoring Events

1. Sinus Tachycardia
 - a. Sustained >90 beats per minute for adults
2. Bradycardia
 - a. Sustained <40 beats per minute for ages 6 through adult
3. Asystole
 - a. Pauses for more than 3 seconds for ages 6 through adult
4. Wide Complex Tachycardia (V-Tach)
 - a. 3 consecutive beats at >100 bpm; QRS duration of >120 msec.
5. Narrow Complex Tachycardia (SVT)
 - a. 3 consecutive beats >100bpm; QRS duration of <120 msec
6. Atrial Fibrillation
 - a. Irregularly irregular ventricular rhythm with...
 - b. Consistent P waves, rapid oscillation; vary in size, shape, timing

Cardiac Scoring: Notes

Note	Comments
ECG	Significant arrhythmias such as a heart block should be reported <u>if quality of single lead is sufficient for accurate scoring</u>
ECG	Ectopic beats should be reported <u>if felt to be clinically significant</u>
ECG	Sinus rates vary by age; <u>faster in younger children</u> as compared to adults.
ECG	<u>Sustained sinus bradycardia or tachycardia is defined by more than 30 seconds of stable rhythm</u> to distinguish it from <u>transient responses</u> , associated sleep disordered breathing events or arousals

Movement – LM & PLM

ADULT & PEDIATRIC RULES



Movement Rules

✓ Adult & Pediatric

Appeared in Manual:

2012 – v2.0.0

- Note with some technical specifications and some scoring rules

2016 – v2.3.0

- Technical Specifications were added in great details

A. Scoring Periodic Limb Movements in Sleep (PLMS)

Technical Specifications

Monitoring Leg Movement (LM)

1. Surface Electrodes
2. Placed longitudinally and symmetrically in middle of anterior tibialis
 - a. 2-3 cm apart, OR
 - b. 1/3 the length of the muscle; if shorter
3. Both legs monitored separately
 - a. Both legs combined into a single channel may result in less detection of LM events
4. Notch filters avoided
5. Impedances <10kOhms; <5kOhms ideal

Original Movement Rules: Notes

Note	Comments
1	Surface electrodes placed longitudinally and symmetrically around middle of muscle; 2-3 cm apart or 1/3 of the length of the anterior tibialis muscle whichever is shorter
2	Both legs should be monitored; <u>separate channels</u> preferred; Upper limbs could be sampled, if preferred
3	<u>60 Hz Notch filters should be avoided</u> ; At least less than <u>10,000 Ohms</u> ; Sensitivity of <u>-100 and +100</u> are preferred
4	Amplitude increase rule <u>based on resting amplitude less than 10uV between positive and negative</u>
5	LM should NOT be scored if it occurs during 0.5 seconds before an apnea, hypopnea RERA or sleep disordered breathing events to 0.5 seconds following the event
6	An arousal and a limb movement that occur in a PLM series should be considered associated if occur <u>simultaneously or within 0.5 seconds, regardless which came first</u>
7	When PLMs occur within an interval of 10 seconds and each with a 3 second arousal, <u>only the first arousal</u> may be scored.



Figure 1. Placement of electrodes on the anterior tibialis muscle for monitoring leg movements. Illustration may not be to scale.

Movement Rules

✓ Adult & Pediatric

A. Scoring Periodic Limb Movements in Sleep (PLMS)

Technical Specifications

Monitoring Upper Extremities

1. Flexor Digitorum Superficialis
 - a. Transient muscle activity in REM Sleep
2. Extensor Digitorum Communis
 - a. Transient muscle activity in REM Sleep

Monitoring Bruxism

1. Masseter Muscle
 - a. Bruxism, if clinically indicated

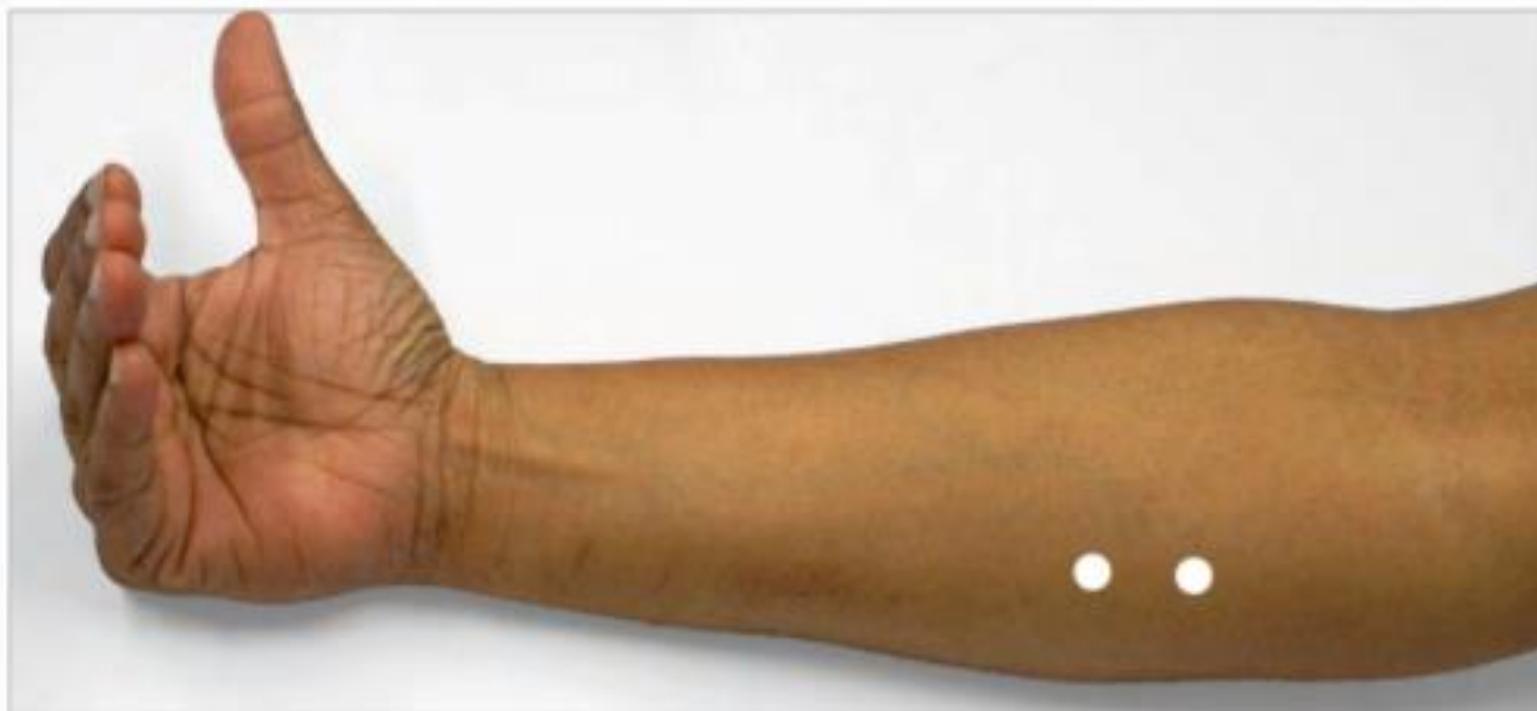


Figure 2. Placement of electrodes on the flexor digitorum superficialis for detecting transient muscle activity in REM sleep. Illustration may not be to scale.

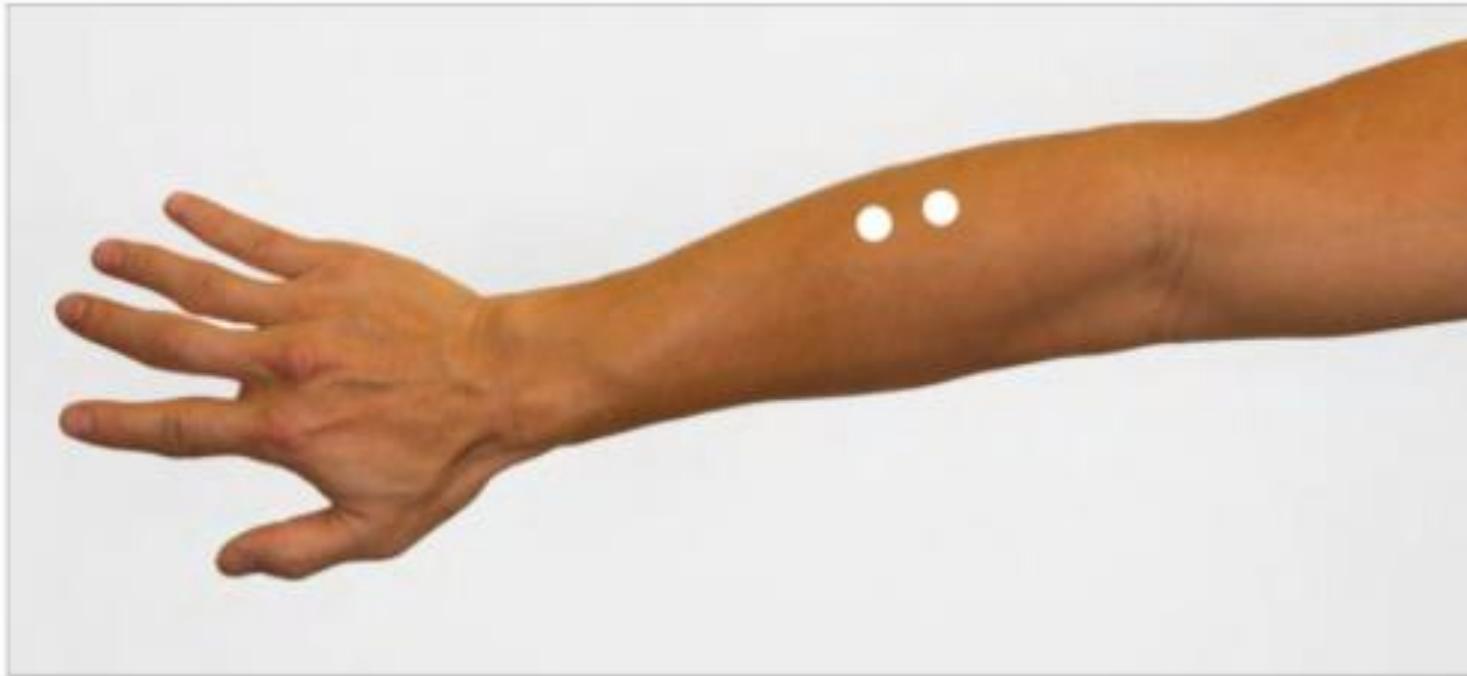


Figure 3. Placement of electrodes on the extensor digitorum communis for detecting transient muscle activity in REM sleep. Illustration may not be to scale.

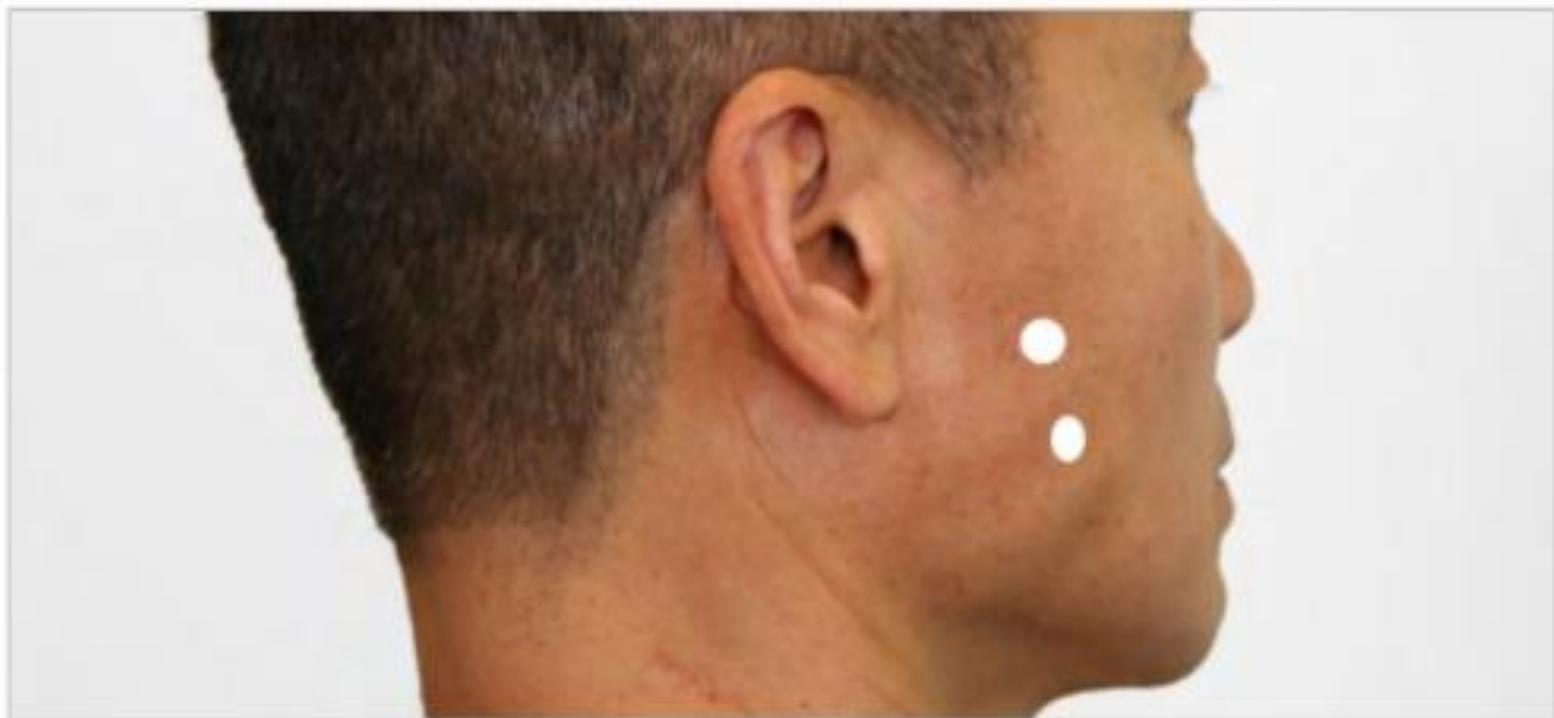


Figure 4. Placement of electrodes on the masseter muscle for detecting bruxism. Illustration may not be to scale.

Movement Rules

✓ Adult & Pediatric

A. Scoring Periodic Limb Movements in Sleep (PLMS)

Technical Specifications

For Diagnosis of RBD

1. Video PSG is Essential
 - a. Time-Synchronized
 - b. Audio-Equipped

Monitoring RMD

1. Electrodes applied to the large muscle groups involved
2. Video PSG is Essential
 - a. Time-Synchronized
 - b. Audio-Equipped



Figure 5. Placement of electrodes on the neck paraspinal muscles for monitoring rhythmic movement disorder. Illustration may not be to scale.

Technical Movement: Notes

Note	Comments
1	Patient should move the muscle group being collected -Anterior Tibialis – Point toes toward head -Flexor Digitorum Superficialis – Bend at base of fingers -Extensor Digitorum Communis – Extend fingers back without wrist moving -Masseter – bite down
2	If two electrodes, 2-3 cm apart. Masseter can just be one electrode
3	Surface electrodes 2-3 cm apart

Movement Rules

✓ Adult & Pediatric

Appeared in Manual:

2012 – v2.0.0

2016 – v2.3.0

- Illustrations added to help clarify scoring rules for LMs and:
 - PLMs
 - Arousal
 - Wake does not terminate a period

A. Scoring Periodic Limb Movements in Sleep (PLMS)

Movement Rules – Scoring PLMS

Significant Leg Movement (LM) Event

1. DURATION: 0.5 – 10.0 seconds
2. AMPLITUDE: 8uV increase above resting EMG
3. TIMING:
 - a. point where 8uV increased occurred
 - b. Point where amplitude drops to 2uV, after 0.5 in duration

Movement Rules

✓ Adult & Pediatric

A. Scoring Periodic Limb Movements in Sleep (PLMS)

Movement Rules – Scoring PLMS

PLM Series

1. NUMBER: 4 LM
2. PERIOD: 5 – 90 seconds apart; onset to onset
3. Leg movements on 2 different legs separated by less than 5 seconds are counted as a single LM

Single LM

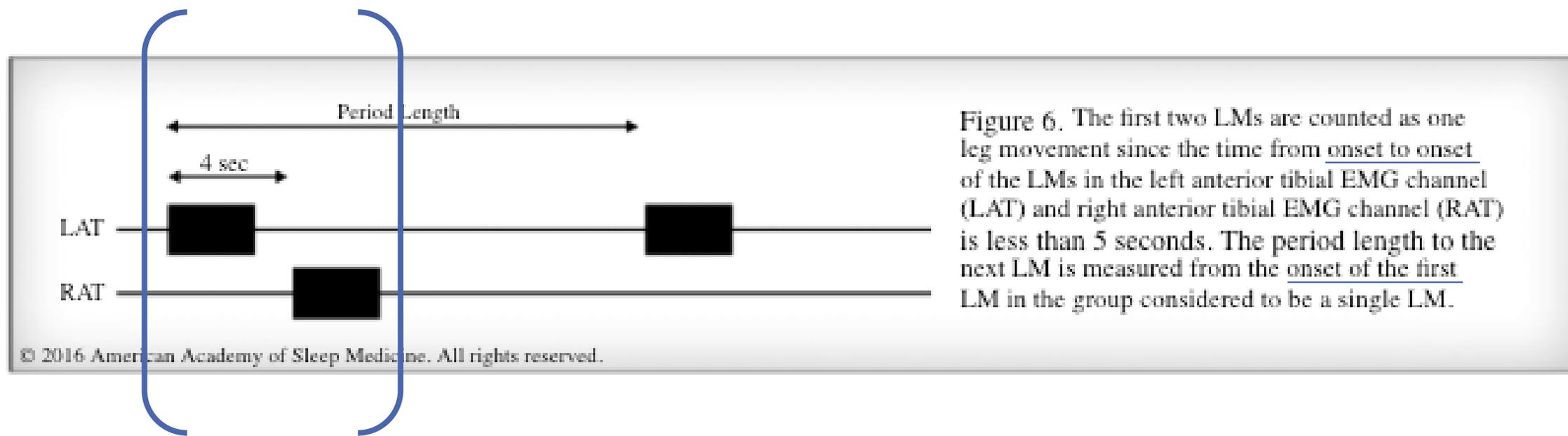
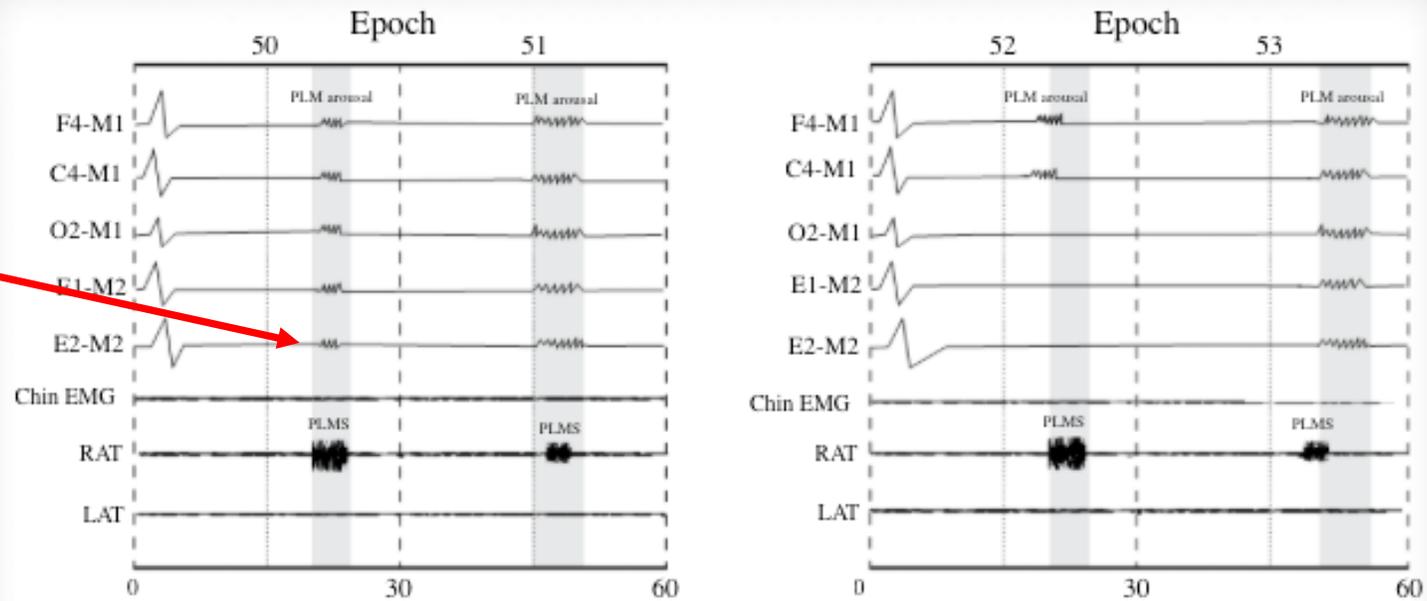


Figure 6. The first two LMs are counted as one leg movement since the time from onset to onset of the LMs in the left anterior tibial EMG channel (LAT) and right anterior tibial EMG channel (RAT) is less than 5 seconds. The period length to the next LM is measured from the onset of the first LM in the group considered to be a single LM.

“associate arousal”
when occurs
simultaneously



“associate arousal”
when occurs as
overlap

“associate arousal”
when occurs within
0.5 secs BEFORE
START or AFTER END

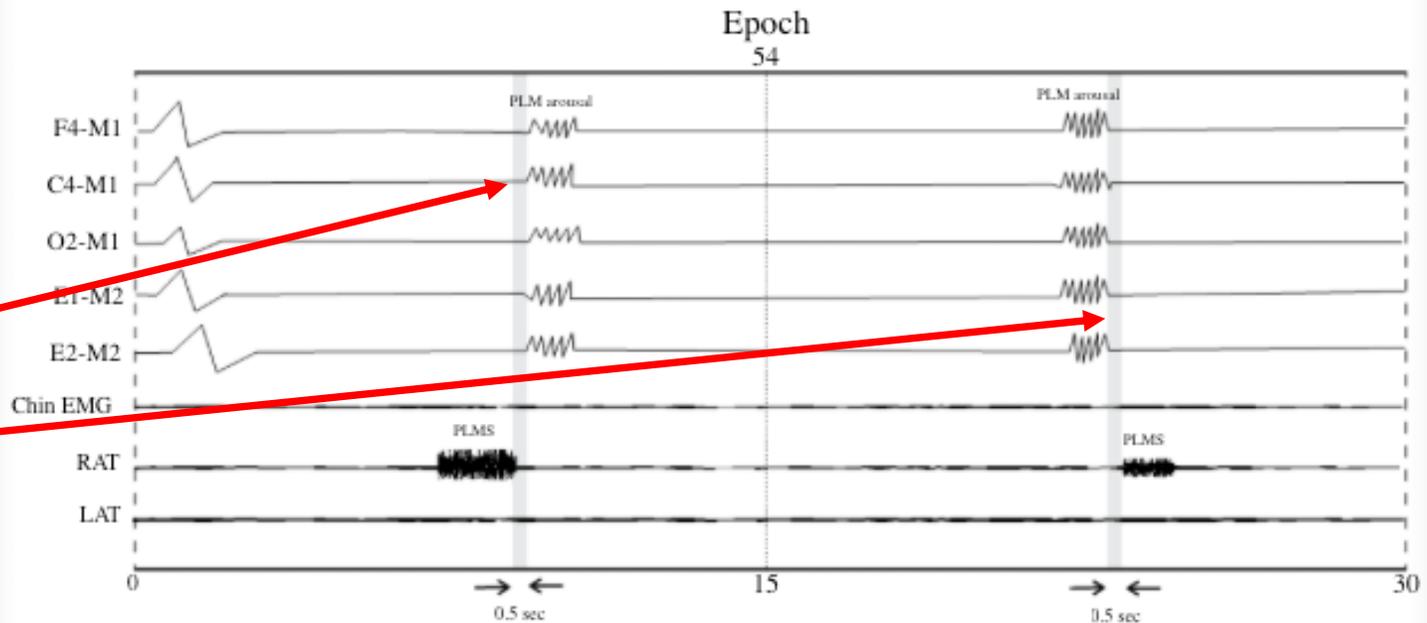
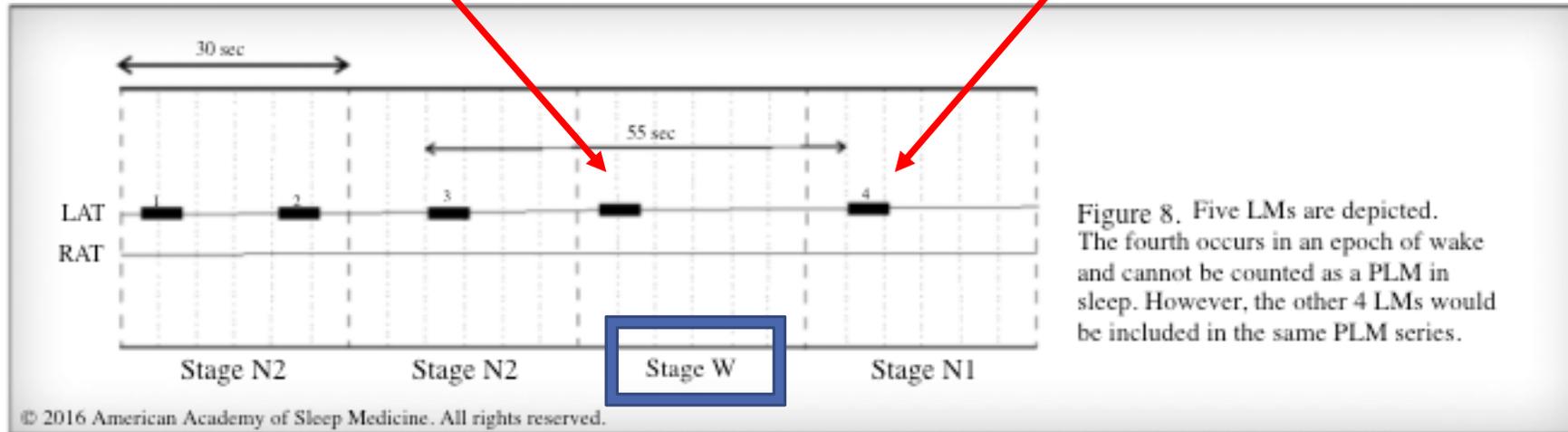


Figure 7. An arousal and LM occurring in a PLM series are considered to be associated if they occur simultaneously (epochs 50 and 51), overlap (epochs 52 and 53) or if the time from the end of one event to the start of the next is less than 0.5 seconds, regardless which event comes first (epoch 54).

Not counted in PLM Series,
due to stage W

Counted in PLM Series



Note 1. Rule 1.c. defines a significant leg movement event by an absolute increase of $8 \mu\text{V}$ 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 $+10 \mu\text{V}$ between negative and positive deflection ($\pm 5 \mu\text{V}$) or $+5 \mu\text{V}$ for rectified signals.

Note 2. When periodic limb movements occur with an interval of less than 10 seconds and each is associated with a ≥ 3 second change in the EEG/chin EMG meeting criteria for an arousal, only the first EEG/chin EMG change should be scored as an arousal (assuming it is preceded by at least 10 seconds of sleep). Both limb movements may be scored, assuming the onsets are separated by 5 seconds or more, but only one PLM associated with an arousal (and only one arousal) would be scored.

Movement – Others

ADULT & PEDIATRIC RULES



Movement Rules

✓ Adult & Pediatric

Appeared in Manual:
2012 – v2.0.0

- No changes

B. Scoring Alternating Leg Muscle Activation (ALMA)

Movement Rules –

Alternating Leg Muscle Activation (ALMA)

1. NUMBER: 4 alternating LM
2. FREQUENCY: 0.5 – 3.0 Hz

NOTES:

1. Alternating between legs
2. Usual duration is 100 – 500 msec
3. Benign movement phenomenon

Movement Rules

✓ Adult & Pediatric

Appeared in Manual:
2012 – v2.0.0

- No changes

C. Scoring Hypnagogic Foot Tremor (HFT)

Movement Rules –

Hypnagogic Foot Tremor (HFT)

1. NUMBER: 4 bursts
2. FREQUENCY: 0.5 – 4.0 Hz

NOTES:

1. Usual duration is 250 – 1000 msec
2. Benign movement phenomenon

Movement Rules

✓ Adult & Pediatric

Appeared in Manual:
2012 – v2.0.0
▪ No changes

D. Scoring Excessive Fragmentary Myoclonus (EFM)

Movement Rules –

Excessive Fragmentary Myoclonus (EFM)

1. DURATION: 150 msec max, usually
2. At least 20 minutes of NREM sleep
3. At least 5 EMG potentials per minute

NOTES:

1. May be visible or not visible movements
2. Seen in REM sleep in normal people
3. Benign movement phenomenon

Movement Rules

✓ Adult & Pediatric

Appeared in Manual:
2012 – v2.0.0

- No changes
- Changed Note #2 from “additional masseter” to changes more prominent than in chinEMG

E. Scoring Bruxism

Movement Rules –

Bruxism

1. Brief (phasic) or Sustained (Tonic) elevations cEMG
 - a. Brief: 0.25-2 seconds long AND at least episodes in sequence
 - b. Sustained: duration more than 2 seconds
2. At least twice the background cEMG tone
3. Must be separated by 3 seconds of stable background
4. Can be scored by audio and PSG with 2 audible grinding

NOTES:

1. 2 forms of jaw contractions; phasic or tonic
2. Additional masseter electrodes may be used, if preferred
3. Changes in masseter may be more visible than normal chinEMG channels

Movement Rules

✓ Adult & Pediatric

Appeared in Manual:

2012 – v2.0.0

- No Changes

2016 – v2.3.0

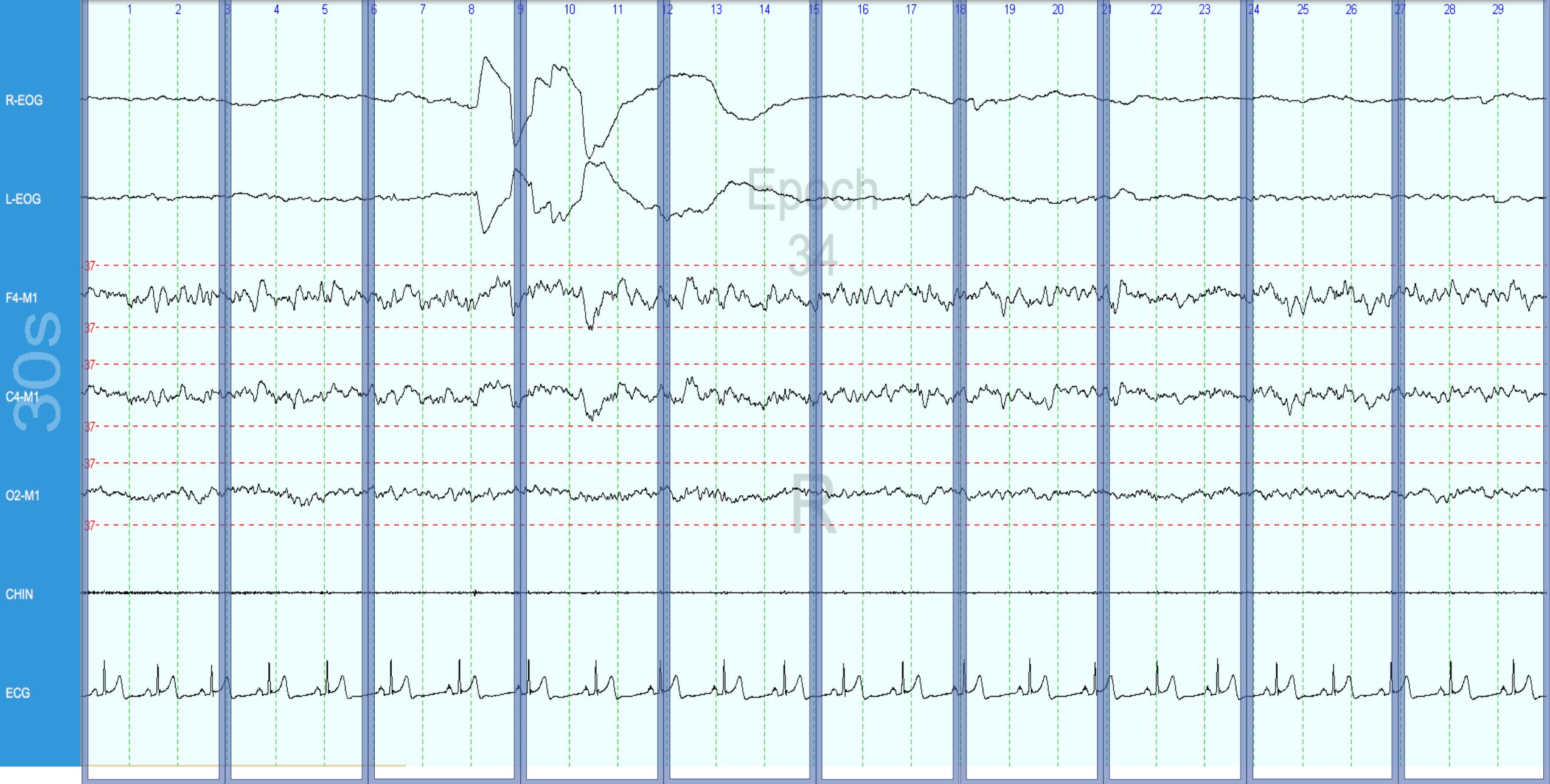
- Dropped Note 1 about video PSG being essential since added to Technical Specifications

F. Scoring PSG Features of REM Behavior Disorder (RBD)

Movement Rules – Definitions

REM Sleep Behavior Disorder (RBD)

1. Tonic Activity: Sustained Muscle Activity
 - a. At least 50% of the epoch has cEMG like NREM
2. Phasic Activity: Excessive Transient Muscle Activity
 - a. At least 50% of the 10 “3 second Mini-Epochs” contains bursts
 - b. Burst defined as 0.1 – 5 seconds long; 4x cEMG background increase
3. RBD characterized must have EITHER or BOTH
 - a. Sustained muscle activity in REM sleep in the cEMG
 - b. Excessive transient muscle activity during REM sleep in the cEMG or limb EMG



RBD Rules: Notes

Note	Comments
	Time synchronized, audio equipped videoPSG demonstrating dream enactment or a characteristic clinical history are necessary to <u>make the diagnosis of RBD</u> in addition to study
1	Transient muscle activity and occasional visible twitching of small muscle groups are a <u>normal phenomenon seen in REM</u>
2	Sustained muscle activity or the excessive transient muscle activity observed in REM sleep may be <u>interrupted by superimposed behaviors of RBD</u> , because they are acting out dreams
3	In normal people there is an atonia seen in REM sleep I the chin and leg EMG, therefore the background tone should decrease. But with RBD that atonia is lost increasing the tone

Movement Rules

✓ Adult & Pediatric

Appeared in Manual:

2012 – v2.0.0

- No Changes

2016 – v2.3.0

- Dropped entire Note sections since added to Technical Specifications
 - Bipolar surface electrodes should be used
 - Video PSG should be used

G. Scoring PSG Features of Rhythmic Movement Disorder

Movement Rules – Definitions

Rhythmic Movement Disorder (RMD)

1. Frequency:
 - a. Min = 0.5 Hz
 - b. Max = 2.0 Hz
2. Number:
 - a. Min # of Individual Movements is 4 = “Cluster”
3. Amplitude:
 - a. 2x the background EMG activity

Respiratory

ADULT SCORING RULES

Respiratory Rules – Part 1

✓ For Adults

Appeared in Manual:
2012 – v2.0.0
▪ No Changes

A. Technical Specifications

Technical Specifications

1. Apnea – use oronasal thermal airflow sensor
 - a. Alternative = Pressure Transducer, RIPsum, RIPflow
2. Hypopnea – use nasal pressure transducer
 - a. Alternative = thermal sensor, RIPsum, RIPflow, RIP belts
3. Use PAP device flow signal for apneas/hypopneas
4. Respiratory Effort
 - a. Esophageal manometry; RIP belts, PVDF belts
5. Oxygen Saturation – pulse ox; <3 sec avg. at 80 bpm
6. Snoring – microphone, piezoelectric sensor or Nasal Pressure Transducer
7. Hypoventilation – aCO₂, tcCO₂ or etCO₂
8. Hypoventilation during PAP - aCO₂ or tcCO₂

Respiratory Technical: Notes

Note	Comments
1	Thermal sensor includes thermistors, thermocouples or polyvinylidene fluoride (PVDF) sensors
2	<u>RIPsum is sum of signals</u> for chest and abdomen belts; <u>estimate of tidal volume</u> RIPflow is time derivative of RIPsum and estimate of airflow PVDFsum is sum of signals from PVDF chest and abdomen belts Using RIP or PVDF is optional in recording
3	Using nasal pressure signal without root transformation for hypopneas will give slightly higher index. Usually not clinically significant for most patients.
4	Monitoring <u>snoring and hypoventilation</u> is optional
5	etCO ₂ and tcCO ₂ should be <u>interpreted with clinical judgement</u> and not assumed to be an accurate aPCO ₂
6	tcCO ₂ should be calibrated with a reference gas; usually a two minute lag from aCO ₂ samples etCO ₂ may often fail or read falsely low in patients with marked nasal obstruction, secretions, mouth breathers or getting supplemental oxygen. Need plateau in signal for validity.

Respiratory Rules – Part 1

✓ for Adults

Appeared in Manual:
2012 – v2.0.0
▪ No Changes

B. Measuring Event Duration

Measuring Event Duration

1. Apnea or Hypopnea:
 - a. Nadir preceding first breath clearly reduced
 - b. To beginning of first breath returned to “baseline”
2. Apnea Duration:
 - a. Use oronasal thermal or PAP Flow
 - b. Use alternative, if unreliable
3. Hypopnea Duration:
 - a. Use nasal pressure or PAP flow
 - b. Use alternative, if unreliable
4. “Baseline Breathing Amplitude” Issues
 - a. Terminate event when there is a clear and sustained increase in breathing amplitude or resaturation of at least 2%

Apnea

ADULT RESPIRATORY RULES

Respiratory Rules – Part 1

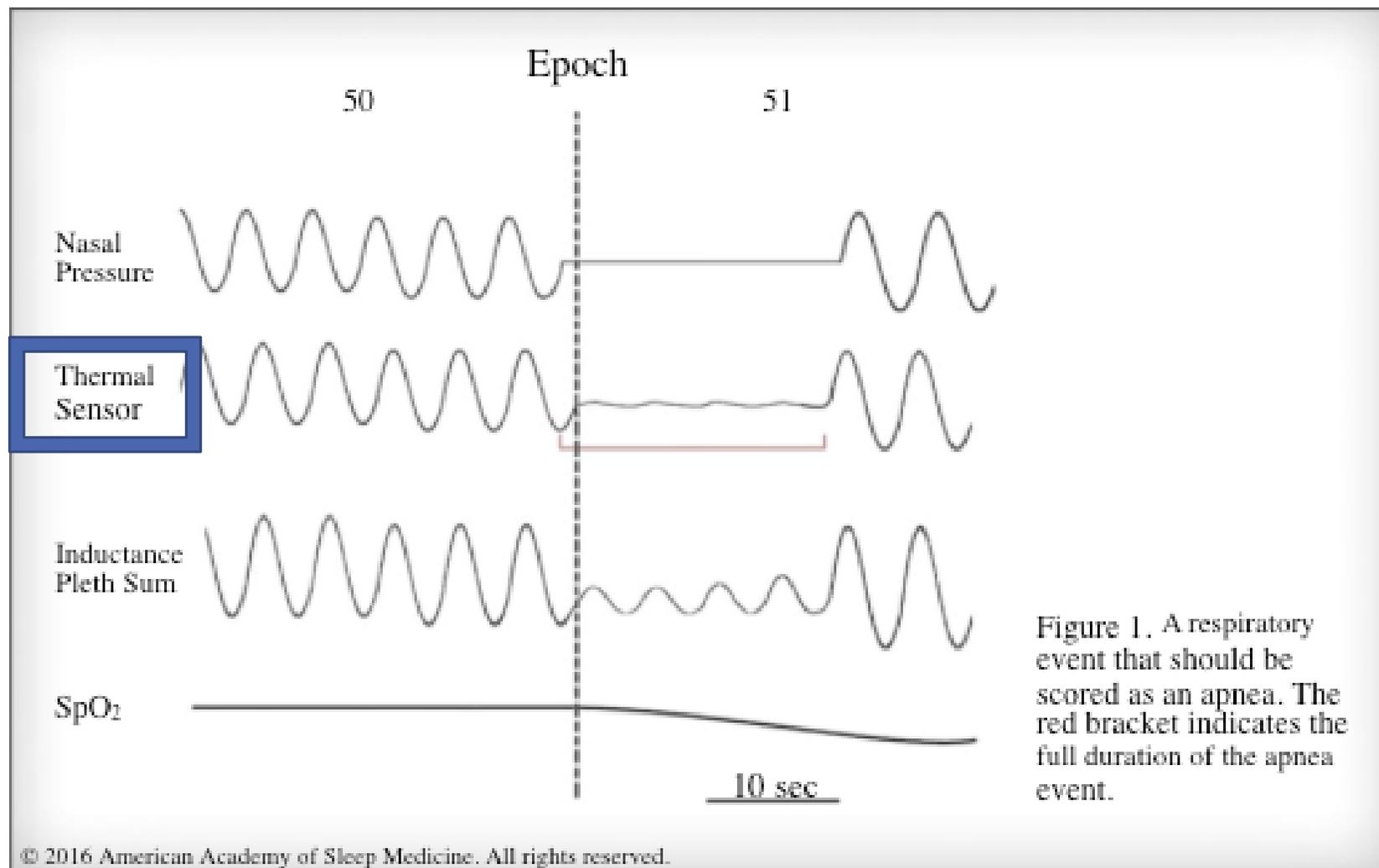
✓ For Adults

Appeared in Manual:
2012 – v2.0.0
▪ No Changes

C. Scoring of Apneas

Scoring of Apneas

1. Apnea when BOTH criteria are met
 - a. >90% drop from baseline; for at least 10 seconds
2. Obstructive
 - a. Continued or increased inspiratory effort throughout event
3. Central
 - a. Absent inspiratory effort throughout event
4. Mixed
 - a. Absent of inspiratory effort for first part of event
 - b. Followed by resumption of inspiratory effort in the second portion of event



Apnea Scoring: Notes

Note	Comments
	Apnea <u>does not require desaturation</u>
	If event qualifies for hypopnea and an apnea, <u>then score as apnea</u>
	If apnea or hypopnea occurs entirely within an <u>epoch of W, it should not be scored</u> . Special note should be <u>given if events lead to long “arousals” that impacts the ability to score an epoch as sleep</u>
	<u>No sufficient evidence to support a specific duration of the central and obstructive components of a mixed apnea</u> ; thus there is <u>no duration component for a mixed apnea</u>

Hypopnea

ADULT RESPIRATORY RULES

Respiratory Rules – Part 1

✓ for Adults

Appeared in Manual:
2012 – v2.0.0

- Note suggested a separate calculation for hypopneas with >4% desats for insurance and new Accreditation standards

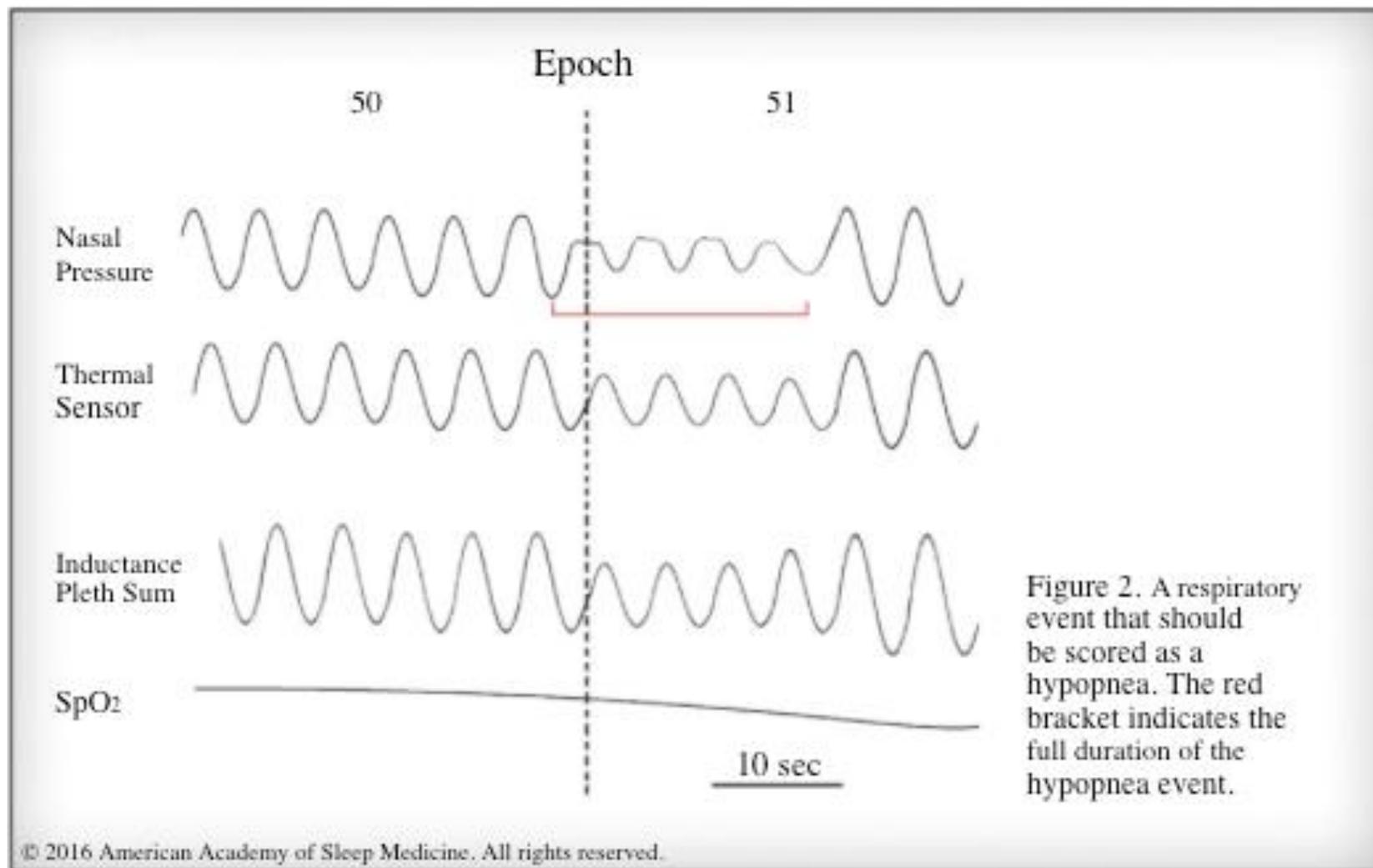
2013 – v2.0.3

- Added Rule 1B, which removes arousal at 4% desat

D. Scoring of Hypopneas

Scoring of Hypopneas

1. Distinguishing between obstructive or central is optional
2. 1A Hypopnea when ALL criteria are met
 - a. >30% drop from baseline; for at least 10 seconds
 - b. >3% desaturation from pre-event baseline **OR** Arousal
3. 1B Hypopnea when ALL criteria are met
 - a. >30% drop from baseline; for at least 10 seconds
 - b. >4% desaturation from pre-event baseline
4. Obstructive – if ANY observed
 - a. Snoring, increased inspiratory flattening, paradox appears
5. Central – if NONE observed
 - a. Snoring, increased inspiratory flattening, paradox appears



Hypopnea Scoring: Notes

Note	Comments
	The <u>report should indicate</u> which hypopnea rule was used; 1A or 1B
	<u>Supplemental oxygen may blunt desaturation</u> . No scoring guidelines when patient is on supplemental oxygen and no desaturation is observed. Note in report should be made if patient is using supplemental oxygen during diagnostic period of a study
	For Alternative hypopneas sensors see Technical Specifications for adults

RERA

ADULT RESPIRATORY RULES

Respiratory Rules – Part 1

✓ For Adults

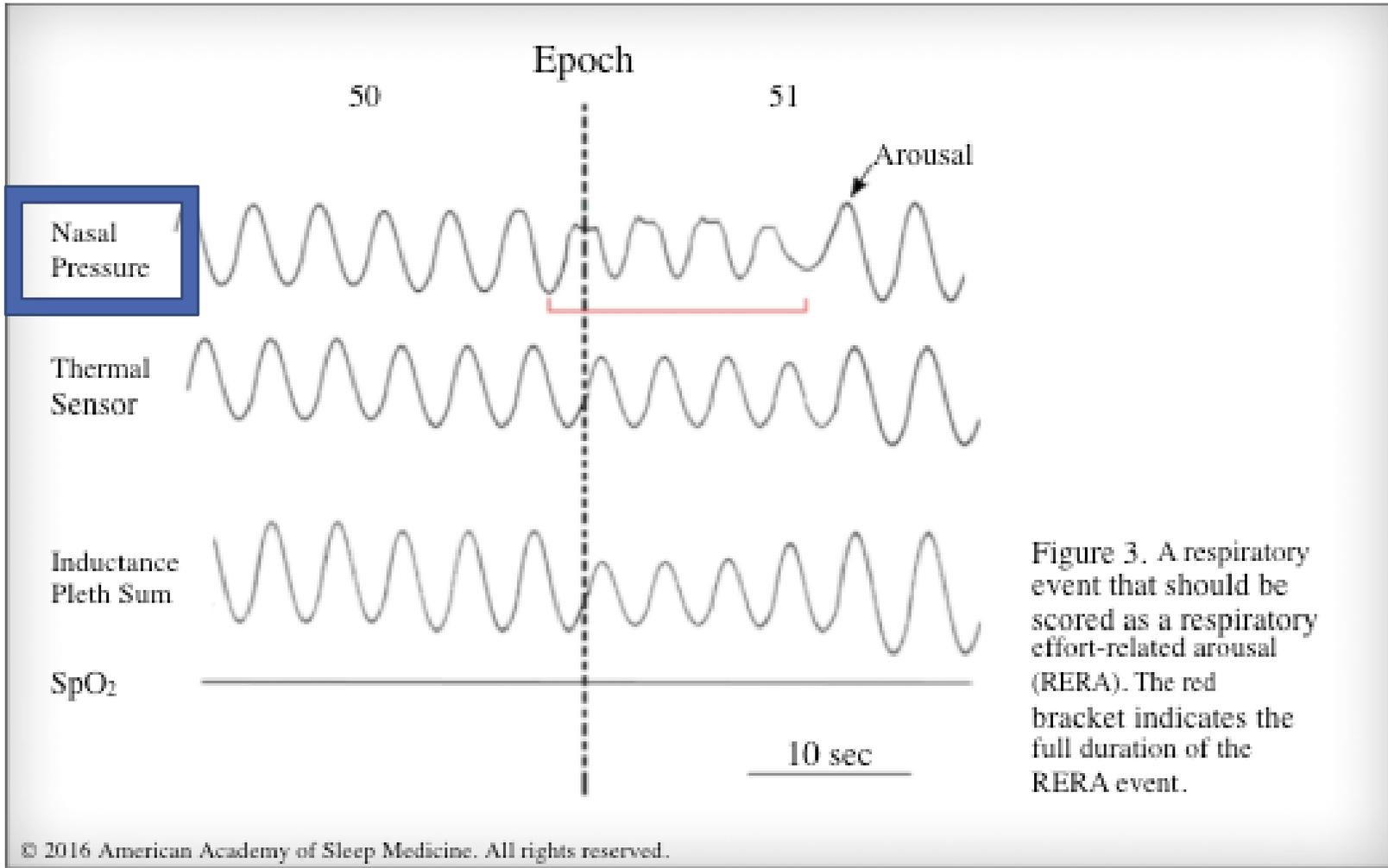
Appeared in Manual:
2012 – v2.0.0

- No changes

E. Scoring of Respiratory Effort-Related Arousal

Scoring of RERA

1. Scoring of RERA is optional
2. Sequence of breath lasting at least 10 seconds
 - a. Shows increased respiratory effort
 - b. Shows flattening of the inspiratory portion of signal
 - c. MUST lead to an arousal
 - d. MUST NOT qualify for APNEA or HYPOPNEA



Hypoventilation

ADULT RESPIRATORY RULES

Respiratory Rules – Part 1

✓ For Adults

Appeared in Manual:

2012 – v2.0.0

2014 – v2.0.3

- Added the conversion factor

F. Scoring Hypoventilation

Scoring of Hypoventilation

1. Monitoring and Scoring of Hypoventilation is optional
2. If EITHER of the below occur:
 - a. Increase in arterial PCO₂ to a value >55mmHg for >10 minutes
 - b. >10mmHg increase in arterial PCO₂ during Sleep and exceeds 50mmHg for >10 minutes
3. Conversion: 1 mmHg = 0.133 kPa
 - a. To change the unit of the pressure from mmHg to kPa

Cheyne-Stokes

ADULT RESPIRATORY RULES

Respiratory Rules – Part 1

✓ For Adults

Appeared in Manual:
2012 – v2.0.0
▪ No changes

G. Scoring of Cheyne-Stokes Breathing

Scoring of Cheyne-Stokes Breathing

1. If BOTH of the below occur:
 - a. Episodes of >3 consecutive CA or CH separated by a crescendo and decrescendo change in breathing amplitude within a cycle of >40 seconds
 - b. Episodes of >5 CA or CH per hour of sleep associated with crescendo/decrescendo breathing pattern recorded for over 2 hours of monitoring

NOTES:

2. Cycle length is the time from the beginning of a CA to the end of the next C/D respiratory phase (next apnea)
3. Central apneas that occur within a a run of Cheyne-Stokes breathing should be scored as individual apneas as well

-3 Central
Events in a
row

-40 seconds
of crescendo-
decrecendo
breathing in
between

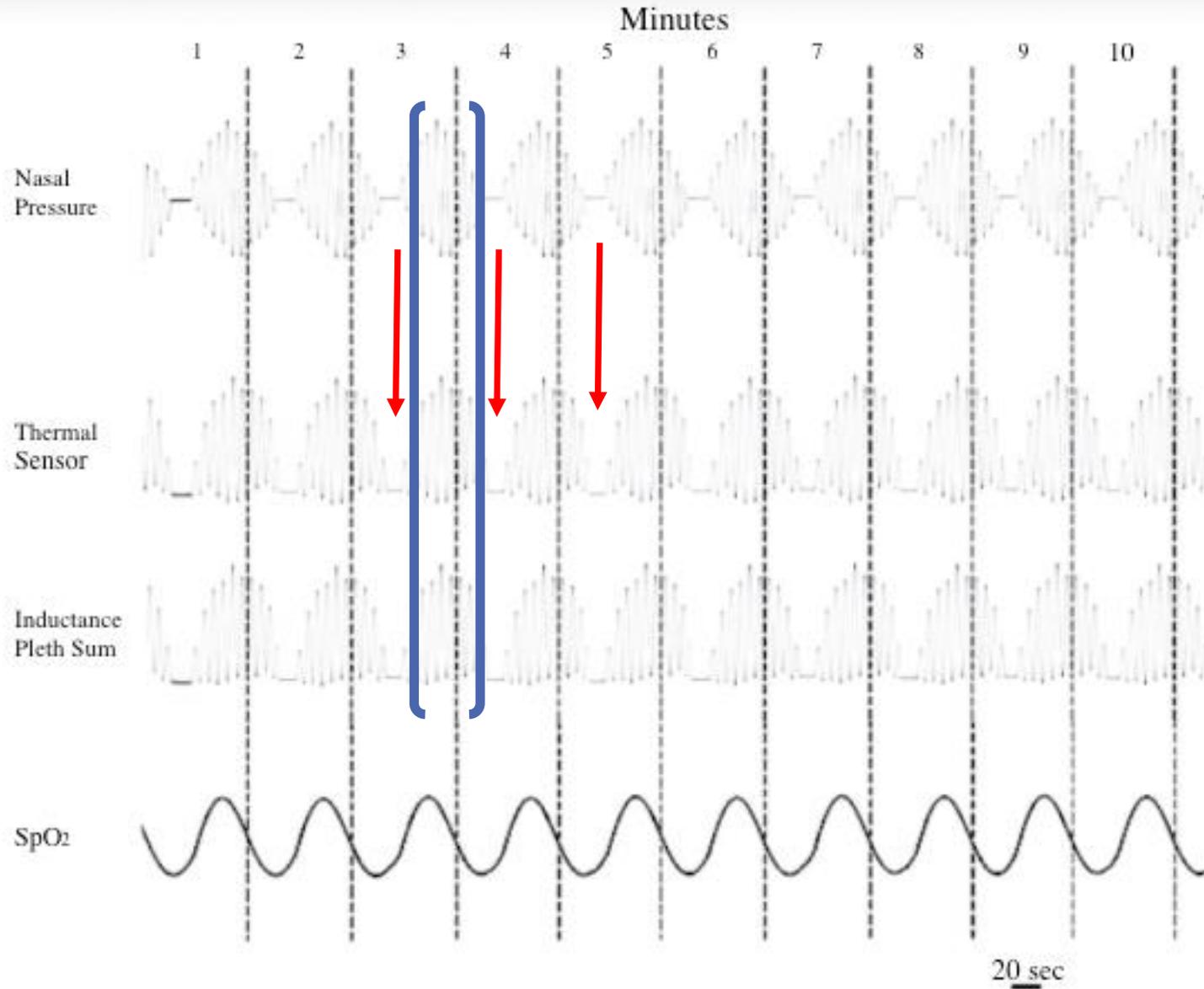


Figure 4. A respiratory event that should be scored as Cheyne-Stokes breathing due ≥ 3 consecutive apneas with crescendo and decrescendo breathing in between.

Home Sleep Apnea Testing (HSAT)

FOR ADULTS – PART 1

UTILIZING RESPIRATORY FLOW AND/OR EFFORT PARAMETERS

Home Sleep Apnea Testing (HSAT)

✓ Adult

Appeared in Manual:

2015 – v2.2

2017 – v2.4

- Moved the Sleep/Wake time estimates from Optional to Recommended
- Added REM time estimates to the Sleep/Wake sections

A. General Parameters to Be Reported

Recording Parameters

1. Recommended vs Optional (per Scoring Manual)
2. Recommended (MUST be reported)
 - a. Type of Device
 - b. Type of Airflow Sensors
 - i. RIPsum can be used for tidal volume sensor
 - c. Type of Respiratory effort sensors(s) [dual or single]
 - d. Oxygen Saturation
 - e. Heart rate (ECG or derived from oximeter)

Home Sleep Apnea Testing (HSAT)

✓ Adult

Appeared in Manual:
2015 – v2.2
▪ No change

A. General Parameters to Be Reported

Recording Parameters

1. Recommended vs Optional (per Scoring Manual)
2. Optional (at discretion of provider)
 - a. Body position
 - b. Sleep/Wake and REM time estimates
 - i. If so, then use EEG, EOG and cEMG
 - c. Snoring
 - i. acoustic
 - ii. piezo-electric sensor
 - iii. via pressure transducer

Note 1. For alternative measures see Part 2: HSAT Utilizing Peripheral Arterial Tonometry (PAT).

Note 2. Tidal volume sensors (i.e. RIPsum) can also be used.

Note 3. Sleep should be determined using EEG, EOG, and chin (submental) EMG recording. The method used to determine monitoring time (MT) should be specified in the report.

B. Recorded Data to be Reported – HSAT for Adults

Recording Start Time		Hour:Min
Recording End Time		Hour:Min
Total Sleep Time (TST)	OPTIONAL	In minutes
Total Recording Time (TRT)		Start to Stop; Plus wake and artifact
Monitoring Time (MT)		Used to calculate respiratory event index
Average heart rate		
Highest heart rate		
Lowest heart rate		

B. ORIGINAL Respiratory Events listed in v2.2 and 2.3; removed in 2.4- RECOMMENDED

Number of Respiratory Events		
Number of Apneas		
Number of Hypopneas		
Number of Obstructive, Central, Mixed Apneas	OPTIONAL	
Number of Apneas + Hypopneas		
Respiratory Event Index (REI)		$((\# \text{ RE}) \times 60) / \text{MT}$
REI or AHI in supine and non-supine position	OPTIONAL	
Central Apnea Index (CAI)	OPTIONAL	$((\# \text{ CA}) \times 60) / \text{MT}$
Apnea Hypopnea Index (AHI)		$((\# \text{ A} + \# \text{ H}) \times 60) / \text{MT}$
Opt. 1 Atrial Oxygen Saturation		Mean Value, Max Value, Min Value
Opt. 2 Oxygen Desaturation Index (ODI)	3% or 4%	$(\# \text{ OD} \times 60) / \text{MT}$
Opt. 3 Arterial Oxygen Saturation		% of Time at or below 88% or other thresh.
Occurrence of Snoring	OPTIONAL	

Monitoring Time = Total Recording Time , however it is used as Total Sleep Time when calculating Event Index

- Note 1. **Monitoring time (MT)** = Total recording time minus periods of artifact and time the patient was awake as determined by actigraphy, body position sensor, respiratory pattern, or patient diary. The method used to determine MT should be stated. For reimbursement purposes, individual practitioners may need to indicate in their HSAT report that monitoring time (MT) is being used in place of total recording time (TRT).
- Note 2. Respiratory event index (REI) = Total number of respiratory events scored $\times 60$ divided by monitoring time (MT). For reimbursement purposes, individual practitioners may need to indicate in their HSAT report that REI is a surrogate for AHI.
- Note 3. This assumes monitoring EEG, EOG, and submental chin EMG.
- Note 4. Reporting all three parameters may provide important information for the clinician.
- Note 5. ODI should report the same desaturation as used for scoring hypopneas. For example, if hypopnea is scored based on a $\geq 3\%$ desaturation, the ODI should be the number of $\geq 3\%$ desaturations $\times 60$ divided by MT.

C. Summary Statements – HSAT for Adults - Part 1

Date of Test / Date of Interpretation	RECOMMENDED	
Technical Adequacy of Study	RECOMMENDED	Repeat for tech. failure; limitations of study
Interpretation of REI or AHI	RECOMMENDED	Based on MT
Occurrence of Snoring	RECOMMENDED	
Interpretation	RECOMMENDED	Supports diagnosis of OSA or not
Interpretation	RECOMMENDED	Statement of severity, if applicable
Interpretation	RECOMMENDED	Non-diagnostic, recommend attended study
Printed name and signature of interpreting	RECOMMENDED	Verifies review of raw data
Recommendation for Management	RECOMMENDED	Must meet AASM C.P. Guidelines and PP
Chain of Custody	OPTIONAL	

D. Technical and Digital Specifications – HSAT Equipment Recording Features for Adults - Part 1

FDA Approval of Device	RECOMMENDED	
Unique identifier for each unit	RECOMMENDED	
Must meet minimum definition for CPT	RECOMMENDED	95800, 95801, 95806
Ability to record oximetry	RECOMMENDED	
Ability to record a measure of heart rate	RECOMMENDED	
Ability to display raw data for review	RECOMMENDED	Manual scoring or editing of auto-score
Ability to calculate a REI	RECOMMENDED	Based on MT as surrogate for AHI via PSG
Ability to determine chain of custody	OPTIONAL	

Note 1. 95800—Sleep study, unattended, simultaneous recording; heart rate, oxygen saturation, respiratory analysis (e.g. by airflow or peripheral arterial tone), and sleep time
95801—Sleep study, unattended, simultaneous recording; heart rate, oxygen saturation, respiratory analysis (e.g. by airflow or peripheral arterial tone)
95806—Sleep study, unattended, simultaneous recording; heart rate, oxygen saturation, respiratory airflow and respiratory effort (e.g. thoracoabdominal movement)

Note 2. Raw tracings must be viewable in detail with the ability to edit events.

Home Sleep Apnea Testing (HSAT)

✓ Adult

Appeared in Manual:

2015 – v2.2

2017 – v2.4

- No Changes

E. HSAT Respiratory Events Rules: Technical Specifications

1. For identification of RE based on respiratory airflow , use at least one...
 - a. Oronasal thermal airflow sensor (Recommended)
 - b. Nasal pressure transducer (Recommended)
 - c. Alternative Sensors
 - i. RIPsum/RIPflow (recommended)
 - ii. PVDFsum (acceptable)
2. For monitoring respiratory effort, use one...
 - a. Single or dual thoracoabdominal RIP belts (recommended)
 - b. Single or dual thoracoabdominal PVDF belts (acceptable)
 - c. Single or dual thoracoabdominal Piezo belts (acceptable)
 - d. Single or dual pneumatic belts (acceptable)

Home Sleep Apnea Testing (HSAT)

✓ Adult

Appeared in Manual:

2015 – v2.2

2017 – v2.4

- No Changes

E. HSAT Respiratory Events Rules: Technical Specifications

3. For monitoring oxygen saturation, use pulse oximetry
4. For monitoring snoring, use one... (Optional)
 - a. Acoustic sensor (snore mic)
 - b. Piezoelectric sensor
 - c. Nasal pressure transducer

Note 1. **At least one airflow sensor is required.** Ideally both an oronasal thermal sensor and a nasal pressure transducer should be used to record airflow. An alternative sensor (as listed above) may be substituted for an oronasal thermal sensor.

Note 2. Thermal sensors include thermistors, thermocouples, or polyvinylidene fluoride (PVDF) airflow sensors. If used without simultaneous nasal pressure monitoring, some thermal sensors may be less sensitive for detection of hypopneas.

Note 3. Using the nasal pressure signal without square root transformation for scoring sleep-related respiratory events (SRE) will result in a slightly higher hypopnea index than scoring using a square root transformation of the signal. This difference is not clinically significant in most patients.

Note 4. If the nasal pressure signal is used without simultaneous recording of oronasal thermal sensor signal, some hypopneas may be classified as apneas.

Note 5. The RIPsum is the sum of the signals from thoracic and abdominal RIP sensors (belts) and excursions in the signal are an estimate of tidal volume. The RIPflow is the time derivative of the RIPsum and excursions in the signal are an estimate of airflow. The PVDFsum is the sum of signals from thoracic and abdominal PVDF sensors (belts).

Note 6. **Only CPT code 95806 requires respiratory effort monitoring.** If respiratory effort monitoring is performed one of these technologies should be used. The use of two belts is preferred; however, one respiratory monitoring belt is acceptable.

Note 7. The recording device should meet the same requirements for oximetry as the in-laboratory PSG.

Home Sleep Apnea Testing (HSAT)

✓ Adult

Appeared in Manual:

2015 – v2.2

2017 – v2.4

- This entire section for HSAT Respiratory Event Rules for scoring apneas was removed

F. HSAT Respiratory Events Rules: Scoring Apnea

1. Score a respiratory event as an apnea when BOTH of the following criteria are met:
 - a. Peak signal excursion drop by >90% of pre-event baseline using a recommended or alternative airflow sensor.
 - b. The duration of the >90% drop in signal is >10 seconds
2. Score as obstructive if it meets apnea criteria AND is associated with continued or increased inspiratory effort throughout the entire period of absent airflow
3. Score as central if it meets apnea criteria AND is associated with absent inspiratory effort throughout the entire period of absent airflow
4. Score as mixed 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

Note 1. Identification of an apnea does not require a minimum desaturation criterion.

Note 2. If a portion of a respiratory event that would otherwise meet criteria for a hypopnea meets criteria for apnea, the entire event should be scored as an apnea.

Note 3. There is not sufficient evidence to support a specific duration of the central and obstructive components of a mixed apnea; thus, specific durations of these components are not recommended.

Note 4. Some devices may not differentiate between different types of apneas.

Home Sleep Apnea Testing (HSAT)

✓ Adult

G. HSAT Respiratory Events Rules: Scoring Hypopnea

RULE 1A

1. If sleep is NOT recorded, score a respiratory event as a hypopnea if ALL of the following criteria are met:
 - a. Peak signal excursion drop by >30% of pre-event baseline using a recommended or alternative airflow sensor.
 - b. The duration of the >30% drop in signal is >10 seconds
 - c. There is a >3% oxygen desaturation from pre-event baseline

RULE 1B

1. If sleep is NOT recorded, score a respiratory event as a hypopnea if ALL of the following criteria are met:
 - a. Peak signal excursion drop by >30% of pre-event baseline using a recommended or alternative airflow sensor.
 - b. The duration of the >30% drop in signal is >10 seconds
 - c. There is a >4% oxygen desaturation from pre-event baseline

Home Sleep Apnea Testing (HSAT)

✓ Adult

G. HSAT Respiratory Events Rules: Scoring Hypopnea

RULE 2A

1. If sleep IS recorded, score a respiratory event as a hypopnea if ALL of the following criteria are met:
 - a. Peak signal excursion drop by >30% of pre-event baseline using a recommended or alternative airflow sensor.
 - b. The duration of the >30% drop in signal is >10 seconds
 - c. There is a >3% oxygen desaturation from pre-event baseline OR event is associated with an arousal

RULE 2B

1. If sleep IS recorded, score a respiratory event as a hypopnea if ALL of the following criteria are met:
 - a. Peak signal excursion drop by >30% of pre-event baseline using a recommended or alternative airflow sensor.
 - b. The duration of the >30% drop in signal is >10 seconds
 - c. There is a >4% oxygen desaturation from pre-event baseline

Note 1. The criteria used to score a respiratory event as a hypopnea should be specified in the report.

Note 2. Scoring a hypopnea based on arousals is only possible if sleep is recorded.

Home Sleep Apnea Testing (HSAT)

FOR ADULTS – PART 2

UTILIZING PERIPHERAL ARTERIAL TONOMOMETRY (PAT)

Home Sleep Apnea Testing (HSAT)

✓ Adult

Appeared in Manual:

2015 – v2.2

2017 – v2.4

- No changes

A. General Parameters to Be Reported

Recording Parameters

1. Recommended vs Optional (per Scoring Manual)
2. Recommended (MUST be reported)
 - a. Type of Device
 - b. Sleep/Wake and REM time estimates (via Actigraphy)
 - c. Airflow/Effort Surrogate (PAT) signals
 - d. Oxygen Saturation
 - e. Heart rate
3. Optional
 - a. Occurrence of Snoring
 - b. Body Position (if recorded)

B. Recorded Data to be Reported – HSAT for Adults

Recording Start Time		Hour:Min
Recording End Time		Hour:Min
<u>Estimated</u> Sleep Time (TST)		In minutes;
<u>Estimated</u> % of REM, Deep, Light Sleep	OPTIONAL	
Duration of Recording Time (TRT)		Start to Stop; Plus wake and artifact
Monitoring Time (MT)		Time used to calculate respiratory event index
Heart Rate		Average, Highest and Lowest
Number of Sleep-Related Events		RE
Oxygen Desaturation Index (4%)		ODI >4% ((# x60) / MT))

C. Summary Statements – HSAT for Adults - Part 2

Date of Test / Date of Interpretation	RECOMMENDED	
Technical Adequacy of Study	RECOMMENDED	Repeat for tech. failure; limitations of study
Interpretation of Estimated Sleep Time	RECOMMENDED	
Interpretation of REI or AHI	RECOMMENDED	Based on MT
Occurrence of Snoring	OPTIONAL	
Interpretation	RECOMMENDED	Supports diagnosis of OSA or not
Interpretation	RECOMMENDED	Statement of severity, if applicable
Interpretation	RECOMMENDED	Non-diagnostic, recommend attended study
Printed name and signature of interpreting	RECOMMENDED	Verifies review of raw data
Recommendation for Management	RECOMMENDED	Must meet AASM C.P. Guidelines and PP
Chain of Custody	OPTIONAL	

D. Technical and Digital Specifications – HSAT Equipment Recording Features for Adults - Part 2

FDA Approval of Device	RECOMMENDED	
Unique identifier for each unit	RECOMMENDED	
Must meet minimum definition for CPT	RECOMMENDED	95800, 95801
Ability to record oximetry	RECOMMENDED	
Ability to record a measure of heart rate	RECOMMENDED	
Ability to display raw data for review	RECOMMENDED	Manual scoring or editing of auto-score
Ability to calculate a REI	RECOMMENDED	Based on MT as surrogate for AHI via PSG
Ability to determine chain of custody	OPTIONAL	

Note 1. 95800—Sleep study, unattended, simultaneous recording; heart rate, oxygen saturation, respiratory analysis (e.g. by airflow or peripheral arterial tone) and sleep time
95801—Sleep study, unattended, simultaneous recording; heart rate, oxygen saturation, respiratory analysis (e.g. by airflow or peripheral arterial tone)

Note 2. Raw tracings must be viewable in detail with the ability to edit events.

Note 3. Surrogate AHI is based on estimated sleep time derived from actigraphy rather than EEG measurement of total sleep time (TST).

Home Sleep Apnea Testing (HSAT)

✓ Adult

Appeared in Manual:

2015 – v2.2

2017 – v2.4

- No changes

E. HSAT Respiratory Events Rules: Technical Specifications

1. For identification of RE based on PAT, use one...
 - a. Peripheral arterial tone
 - b. Oxygen desaturation
 - c. Changes in heart rate derived from oximetry
2. For monitoring oxygen saturation, use pulse oximetry

Note 1. The algorithm used by the device must meet current AASM accreditation standards.