MODULE

SCORING SLEEP
SCORING SLEEP

Scoring a sleep study is divided into 4 parts:

3) Scoring sleep stages
4) Scoring respiratory events
5) Scoring arousals
6) Scoring periodic limb movements
LESSON 1: SLEEP STAGE SCORING

OBJECTIVES:
At the end of this lesson the student must be able to:

• Measure frequency and amplitude of waveforms
• Differentiate sleep/wake stages according to patient-specific factor
• Apply standard criteria for scoring sleep stages
LESSON 1: SLEEP STAGE SCORING

Before you assign a stage on each epoch you need to classify the waveforms

**Alpha waves** are EEG waveform activity in the 8 – 13 cycle per second (cps) or 8 – 13 Hz range.

**Theta waves** are EEG waveform activity in the 4 - 7 cps (4 -7 Hz) range.

**Sleep Spindles** are EEG waveform activity in the 13 – 16 cps (13 – 16 Hz) range.

**Delta waves** are EEG waveform activity 0.5 – 3 cps (0.5 – 3 Hz) range.
LESSON 1: SLEEP STAGE SCORING

To classify the waveforms, you need to count the cycles per second of each wave on your EEG channels

e.g. EEG waves on a 10-second epoch

Count the number of peaks in a 1-second time frame
LESSON 1: SLEEP STAGE SCORING

The **EEG Recommended Derivations** are:

- F4 – M1
- C4 – M1
- O2 – M1

Back-up leads:
- F3 – M2
- C3 – M2
- O1 – M2

Alternative acceptable Derivations are:

- Fz – Cz
- Cz – Oz
- C4 – M1

Back-up electrodes:
- FPz – C3
- C3 – O1
- C4 – M2
LESSON 1: SLEEP STAGE SCORING

The **EOG Recommended Derivations** are:

- E1 – M2
  E1 = 1 cm below the LOC

- E2 – M2
  E2 = 1 cm above the ROC

Alternative acceptable derivations are:

- E1 – FPZ
  E1 = 1 cm below and 1 cm lateral to the outer canthus of the left eye

- E2 – FPZ
  E2 = 1 cm below and 1 cm lateral to the outer canthus of the right eye
LESSON 1: SLEEP STAGE SCORING

The **CHIN EMG Recommended Derivations** are:

Three electrodes should be placed to record EMG:

- One midline 1 cm above the inferior edge of the mandible.
- One 2 cm below the inferior edge of the mandible and 2 cm to the right of the midline.
- One 2 cm below the inferior edge of the mandible and 2 cm to the left of the midline.
LESSON 1: SLEEP STAGE SCORING

Important Things to Know

- Read between the lines
- EEG takes precedence over EOG & EMG
- Pattern Recognition
- Sleep architecture
- Score sleep stages in 30 second sequential epochs (from Lights Out to Lights On)
- Assign a stage to each epoch
- If 2 or more stages coexist during a single epoch, assign the stage comprising the greatest portion of the epoch (majority rules).
LESSON 1: SLEEP STAGE SCORING

Scoring of Sleep Stages

• Stage W (Wakefulness)
• Stage N1 (NREM 1)
• Stage N2 (NREM 2)
• Stage N3 (NREM 3)
• Stage R (REM)
LESSON 1: SLEEP STAGE SCORING

Stage W
The EEG consists of a frequency of 8 – 13 cps (8 – 13 Hz)
It is predominantly seen in the Occipital Region
e.g. Alpha waves on a 10-second epoch

1 second

9 cps
LESSON 1: SLEEP STAGE SCORING

Stage W
The EEG consists of a frequency of 8 – 13 cps (8 – 13 Hz)
The pattern is like Blades of grass
The EOG activity shows conjugate, irregular, sharply
peaked eye movements (0.5-2 Hz frequency)
The EMG activity shows normal or high chin muscle tone
e.g. Alpha waves on a 30-second epoch
LESSON 1: SLEEP STAGE SCORING

Definition of Sleep Onset

It is 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).

It is the first epoch of sleep (no matter what stage) from Lights out.
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Stage N1
The EEG consists of theta waves, 4-7 cps (4-7 Hz)
AKA: Low Voltage Mixed Frequency (LVMF)
e.g. Theta waves on a 10-second epoch
LESSON 1: SLEEP STAGE SCORING

Stage N1
Makes up 5% of the Total Sleep Time (TST)
Vertex Sharp Waves may be present
The EOG shows Slow Eye Movements (SEMs)
The EMG is variable, but is often lower than Stage Wake
e.g. Theta waves on a 30-second epoch
LESSON 1: SLEEP STAGE SCORING

Vertex Sharp Wave
EEG characteristic:
Vertex sharp wave is a sharp negative deflection (upward) followed by a positive deflection (downward) lasting < 0.5 second (seen in the frontal/central regions; during the first half of the stage).

e.g. Stage N1 with vertex sharp wave
LESSON 1: SLEEP STAGE SCORING

Stage N2

The EEG consists of Theta waves interspersed with K-complexes and/or Sleep Spindles
Can be seen in Central, Frontal, or Occipital leads
e.g. Stage N2 with K-complexes and spindles
LESSON 1: SLEEP STAGE SCORING

Stage N2
Makes up 50% of the Total Sleep Time
The EEG consists of Theta waves interspersed with K-complexes and/or Spindles
The EOG activity is similar to EEG
The EMG has variable amplitude, but usually lower than Wake
e.g. Stage N2 (with K complexes and sleep spindles)
LESSON 1: SLEEP STAGE SCORING

K-Complex

- Well delineated negative sharp wave (upward) followed by a positive component (downward) lasting at least 0.5 sec duration.
LESSON 1: SLEEP STAGE SCORING

Sleep Spindles
The EEG consists of a frequency of 11-16 cps (11-16 Hz)
It can be seen in either Central or Frontal leads
The EOG is similar to EEG
e.g. Spindles on a 10-second epoch

Spindles= 13 cps
LESSON 1: SLEEP STAGE SCORING

The pattern is big, black & blotchy signal occurring at 0.5-1.5 second duration

*e.g. Spindles on a 30-second epoch*
LESSON 1: SLEEP STAGE SCORING

Continuation of Stage N2

- Score epochs with low amplitude, mixed frequency EEG activity without K-complexes or sleep spindles if they are preceded by:
  - K-complexes unassociated with arousals or
  - Sleep spindles
LESSON 1: SLEEP STAGE SCORING

Termination of Stage N2

a) Transition to Stage W
b) An arousal (↓ to Stage N1 until a K-complex unassociated with an arousal or sleep spindle occurs)
c) A major body movement followed by slow eye movements and LVMF EEG w/o non-associated K-complex or sleep spindles (Stage N1)
d) Transition to Stage N3
e) Transition to Stage R
LESSON 1: SLEEP STAGE SCORING

a) Termination of Stage N2= transition to Wake Stage
LESSON 1: SLEEP STAGE SCORING

b) An arousal (↓ to Stage N1 until a K-complex unassociated with an arousal or sleep spindle occurs)
LESSON 1: SLEEP STAGE SCORING

c) A major body movement followed by slow eye movements and LVMF EEG w/o non-associated K-complex or sleep spindles (Stage N1)
LESSON 1: SLEEP STAGE SCORING

d) Transition to Stage N3
LESSON 1: SLEEP STAGE SCORING

e) Transition to Stage R
LESSON 1: SLEEP STAGE SCORING

Stage N3
The EEG consists of a frequency of a 0.5-3 cps (0.5-3 Hz) with amplitudes >75 μV from peak-to-peak, occupying >20% of the epoch (cumulative)
The patterns are like Ocean waves or Skyscrapers e.g. Delta waves (Stage N3) on a 10-second epoch

Delta waves= 0.5-3 cps with amplitude of >75 μV
LESSON 1: SLEEP STAGE SCORING

Stage N3
Makes up 20-25% of the Total Sleep Time
It can be seen predominantly in frontal & central regions
The EOG is similar to EEG
The EMG has variable amplitude, often lower than in Stage N2 and sometimes as low as in Stage R sleep
LESSON 1: SLEEP STAGE SCORING

Stage R

Makes up 20 – 25% Total Sleep Time
The EEG consists of LVMF Theta waves, 4-7 cps (4-7 Hz). Alpha waves may be present but will be 1-2 cps slower than Wake Alpha.
Distinct feature is the presence of Sawtooth Waves which are sharply contoured or triangular waves, often serrated, 2-6 Hz, preceding a burst of rapid eye movements (REMs). The EOG shows presence of Rapid Eye Movements The EMG is significantly reduced compared to NREM sleep.
LESSON 1: SLEEP STAGE SCORING

Sawtooth theta waves

EEG channels

EOG channels

EMG channel

Rapid eye movement
LESSON 1: SLEEP STAGE SCORING

Continuation of Stage R
Continue to score Stage R even in the absence of rapid eye movements, for epochs following 1 or more epochs of Stage R, if the EEG continues to show LVMF activity without K-complexes or sleep spindles and the chin EMG tone remains low.
LESSON 1: SLEEP STAGE SCORING

End of Stage R

Stage R is ceased when 1 or more of the following occur:

a) Transition to Stage W or Stage N3

b) An arousal occurs followed by LVMF EEG and SEMs (if chin is up [Stage N1]; if chin is low w/no SEMs then score as Stage R)

c) A major body movement followed by SEM and LVMF EEG w/o non-arousal associated K-complexes or sleep spindles [Stage N1]
LESSON 1: SLEEP STAGE SCORING

End of Stage R (continued)

d) Score the epoch following the major body movement as Stage N1

e) If no slow eye movements and the EMG tone remains low, continue to score as Stage R

f) 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)
LESSON 1: SLEEP STAGE SCORING

a) Transition to Stage W or Stage N3
LESSON 1: SLEEP STAGE SCORING

b) An arousal occurs followed by LVMF EEG and SEMs (if chin is up [Stage N1]; if chin is low w/no SEMs then score as Stage R)
LESSON 1: SLEEP STAGE SCORING

c) A major body movement followed by SEM and LVMF EEG w/o non-arousal associated K-complexes or sleep spindles [Stage N1]
d) Score the epoch following the major body movement as Stage N1
e) If no slow eye movements and the EMG tone remains low, continue to score as Stage R
f) 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)
LESSON 1: SLEEP STAGE SCORING

Transition from Stage N2 to Stage R

• In between Stage N2 and Stage R, score an epoch with a distinct drop in chin EMG and 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.
  • Absence of non-arousal associated K-complexes
  • Absence of sleep spindles
LESSON 1: SLEEP STAGE SCORING

Stage N2 to Stage R

• 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:
  • Presence of non-arousal associated K-complexes or sleep spindles
  • Absence of rapid eye movements
LESSON 1: SLEEP STAGE SCORING

Ex. An epoch with both K-complex (Stage N2) and REM. This is scored as N2 as the 1st half of the epoch consists of K-complexes.
LESSON 1: SLEEP STAGE SCORING

Major Body Movements
Movement and muscle artifact obscuring the EEG for 50% of the epoch to the extent that the sleep stage cannot be determined
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 scorable 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.
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 scorable as Stage W either precedes OR follows the epoch with a major body movement, score as Stage W

e.g. If the previous or succeeding epoch is Stage W, then score this epoch as Stage W
c) Otherwise, score the epoch as the same stage as the epoch that follows it
   e.g. If the next epoch is Stage N1, then score this epoch as Stage N1.
LESSON 1: SLEEP STAGE SCORING

Reference

• AASM Manual for Scoring Sleep, 2007
LESSON 2: RESPIRATORY EVENTS SCORING

OBJECTIVES:
At the end of this lesson the student must be able to:
• Categorize abnormal respiratory events according to the definitions and sub-classifications of apnea, hypopnea, hypoventilation, periodic breathing, Cheyne – Stokes respiration and UARS
• Subdivide respiratory events into correct category
• Discriminate clinically significant events
• Measure respiratory events
• Measure oxygen desaturations
LESSON 2: RESPIRATORY EVENTS SCORING

Event Duration Rules

• 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.
LESSON 2: RESPIRATORY EVENTS SCORING

Score an apnea when ALL of the following criteria are met:

✔️ Drop in the peak thermal sensor or airflow sensor excursion by ≥90% of baseline
✔️ Duration of the event lasts at least 10 seconds.
✔️ At least 90% of the event’s duration meets the amplitude reduction criteria for apnea.
LESSON 2: RESPIRATORY EVENTS SCORING

Classify an apnea in an adult based upon inspiratory effort:

Score a respiratory event as an obstructive apnea if it meets apnea criteria and is associated with continued or increased effort throughout the entire period of absent airflow.
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. **Obstructive Apnea**

The airflow is reduced to at least 90% while there are still efforts on the chest and abdomen channel.
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Obstructive Apnea
LESSON 2: RESPIRATORY EVENTS SCORING

Classify an apnea in an adult based upon inspiratory effort:

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.
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Central Apnea

All the 3 channels (airflow/CPAP flow, chest and abdomen) ceased
LESSON 2: RESPIRATORY EVENTS SCORING

Classify an apnea in an adult based upon inspiratory effort:

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.
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Mixed Apnea

All the 3 channels (airflow, chest and abdomen) ceased then the inspiratory efforts (chest, abdomen) resume while the airflow is still absent
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Mixed Apnea
NOTE

• Identification of an apnea does not require a minimum desaturation criterion.
LESSON 2: RESPIRATORY EVENTS SCORING

Hypopnea Rules

Score a hypopnea if ALL of the following criteria are met:

☒ The nasal pressure signal excursions (or alternative hypopnea sensor) drop by $\geq 30\%$ of baseline.
☒ The duration lasts at least 10 seconds
☒ $\geq 4\%$ desaturation from pre-event baseline.
☒ At least 90% of the event’s duration must meet the amplitude reduction of criteria for hypopnea.
Score a Hypopnea if ALL of the following are met:

- The nasal pressure signal excursions (or alternative hypopnea sensor) drop by $\geq 50\%$ of baseline.
- The duration of this drop lasts at least 10 seconds.
- There is a $\geq 3\%$ desaturation from pre-event baseline or the event is associated with arousal.
- At least 90% of the event’s duration must meet the amplitude reduction of criteria for hypopnea.
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Hypopnea
The airflow is reduced to 50% associated with 4% desaturation (Note the red Max, 95%, & Min, 91.5%, saturation value on the right)
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Hypopnea
The airflow is reduced to 30% with associated 4% desaturation (Max=99%, Min=95%)
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Hypopnea
RESPIRATORY EFFORT-RELATED AROUSAL RULE

Score a respiratory effort-related arousal (RERA) 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.
LESSON 2: RESPIRATORY EVENTS SCORING

NOTE

When scoring RERAs, the use of esophageal pressure is the preferred method of assessing change in respiratory effort, although nasal pressure and inductance plethysmography can be used.
LESSON 2: RESPIRATORY EVENTS SCORING

Cheyne-Stokes Breathing Rule

At least THREE consecutive cycles of cyclical crescendo and decrescendo change in breathing amplitude AND at least ONE of the following:

- 5 or more central apneas OR [central] hypopneas per hour of sleep
- Cyclic crescendo and decrescendo change in breathing amplitude has duration of at least 10 consecutive minutes.
LESSON 2: RESPIRATORY EVENTS SCORING

Cheyne-Stokes Respiration

- Most common cause:
  - CHF
  - Renal failure
  - Meningitis
  - Drug overdose
    - \( \uparrow \) intracranial pressure
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Cheyne-Stoke’s Breathing
Note the 30-50% reduction on all respiratory channels (hypopneas)
LESSON 2: RESPIRATORY EVENTS SCORING

Ex. Cheyne-Stoke’s Breathing

Note the cessation of 3 respiratory channels (central apneas)
LESSON 2: RESPIRATORY EVENTS SCORING

Reference

• AASM Manual for Scoring Sleep, 2007
LESSON 3: EEG AROUSALS SCORING

OBJECTIVE:

At the end of this lesson the student must be able to:

• Apply standard criteria for determining arousals
LESSON 3: EEG AROUSALS SCORING

Scoring Arousals

Scoring during any stage of sleep if there is an abrupt shift of EEG frequency including alpha, theta, and/or frequencies > 16 Hz (but not spindles) that lasts at least 3 seconds, with at least 10 seconds of stable sleep preceding the change.
LESSON 3: EEG AROUSALS SCORING

Rule #1

Subjects must be asleep, defined as $\geq 10$ continuous seconds of the indication of any stage of sleep, before an EEG arousal can be scored.
LESSON 3: EEG AROUSALS SCORING

Rule #2

A minimum of 10 continuous seconds of intervening sleep is necessary to score a second arousal.
LESSON 3: EEG AROUSALS SCORING

Rule #3

The EEG frequency shift must be 3 seconds or greater in duration to be scored as an arousal.
LESSON 3: EEG AROUSALS SCORING

Rule #4
Arousals in NREM sleep may occur without concurrent increases in submental EMG amplitude.
LESSON 3: EEG AROUSALS SCORING

Rule #5

Arousals are scored in REM sleep **only** when accompanied by concurrent increases in submental EMG amplitude.
LESSON 3: EEG AROUSALS SCORING

Another example of Rule #5
LESSON 3: EEG AROUSALS SCORING

Rule #6

Arousals cannot be scored based on changes in submental EMG amplitude alone.
LESSON 3: EEG AROUSALS SCORING

Rule #7
Artifacts, K-complexes or Delta waves are not scored as arousals unless accompanied by an EEG frequency shift in at least one derivation. If such activity precedes an EEG frequency shift, it is not included in reaching the 3-second duration criteria.
LESSON 3: EEG AROUSALS SCORING

Rule #8

The occurrence of pen blocking artifact should be considered an arousal only if an EEG arousal pattern is contiguous. The pen blocking event can be included in reaching duration criteria.
LESSON 3: EEG AROUSALS SCORING

Rule #9
Non-current, but contiguous EEG and EMG changes, which were individually less than 3 seconds but together greater than 3 seconds in duration are not scored as arousals.
LESSON 3: EEG AROUSALS SCORING

Another example of Rule #9
LESSON 3: EEG AROUSALS SCORING

Rule #10

Intrusion of alpha activity of less than 3 seconds duration into NREM sleep at a rate greater than 1 burst per 10 seconds is not scored as an EEG arousal. Three seconds of alpha sleep is not scored as an arousal unless a 10 second episode of alpha-free sleep precedes.
LESSON 3: EEG AROUSALS SCORING

Rule #11

Transitions from one stage of sleep to another are not sufficient of themselves to be scored as EEG arousals unless they meet the criteria indicated above.
LESSON 3: EEG AROUSALS SCORING

Reference

• AASM Manual for Scoring Sleep, 2007
LESSON 4: PERIODIC LIMB MOVEMENT IN SLEEP (PLMS) SCORING

OBJECTIVES:
At the end of this lesson the student must be able to:

• Measure frequency, duration, and amplitude of limb movements
• Apply scoring rules for limb movements
LESSON 4: PLMS SCORING

The following rules define a significant leg movement event:

- Minimum duration is 0.5 seconds
- Maximum duration is 10 seconds

4. Minimum amplitude is an 8 $\mu$V increase in EMG voltage above resting EMG

5. Timing of the onset is defined as the point at which there is an 8 $\mu$V increase in EMG voltage above resting EMG.

6. Timing of the ending of a LM event is defined as the start of a period lasting at least 0.5 sec during which the EMG does not exceed 2 $\mu$V above resting EMG.
LESSON 4: PLMS SCORING

Scoring Limb Movements

• 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.
LESSON 4: PLMS SCORING

Scoring PLMS
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.
Application

- Surface electrodes should be placed longitudinally and symmetrically around the middle of the muscle so that they are 2-3 cm apart OR 1/3 of the length of the anterior tibialis muscle; whichever is shorter.
LESSON 4: PLMS SCORING

Impedances

- Use of 60 Hz (notch) filters should be avoided.
- Acceptable impedances $\leq 10,000 \ \Omega$
- Preferred impedances $\leq 5,000 \ \Omega$
- Sensitivity limits of -100 and 100 $\mu$V are preferred.
LESSON 4: PLMS SCORING

Scoring Criteria
Bursts of anterior tibialis muscle activity lasting 0.5-10 seconds and with an amplitude of at least \(8 \, \mu V\) from resting EMG.

4 LMs separated by at least 5 secs but not more than 90 secs. Separation is measured from LM onset to LM onset.
LESSON 4: PLMS SCORING

• Another example of PLMS
LESSON 4: PLMS SCORING

- Another example of PLMS
LESSON 4: PLMS SCORING

- PLMS Reference
- Sleep, Vol. 16, No. 8. 1993