

# Introduction to polysomnography



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## 수면다원검사 (Polysomnography)

수면 질환 **evaluation**에 기본적인 검사

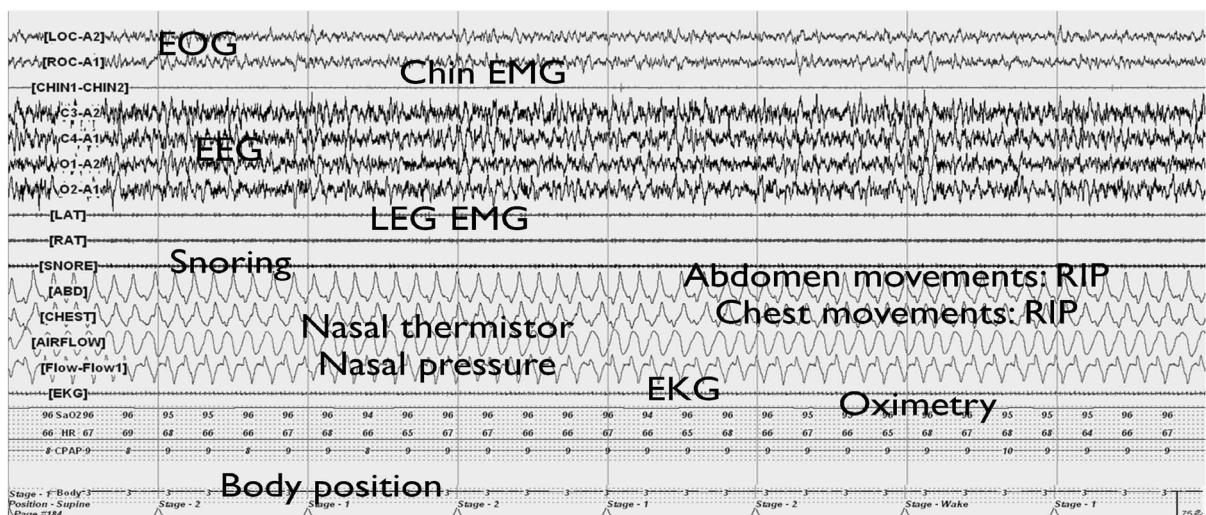
수면 무호흡증, 사건수면 (야경증, 몽유병, 렘수면장애), 수면 관련 뇌전증 등등



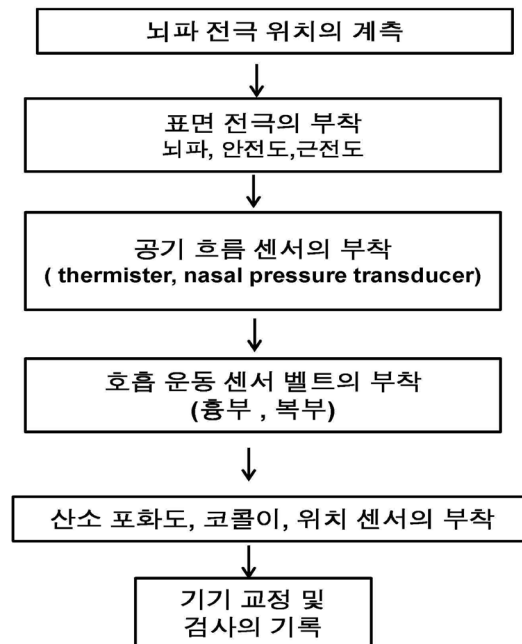
## 수면다원검사 (Polysomnography)

- ✓ EEG
- ✓ EOG
- ✓ Chin EMG
- ✓ Leg EMG
- ✓ Airflow: thermal sensor and nasal cannula pressure transducer
- ✓ Respiratory effort: RIP
- ✓ Pulse oximetry
- ✓ Snoring sounds/vibration
- ✓ Electrocardiogram
- ✓ Body position: piezoelectric belt
- ✓ Carbon dioxide
- ✓ Expanded EEG montages
- ✓ Video-PSG
- ✓ Esophageal pressure manometry
- ✓ Intraesophageal pH probe
- ✓ Arm EMG
- ✓ Nocturnal penile tumescence

## 수면다원검사 (Polysomnography)

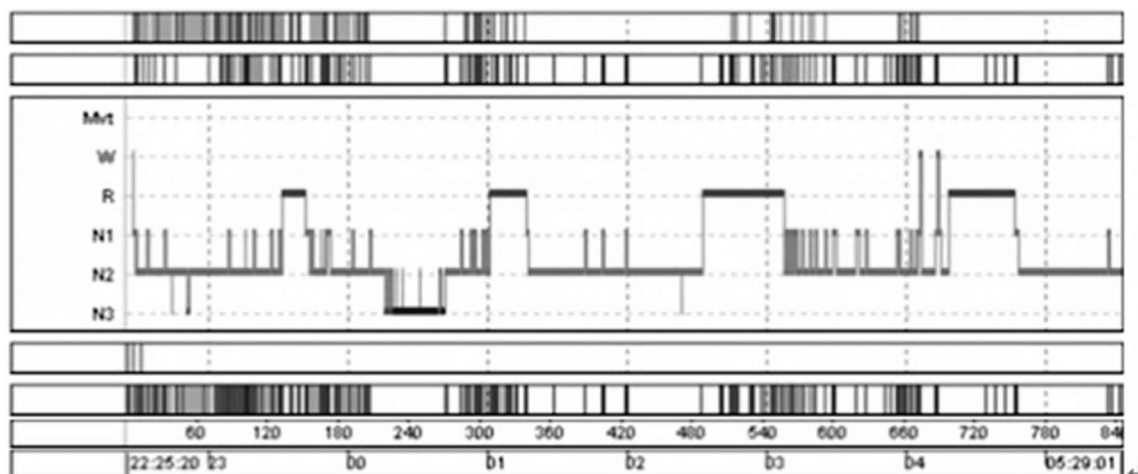


## 수면 다원 검사 기록기의 부착 흐름도



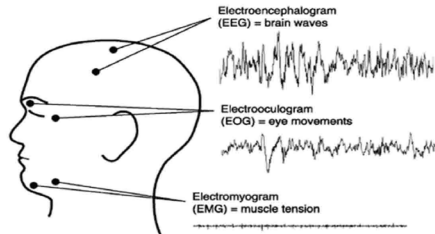
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## Hypnogram

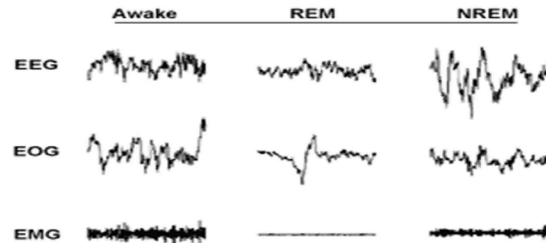


## Basic of Sleep staging

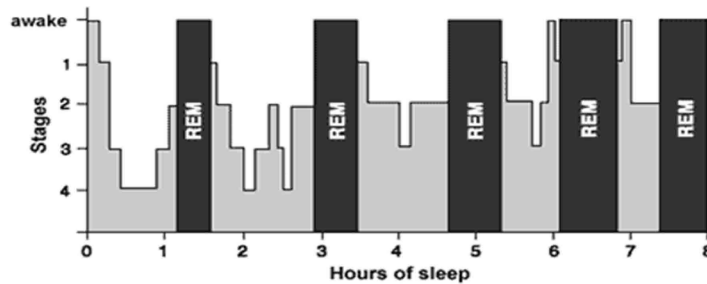
Placement of electrodes to determine EEG, EOG, and EMG



Characteristic EEG, EOG, and EMG patterns for wakefulness, REM sleep, and NREM sleep. Each 3-sec recording



A typical hypnogram from a young, healthy adult. Light-gray areas represent non-rapid eye movement (NREM) sleep. Stages scored from every **30-sec** of recordings of whole night polysomnography.



## EEG

### ▪ The recommended EEG derivations

- F4-M1
- C4-M1
- O2-M1

Backup electrodes F3,C3,O1, M2

F3-M2,C3-M2,O1-M2

### ▪ Acceptable EEG derivations

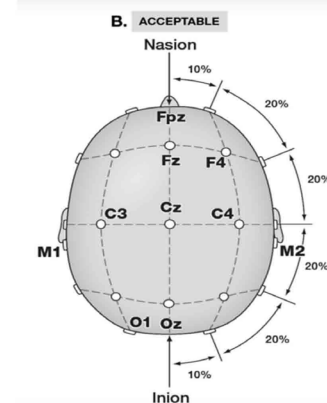
- Fz-Cz
- Cz-Oz
- C4-M1

Backup electrodes Fpz, C3,O1,M2

Fpz-C3, C3-O1, C3-M2

단, Fz-Cz는 서파 수면 여부를 결정하기 위한 Frontal activity의 amplitude를 측정하기는 부적합.

- 1) Acceptable EEG+ Acceptable EOG 설정: E1-Fpz
- 2) Acceptable EEG+ Recommended EOG: C4-M1 or C3-M2
- 3) Recommended EEG+ Recommended EOG: F4-M1



2016. 01.30



## EOG

### ▪ The recommended EOG derivations

- E1-M2 , E2-M1
- E2는 우측 외안각( outer canthus)의 상방 1cm,  
E1은 좌측 외안각 하방 1cm



### ▪ Acceptable EOG derivations

- E1-Fpz , E2-Fpz
- E2는 우측 외안각의 우측 1cm, 하방 1cm  
E1은 좌측 외안각의 좌측 1cm, 하방 1cm



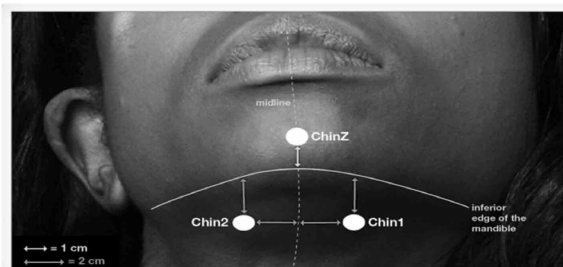
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## Chin EMG

- 턱근전도를 위해서는 3개의 전극  
(electrode)가 필요

- 하악의 아래 모서리( inferior edge) 중앙으로부터  
1cm 위에 하나
- 하악의 아래 모서리로부터 2cm 아래 , 오른쪽으로  
2cm 위치에 하나
- 하악의 아래 모서리로부터 2cm 아래 , 왼쪽으로  
2cm 위치에 하나

### Recommended



- Standard chin EMG: 하악골 상방의 전극과  
한쪽 하방 전극으로 구성, 나머지 하나의 하악골  
전극은 backup electrode.

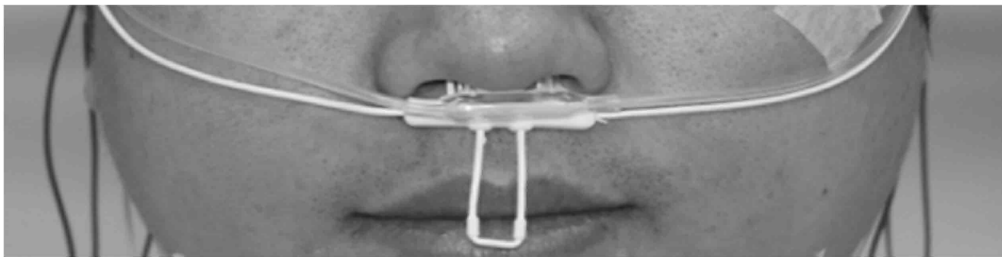
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## Leg EMG

- 표면 전극(surface electrode)은 세로방향 (longitudinally), 대칭적으로 (symmetrically) 이 되도록 부착
- 표면 전극은 Anterior tibialis 에 부착하고 두 전극 간의 거리는 2-3cm 간격을 두거나, anterior tibialis muscle 길이의 1/3 의 정도 되는 길이 중 짧은 것을 선택한다.

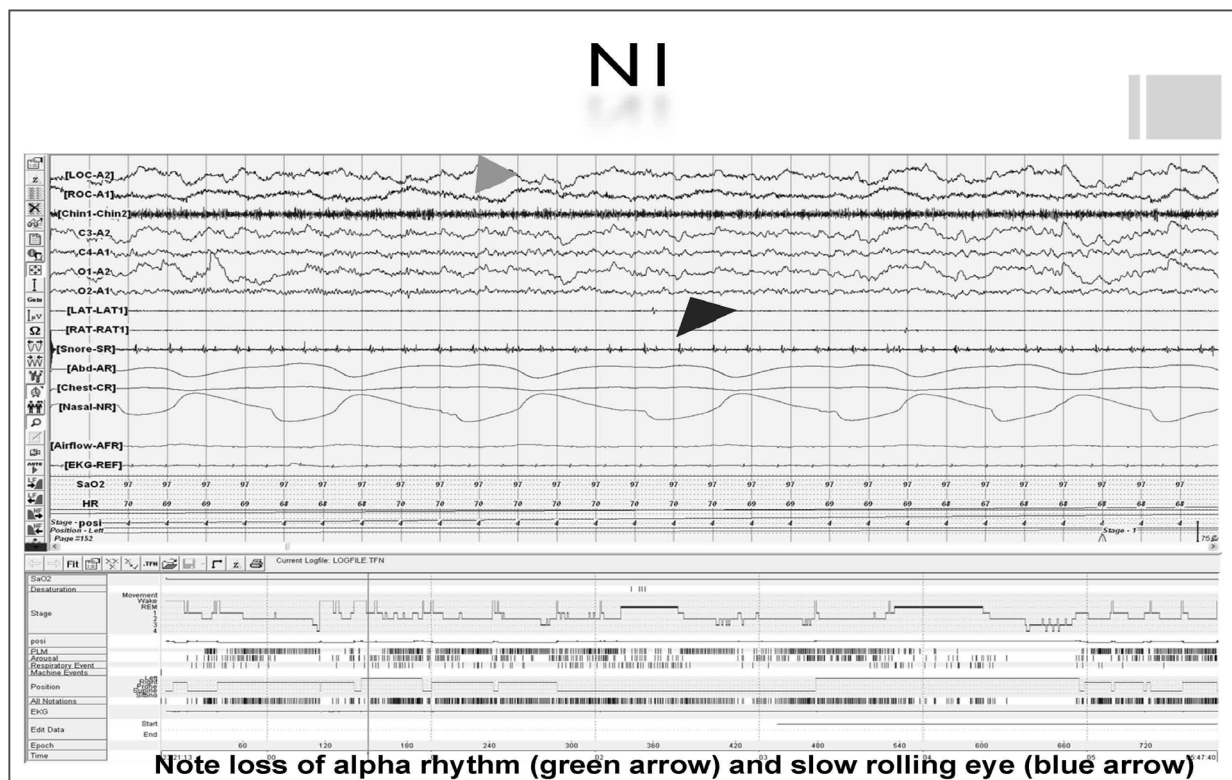
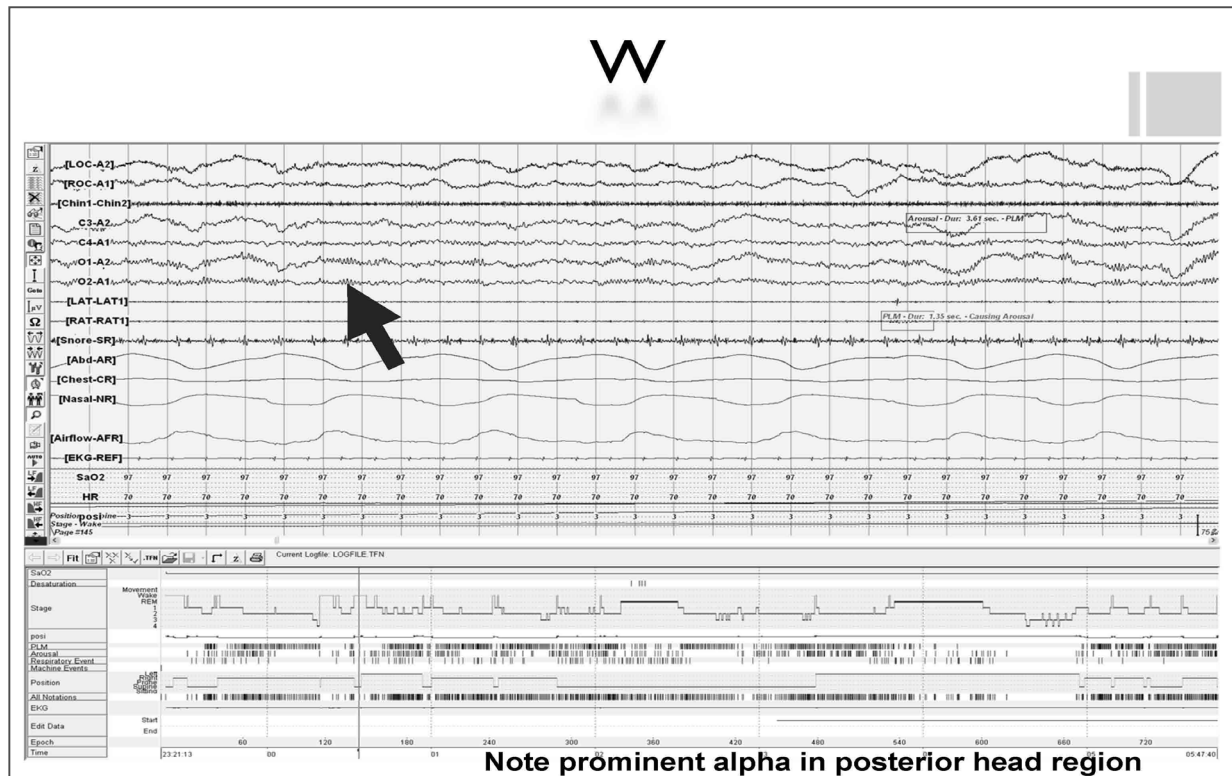
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## Air flow

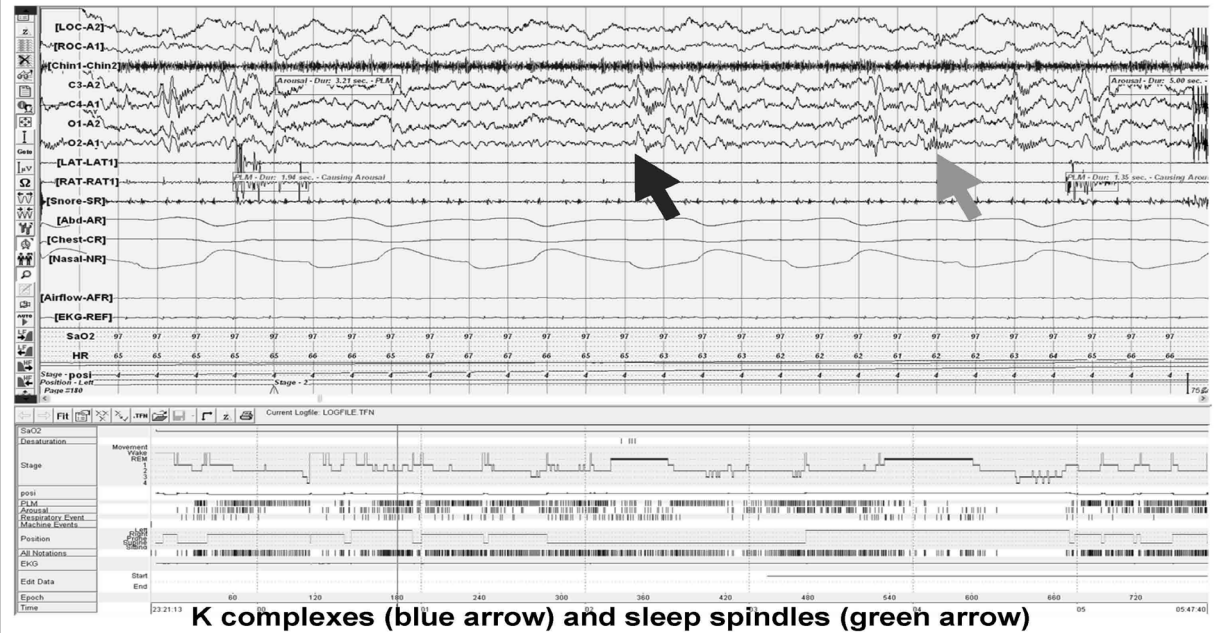


Oronasal thermister + Nasal pressure transducer

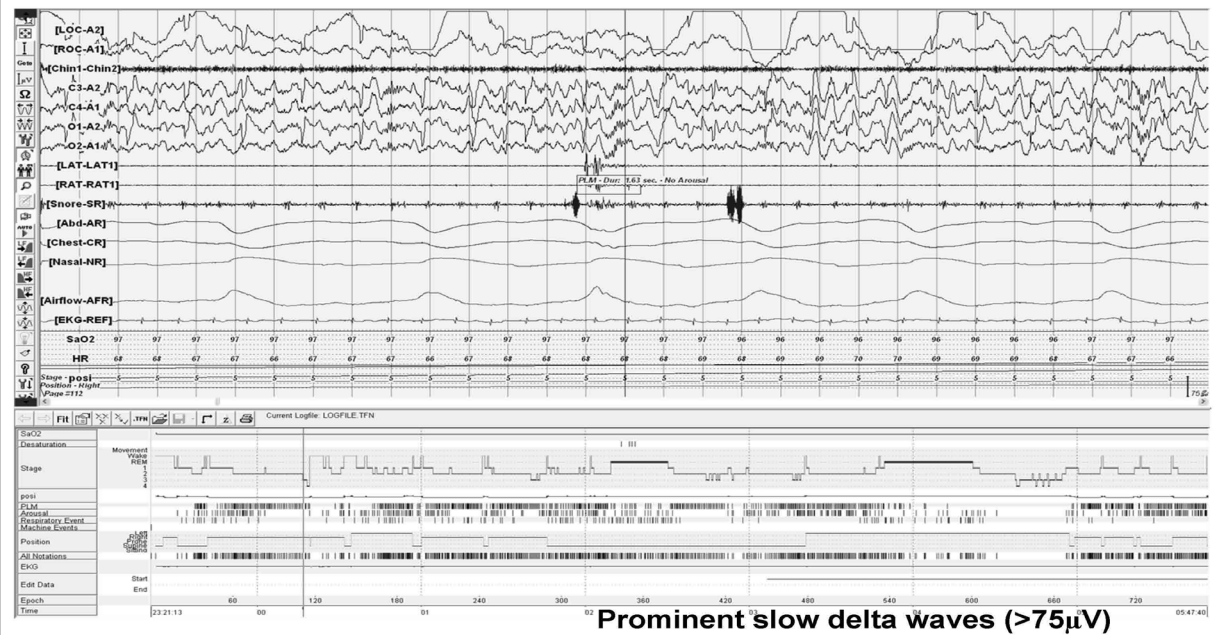
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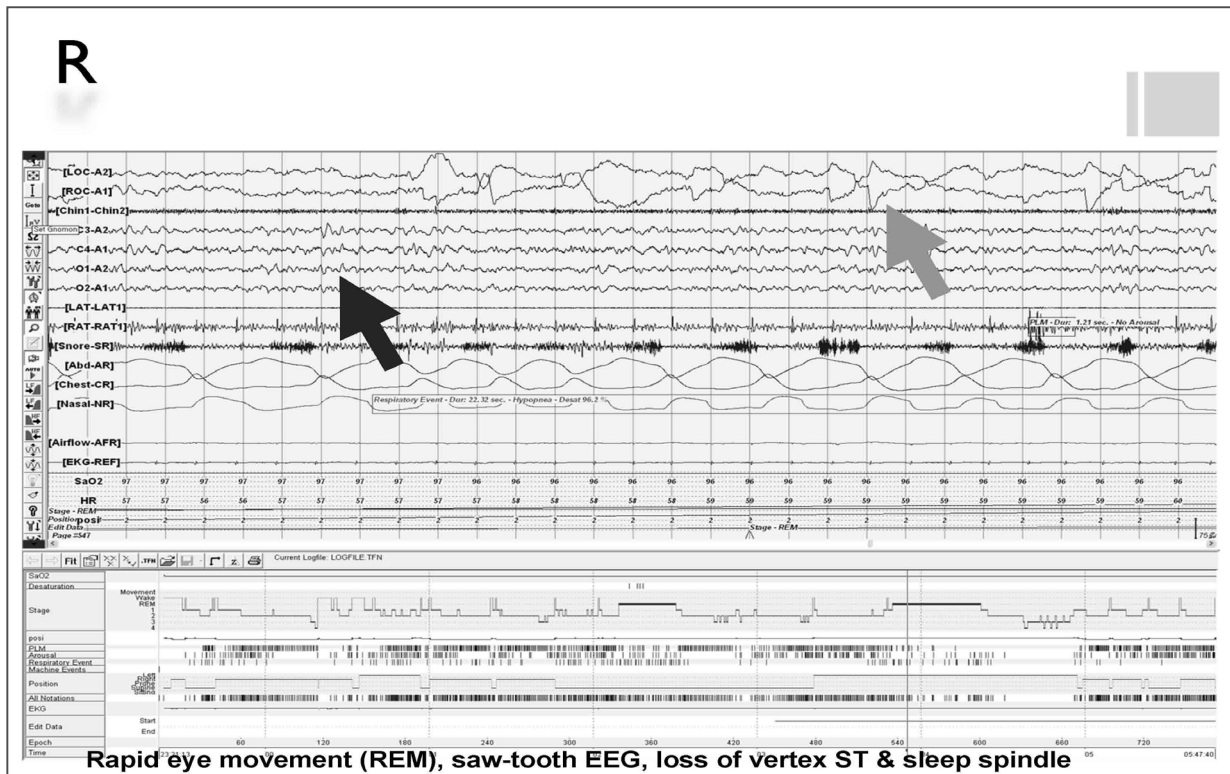


# N2



# N3





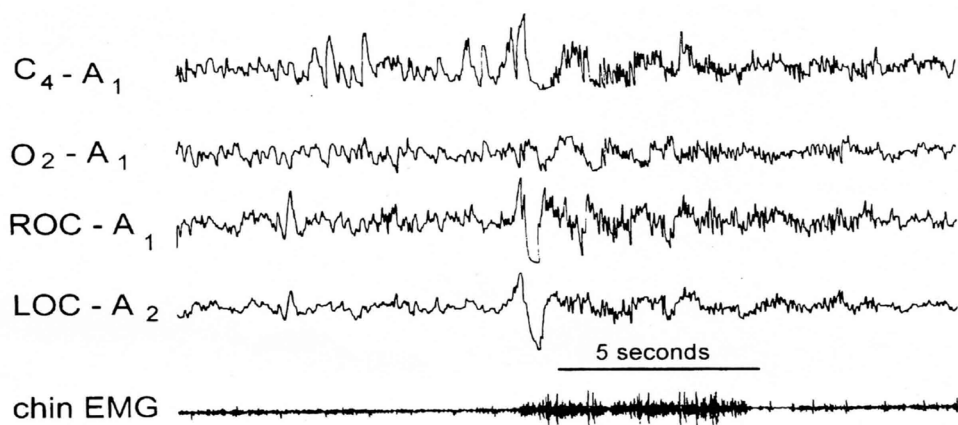
## Sleep Stages by PSG

- ✓ The sleep stage assigned to each epoch (**30 seconds**) is the stage occupying the **majority** of time within that epoch.
- ✓ N 1 is scored when alpha activity occupies less than 50% of an epoch: low-voltage, mixed frequency pattern with theta wave activity.
- ✓ N 2 is defined by presence of either sleep spindles or K complexes: sleep
  - ✓ **spindles** – oscillations of 12-14 Hz with a duration of 0.5-1.5 seconds
  - ✓ **K complex** – high amplitude, biphasic wave of at least 0.5-second duration.
- ✓ N 3 is scored when more than **20%** of an epoch has slow wave activity: slow (delta) wave – EEG activity slower than **2 Hz** (longer than 0.5-second duration) that has an amplitude (peak to peak) of **≥75 μV**.
- ✓ Stage R is defined only by rapid eye movement, although saw-tooth waves and low-voltage mixed frequency pattern may be present on EEG.
  - ✓ \* Incipient spindles (shorter than 0.5-second duration) on EEG are evidence for stage I

## Arousal (not wake)

- ✓ **Abrupt shift** in EEG frequency, which may include theta, alpha, and/or frequencies  $> 16$  Hz, but not spindles, of **3-second or longer** duration:
- ✓ Preceding artifacts, K-complex, or delta waves is not included in reaching the 3-second duration criteria
- ✓ Many disorders that are associated with EDS are associated with frequent, brief arousals
- ✓ Arousal index (number of arousals per hour of sleep): EDS generally is associated with an arousal index of  $> 25/\text{hour}$

## Arousal (not wake)



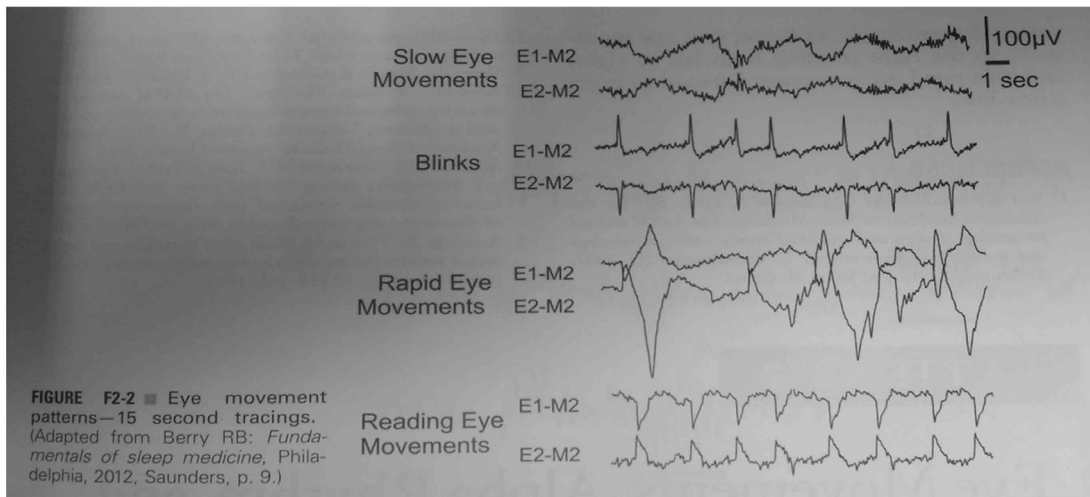
## Sleep Cycles

- ❖ Stage W (Wakefulness)
  - ❖ Stage N1 (NREM 1): < 10%
  - ❖ Stage N2 (NREM 2): 45~65%
  - ❖ Stage N3 (NREM 3 & 4, Slow-wave sleep): 5~40%
  - ❖ Stage R (REM): 20~25%
- \* 4 to 7 cycles per night: **N1 – N2 – N3 – N2 – R**
- \* N3 predominates in the first 1/3, and R increases during the last few hours

## Sleep Staging Rules – Stage W

### 1. Score in accordance with the following definitions:

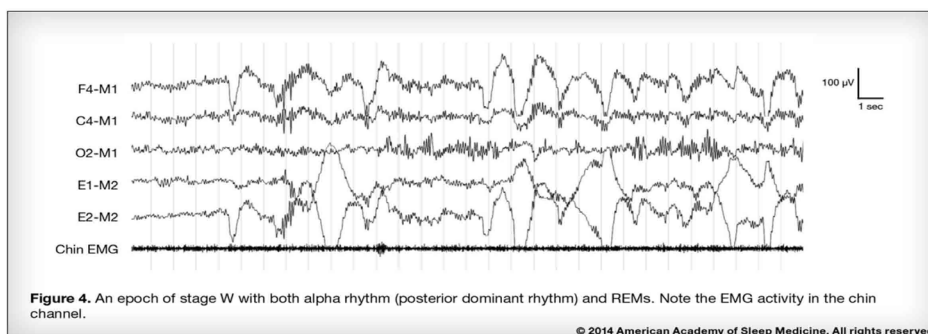
- **Alpha rhythm (posterior dominant rhythm):** Trains of sinusoidal 8-13 Hz activity recorded over the occipital region with eye closure, attenuating with eye opening.
- **Eye blinks:** Conjugate vertical eye movements at a frequency of 0.5-2 Hz present in wakefulness with the eyes open or closed.
- **Reading eye movements:** Trains of conjugate eye movements consisting of a slow phase followed by a rapid phase in the opposite direction as the individual reads.
- **Rapid eye movements (REM):** Conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500 msec. While rapid eye movements are characteristic of stage R sleep, they may also be seen in wakefulness with eyes open when individuals scan the environment.
- **Slow eye movements (SEM):** Conjugate, reasonably regular, sinusoidal eye movements with an initial deflection usually lasting >500 msec.



## Sleep Staging Rules – Stage W

**2. Score epochs as stage W when more than 50% of the epoch contains EITHER 2a or 2b or BOTH: (see Figure 4)**

- a. Alpha rhythm (posterior dominant rhythm) over the occipital region (individuals generating alpha rhythm with eye closure)
- b. Other findings consistent with stage W (all individuals)
  - i. Eye blinks (0.5 to 2 Hz)
  - ii. Rapid eye movements associated with normal or high chin muscle tone
  - iii. Reading eye movements





## Sleep Staging Rules – Stage W

- **Note 1.** Stage W represents the waking state, ranging from full alertness through early stages of drowsiness. Electrophysiological and psychophysiological markers of drowsiness may be present during stage W and may persist into stage N1.
- **Note 2.** In stage W, the majority of individuals with eyes closed will demonstrate alpha rhythm (posterior dominant rhythm). The EEG pattern with eyes open consists of low-amplitude activity (chiefly beta and alpha frequencies) without the rhythmicity of alpha rhythm. About 10% of individuals do not generate an alpha rhythm upon eye closure, and a further 10% may generate a limited alpha rhythm. In these individuals, the occipital EEG activity is similar during eye opening and eye closure.
- **Note 3.** The EOG during wakefulness may demonstrate rapid eye blinks at a frequency of about 0.5-2 Hz. The earliest sign of drowsiness is the absence of eye blinks. As drowsiness develops, slow eye movements may develop, even in the presence of continued posterior dominant rhythm. If the eyes are open, voluntary rapid eye movements or reading eye movements may be seen.
- **Note 4.** The chin EMG during stage W is of variable amplitude but is usually higher than during sleep stages.
- **Note 5.** Time with the patient disconnected from the recording equipment should be scored as stage W. Brief episodes of sleep during this time, if they occur, are not considered significant for the stage scoring summary.

## Sleep Staging Rules – Stage N1

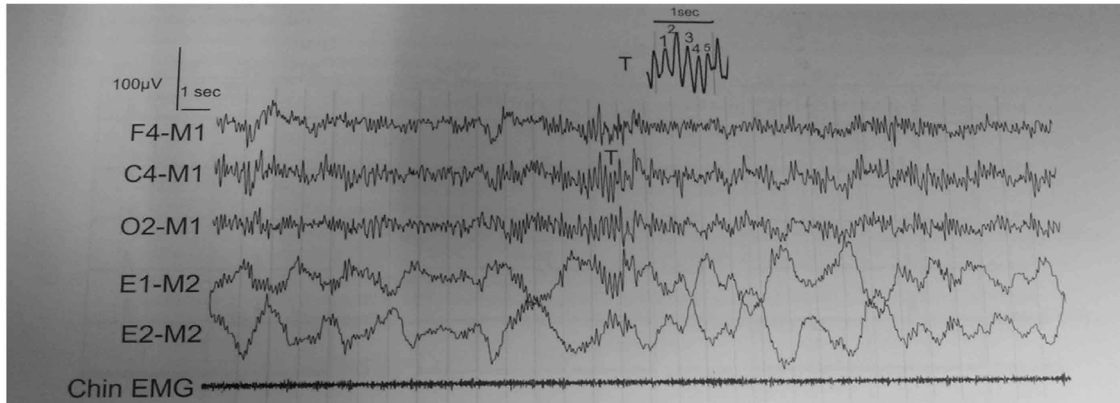
### 1. Score in accordance with the following definitions:

- **Slow eye movements (SEM):** Conjugate, reasonably regular, sinusoidal eye movements with an initial deflection usually lasting >500 msec.
- **Low-amplitude, mixed-frequency EEG activity:** Low-amplitude, predominantly 4-7 Hz activity.
- **Vertex sharp waves (V waves):** Sharply contoured waves with duration <0.5 seconds maximal over the central region and distinguishable from the background activity.
- **Sleep onset:** The start of the first epoch scored as any stage other than stage W. (In most subjects this will usually be the first epoch of stage N1.)

### 2. In individuals who generate alpha rhythm, score stage N1 if the alpha rhythm is attenuated and replaced by low-amplitude, mixed-frequency activity for more than 50% of the epoch.<sup>N1,N2,N3</sup>

### 3. In individuals who do not generate alpha rhythm, score stage N1 commencing with the earliest of ANY of the following phenomena:<sup>N1,N2,N3,N4,N5</sup>

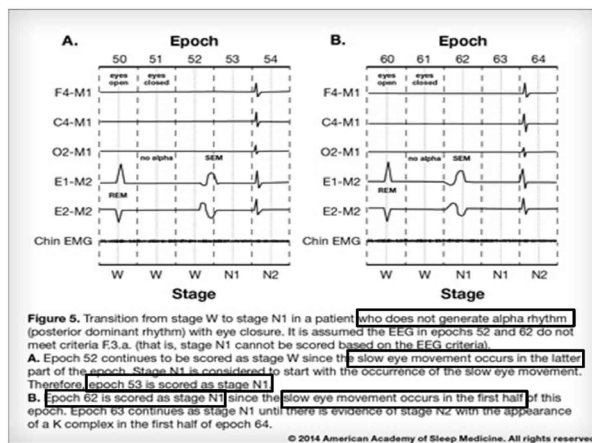
- a. EEG activity in range of 4-7 Hz with slowing of background frequencies by  $\geq 1$  Hz from those of stage W
- b. Vertex sharp waves
- c. Slow eye movements



**FIGURE F3-4 ■ Stage N1.** A 30 second epoch of stage N1 showing low-amplitude, mixed-frequency electroencephalography (EEG) output without K-complexes or sleep spindles. Slow eye movements (SEMs) are prominent here but are not required for scoring stage N1. In individuals who do not generate alpha on eye closure, the presence of slow eye movements is a criteria for scoring stage N1. Note the activity at (T) is theta activity of 5 hertz (Hz) (theta is 4–8 Hz).

## Sleep Staging Rules – Stage N1

4. An epoch is scored as stage N1 if the **majority** of the epoch meets the criteria for stage N1 (EEG showing LAMF EEG activity) **in the absence of evidence for another sleep stage**. Subsequent epochs with an EEG showing LAMF EEG activity are scored as stage N1 until there is evidence for another sleep stage (usually stage W, stage N2 or stage R).



## Sleep Staging Rules – Stage N1



**5. When an arousal interrupts stage N2 sleep, score subsequent segments of the recording as stage N1 if the EEG exhibits low-amplitude, mixed-frequency activity without one or more K complexes and/or sleep spindles until there is evidence for another stage of sleep (see G. Scoring Stage N2).**

**6. When an arousal interrupts stage R sleep and is followed by a low-amplitude, mixed-frequency EEG without posterior dominant rhythm AND with slow eye movements, score the segments of the record containing the eye movements as stage N1 even if the chin EMG activity remains low (at the stage R level). Continue to score stage N1 until there is evidence for another stage of sleep, usually stage N2 (see G.2) or stage R (see I.2 and I.3).**

## Sleep Staging Rules – Stage N1



**Note 1.** Vertex sharp waves may be present but are not required for scoring stage N1.

**Note 2.** The EOG will often show slow eye movements in stage N1, but these are not required for scoring.

**Note 3.** During stage N1, the chin EMG amplitude is variable, but often lower than in stage W.

**Note 4.** As slow eye movements often commence before attenuation of alpha rhythm, sleep latency may be slightly shorter for some individuals who do not generate alpha rhythm compared to those who do.

**Note 5.** Theta frequency (4-7 Hz) waveforms that are of pathological origin (such as those resulting from neurological impairment, encephalopathy or epilepsy) should not be considered toward the determination of Stage N1 sleep. In a person with a slow background EEG in the awake state, further non-pathological slowing of the background activity of >1 Hz from that seen in the wake state would be considered evidence of Stage N1 sleep.

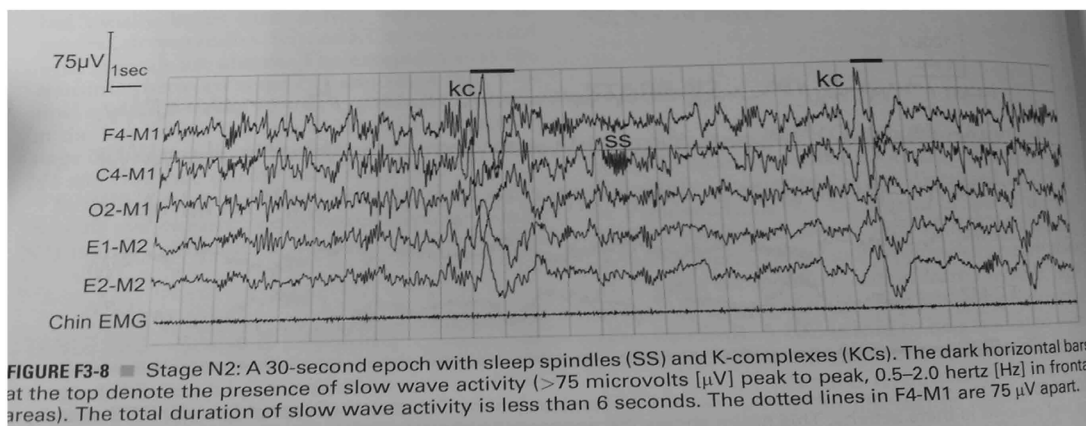
## Sleep Staging Rules – Stage N2

### 1. Score in accordance with the following definitions:

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

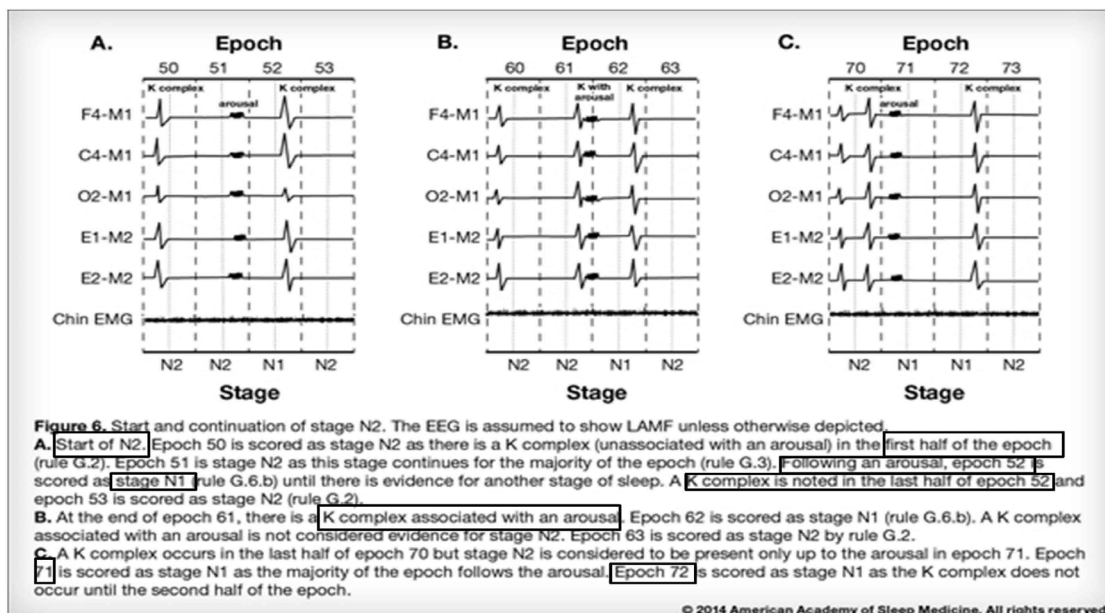
### 2. Begin scoring stage N2 (in absence of criteria for N3) if EITHER or BOTH of the following occur during the first half of that epoch or the last half of the previous epoch:<sup>N1,N2,N3,N4</sup>

- a. One or more K complexes unassociated with arousals
- b. One or more sleep spindles



## Sleep Staging Rules – Stage N2

**3. Score a given epoch as stage N2 if the majority of the epoch meets criteria for stage N2. If the waveforms in rule G.2.a or G.2.b are followed by an arousal in the same or subsequent epoch (see Figure 6), the segment of the recording preceding the arousal is considered stage N2 (see rule G.6.b).<sup>N1,N5</sup>**

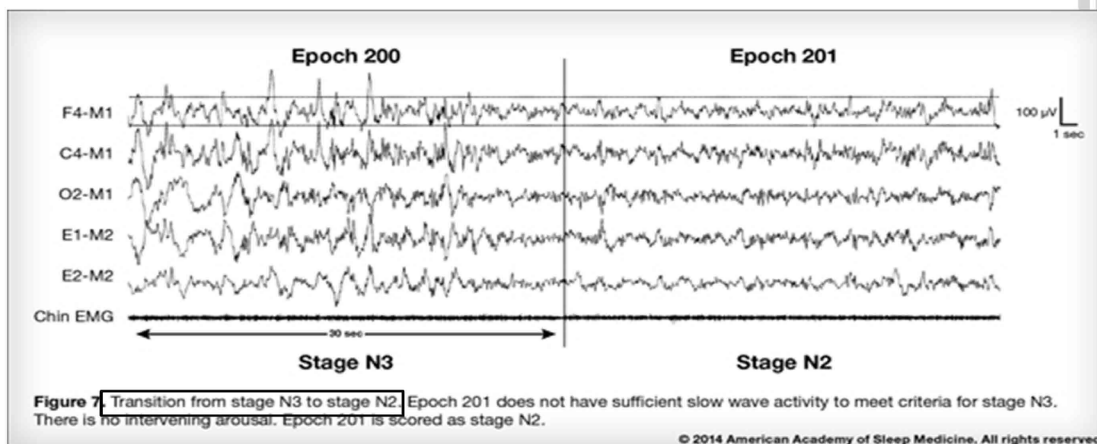


## Sleep Staging Rules – Stage N2

**4. Continue to score epochs with low-amplitude, mixed-frequency EEG activity without K complexes or sleep spindles as stage N2 if they are preceded by epochs containing EITHER of the following(N2) and there is no intervening arousal:**

- a. K complexes unassociated with arousals
- b. Sleep spindles

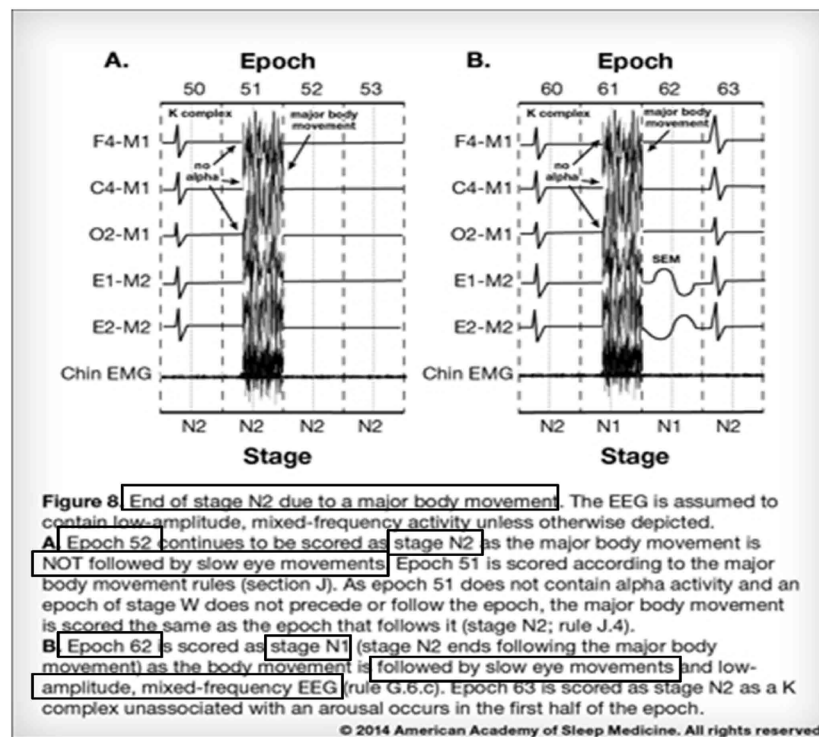
**5. Epochs following an epoch of stage N3 that do not meet criteria for stage N3 are scored as stage N2 if there is no intervening arousal and the epoch does not meet criteria for stage W or stage R. (see Figure 7)**



## Sleep Staging Rules – Stage N2

### 6. End scoring stage N2 sleep when ONE of the following events occurs:<sup>N6,N7</sup>

- Transition to stage W
- An arousal followed by low-amplitude, mixed-frequency EEG (change to stage N1 until a K complex unassociated with an arousal or a sleep spindle occurs) (see Figure 6). This assumes that the epoch does not meet criteria for stage R (rule I.3) (see Figure 10C).
- A **major body movement**
  - followed by **slow eye movements** and low-amplitude, mixed-frequency EEG without non-arousal associated K complexes or sleep spindles (score the epoch following the major body movement as **stage N1**;
  - score the epoch as **stage N2** if there are **no slow eye movements**; (the epoch containing the body movement is scored using the major body movement rules under section J))
- Transition to stage N3
- Transition to stage R



## Sleep Staging Rules – Stage N2

**Note 1.** An epoch of stage N2 meeting criteria in rule G.2 is termed **definite stage N2**. If there is a conflict between a stage N2 and stage R scoring rule, the stage R rule takes precedence (see I.4).

**Note 2.** Continue to score stage N1 for epochs with arousal-associated K complexes unless they contain sleep spindles or K complexes not associated with arousals.

**Note 3.** For the purposes of scoring N2 sleep, arousals are defined according to the arousal rule in section V.A.1.

**Note 4.** Although frequency changes associated with arousals and sleep spindles are more typically noted in the central and occipital derivations respectively, these events should be used to score sleep even if they are only noted in the frontal derivations.

**Note 5.** For scoring epochs with a mixture of K complexes and/or sleep spindles and REMs, see rule I.7.

**Note 6.** The EOG usually shows no eye movement activity during stage N2 sleep, but slow eye movements may persist in some individuals.

**Note 7.** In stage N2, the chin EMG is of variable amplitude, but is usually lower than in stage W, and may be as low as in stage R sleep.

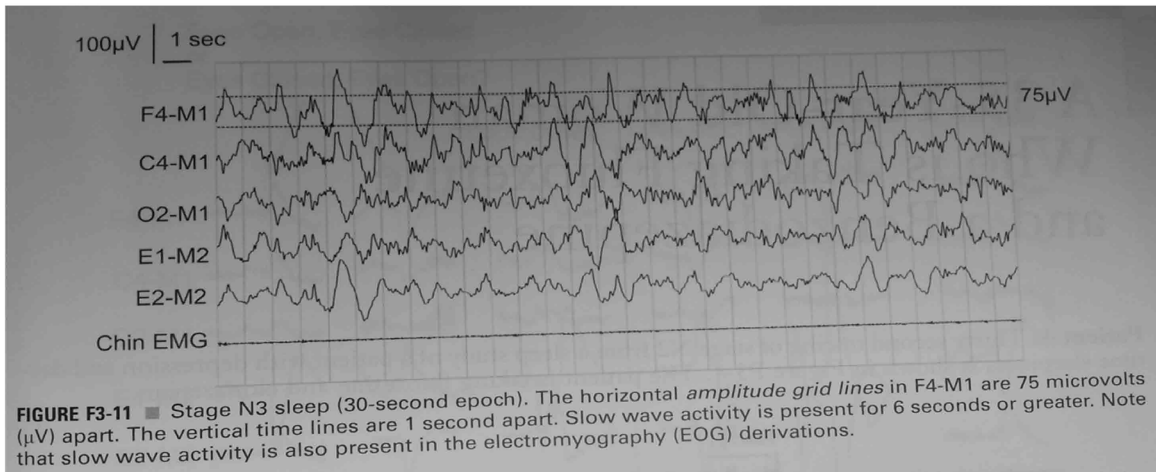
## Sleep Staging Rules – Stage N3

**1. Score in accordance with the following definition:**<sup>N2,N3</sup>

- **Slow wave activity:** Waves of frequency 0.5 Hz-2 Hz and peak-to-peak amplitude >75  $\mu$ V, measured over the frontal regions referenced to the contralateral ear or mastoid (F4-M1, F3-M2).

**2. Score stage N3 when  $\geq 20\%$  of an epoch consists of slow wave activity, irrespective of age.**<sup>N4,N5,N6</sup>





## Sleep Staging Rules – Stage N3

**Note 1.** Stage N3 represents slow wave sleep and replaces the Rechtschaffen and Kales nomenclature of stage 3 and stage 4 sleep.

**Note 2.** K complexes would be considered slow waves if they meet the definition of slow wave activity.

**Note 3.** Pathological wave forms that meet the slow wave activity criteria, such as those generated by metabolic encephalopathies, epileptic, or epileptiform activity, are not counted as slow wave activity of sleep. Similarly, waveforms produced by artifact or those of non-cerebral origin should not be included in the scoring of slow waves.

**Note 4.** Sleep spindles may persist in stage N3 sleep.

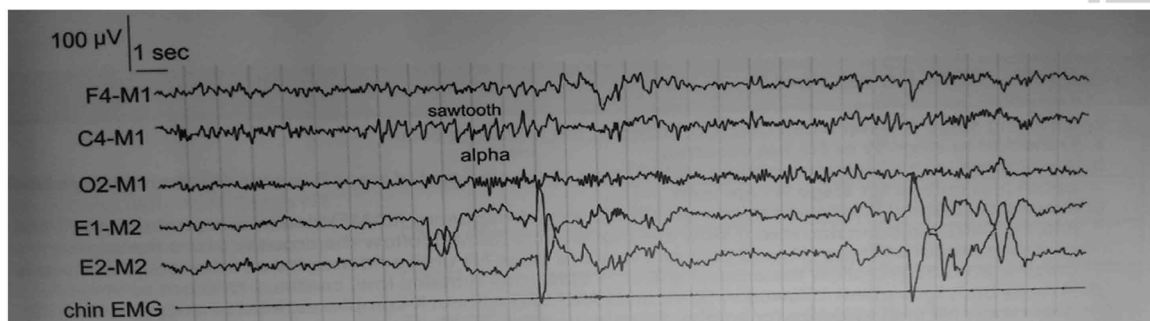
**Note 5.** Eye movements are not typically seen during stage N3 sleep.

**Note 6.** In stage N3, the chin EMG is of variable amplitude, often lower than in stage N2 sleep and sometimes as low as in stage R sleep.

## Sleep Staging Rules – Stage R

### 1. Score in accordance with the following definitions:

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



**FIGURE F4-1** ■ An epoch of definite rapid eye movement (REM) sleep with REMs, low chin electromyography (EMG) tone, and an electroencephalography (EEG) with low amplitude mixed frequency activity without K- complexes or sleep spindles. Sawtooth waves (C4-M1) and a burst of alpha activity (O2-M1) are also present in this epoch and are often present during stage R. However sawtooth waves are not required for scoring stage R. Alpha activity during stage R is often 1 to 2 Hz lower in frequency than the alpha activity during stage W.

## Sleep Staging Rules – Stage R

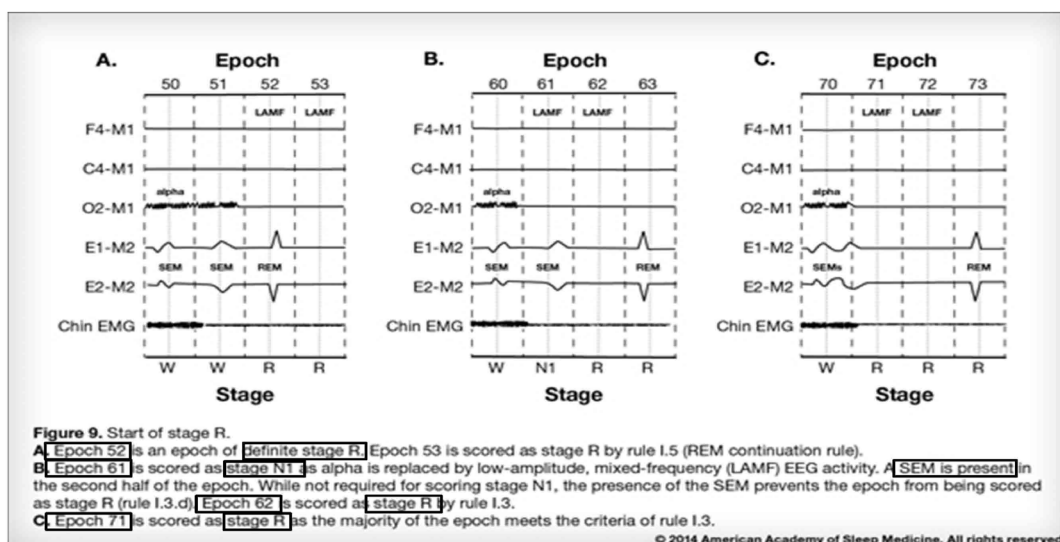
### 2. Score stage R sleep in epochs with ALL of the following phenomena (definite stage R):<sup>N1,N2,N3,N4,N5,N6</sup>

- Low-amplitude, mixed-frequency (LAMF) EEG activity without K complexes or sleep spindles
- Low chin EMG tone for the majority of the epoch and concurrent with REMs
- REMs at any position within the epoch

### 3. Score segments of sleep preceding and contiguous with an epoch of definite stage R (as defined in I.2), *in the absence of rapid eye movements*, as stage R if ALL of the following are present: (see Figures 9, 10 and 11)

- The EEG shows low-amplitude, mixed-frequency activity without K complexes or sleep spindles<sup>N3</sup>
- The chin EMG tone is low (at the stage R level)
- There is no intervening arousal (see Figure 10C)
- Slow eye movements following an arousal or stage W are absent<sup>N6</sup>

## Sleep Staging Rules – Stage R



## Sleep Staging Rules – Stage R

**4. If the *majority* of an epoch contains a segment of the recording meeting criteria for stage R (I.2, I.3, I.5), the epoch is scored as stage R. Stage R rules take precedence over stage N2 rules. (see Figure 10, epoch 62 and Figure 11, epoch 72)**

**5. Continue to score segments of sleep that follow one or more epochs of definite stage R (as defined in I.2), in the absence of rapid eye movements, as stage R if ALL of the following are present: (see Figures 12-16)**

- a. The EEG shows LAMF EEG activity without K complexes or sleep spindles
- b. The chin EMG tone is low (at the stage R level) for the majority of the epoch
- c. There is no intervening arousal

## Sleep Staging Rules – Stage R

**6. End scoring stage R sleep when ONE OR MORE of the following occur:**

- a. There is a transition to stage W or N3
- b. An increase in chin EMG tone above the level of stage R is seen for the majority of the epoch and criteria for stage N1 are met (see Figure 12, epoch 62)
- c. An arousal occurs followed by low-amplitude, mixed-frequency EEG and **slow eye movements** (Score the epoch as stage N1; if there are no slow eye movements and chin EMG tone remains low, continue to score as **stage R**) (see Figure 13)
- d. A **major body movement** followed by **slow eye movements** and low-amplitude, mixed-frequency EEG without non-arousal associated K complexes or sleep spindles (Score the epoch following the major body movement as stage N1; if no slow eye movements are present and the EMG tone remains low, continue to score as **stage R**; the epoch containing the body movement is scored using the criteria under heading J) (see Figure 14)
- e. One or more non-arousal associated K complexes or sleep spindles are present in the first half of the epoch in the absence of rapid eye movements, even if chin EMG tone remains low (Score the epoch as **stage N2**) (see Figure 15)

## Sleep Staging Rules – Stage R

**7. Score segments of the record with low chin EMG activity and a mixture of REMs and sleep spindles and/or K complexes as follows:** <sup>N1,N2,N3,N4,N5,N6</sup>

- a. Segments between two K complexes, two sleep spindles, or a K complex and sleep spindle without intervening REMs are considered to be **stage N2**.
- b. Segments of the record containing REMs without K complexes or sleep spindles and chin tone at the REM level are considered to be **stage R**.
- c. If the majority of an epoch contains a segment considered to be stage N2, it is scored as stage N2. If the majority of an epoch contains a segment considered to be stage R, it is scored as stage R. (see Figure 16)

## Sleep Staging Rules – Stage R

**Note 1.** Epochs defined by rule 1.2 are called epochs of **definite stage R**.

**Note 2.** Low-amplitude, mixed-frequency activity in stage R resembles that seen in stage N1. In some individuals, a greater amount of alpha activity can be seen in stage R than in stage N1. The alpha frequency in stage R often is 1-2 Hz slower than during wakefulness.

**Note 3.** Sawtooth waves or transient muscle activity are strongly supportive of the presence of stage R sleep and may be helpful when the stage is in doubt, however, they are not required for scoring stage R.

**Note 4.** For scoring epochs with low chin EMG tone and a mixture of REMs and K complexes or sleep spindles see 1.7.

**Note 5.** Slow eye movements can occur during stage R but slow eye movements following an arousal in combination with an EEG showing LAMF activity suggests a transition to stage N1 even if the chin tone remains low.

**Note 6.** Segments of the record 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.

## Arousal Rule



1. Score **arousal** during sleep stages N1, N2, N3, or R if there is an abrupt shift of EEG frequency including alpha, theta and/or frequencies greater than 16 Hz (but not spindles) that lasts at least 3 seconds, with at least 10 seconds of stable sleep preceding the change.

Scoring of arousal **during REM** requires a **concurrent increase in submental EMG** lasting at least 1 second.<sup>N1,N2,N3,N4</sup>

## Arousal Rule



**Note 1.** Arousal scoring should incorporate information from both the occipital and central derivations.

**Note 2.** Arousal scoring can be improved by the use of additional information in the recording such as respiratory events and/or additional EEG channels. Scoring of arousals, however, cannot be based on this additional information alone and such information does not modify any of the arousal scoring rules.

**Note 3.** Arousals meeting all scoring criteria but occurring during an awake epoch in the recorded time between "lights out" and "lights on" should be scored and used for computation of the arousal index.

**Note 4.** The 10 seconds of stable sleep required prior to scoring an arousal may begin in the preceding epoch, including a preceding epoch that is scored as stage W.

## Sleep Staging Rules – Epochs with Major Body Movements

### 1. Score in accordance with the following definition:

**Major body movement:** Movement and muscle artifact obscuring the EEG for more than half an epoch to the extent that the sleep stage cannot be determined.

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

### 3. If no alpha rhythm is discernible, but an epoch scoreable as stage W either precedes or follows the epoch with a major body movement, score as stage W.

### 4. Otherwise, score the epoch as the same stage as the epoch that follows it.

MEN (Age in Years)	20-29	30-39	40-49	50-59	60-69	70-79
Total recording time (TRT)	430-454	414-455	390-468	378-468	414-489	444-543
TST (Total sleep time) (minutes [min])	405-445	400-440	390-430	380-425	370-420	360-415
Sleep efficiency (%)	94-98	90-96	87-94	84-92	80-90	76-88
Sleep latency (min)	3-26	2-20	2-20	1-22	2-25	5-30
Rapid eye movement (REM) latency (min)	75-115	70-110	70-105	65-100	65-95	60-90
Wakefulness after sleep onset (WASO) (min)	0-5	5-25	10-50	15-58	20-65	25-80
Stage N1 (%TST)	3-6	5-9	5-11	6-12	6-14	6-15
Stage N2 (%TST)	40-55	45-60	45-65	50-75	55-75	55-75
Stage N3 (%TST)	10-25	7-18	2-15	0-13	0-8	0-5
Stage R (%TST)	22-28	20-26	19-25	18-23	17-22	16-21

WOMEN	20-29	30-39	40-49	50-59	60-69	70-79
Total recording time (TRT)	430-454	425-462	419-464	420-514	420-511	451-563
Total sleep time (TST) (min)	410-460	400-450	390-440	380-430	375-425	370-420
Sleep efficiency (%)	94-98	90-95	87-94	84-92	80-90	76-88
Sleep Latency (min)	3-23	0-20	2-25	3-25	3-25	5-30
REM latency (min)	75-115	70-110	70-105	65-100	65-95	60-90
WASO (min)	0-5	5-25	10-40	15-55	20-65	25-80
Stage N1 (%TST)	2-7	3-8	4-9	5-10	5-12	5-15
Stage N2 (%TST)	40-55	43-58	45-60	50-65	50-65	50-65
Stage N3 (%TST)	15-25	10-21	8-19	5-17	5-15	5-15
Stage R (%TST)	23-29	21-27	20-26	19-24	18-23	17-22

## Sleep Indices

- ✓ Time in bed (TIB): monitoring period – lights out to lights on
- ✓ Total sleep time (TST): Total minutes of sleep
- ✓ Wake after sleep onset (WASO): Minutes of wake after initial sleep onset and before the final awakening
- ✓ Sleep period time (SPT) TST + WASO
- ✓ Sleep efficiency (%)  $(TST \times 100) / TIB$
- ✓ Sleep latency (min) Time from lights out to the first epoch of sleep
- ✓ REM latency (min) Time from sleep onset to the first epoch of REM sleep

## VII. Movement Rules

AASM Manual for Scoring Sleep,  
2007

### 1. Scoring periodic limb movements in sleep (PLMS)

[Recommended]

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

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



## VII. Movement Rules

AASM Manual for Scoring Sleep, 2007

**B. The following rules define a PLM series :**

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

## VII. Movement Rules

AASM Manual for Scoring Sleep,  
2007

**Notes :**

- 1. An LM should not be scored if it occurs during a period from 0.5 seconds preceding an apnea or hypopnea to 0.5 seconds following an apnea and hypopnea.**
- 2. An arousal and a PLM should be considered associated with each other when there is < 0.5 seconds between the end of one event and the onset of the other event regardless of which is first.**
- 3. Surface electrodes should be placed longitudinally and symmetrically around the middle of the muscle so that they are 2 to 3 cm apart or 1/3 of the length of the anterior tibialis muscle, whichever is shorter. Both legs should be monitored for the presence of the leg movements. Separate channels for each leg are strongly preferred. Combining electrodes from the 2 legs to give 1 recorded channel may suffice for some clinical settings, though it should be recognized that this strategy may reduce the number of detected LMs. Movements of the upper limbs may be sampled if clinically indicated.**

## PSG finding – Obstructive apnea syndrome

- Apnea
  - Central type, Obstructive type
- Hyponea
  - Central type, Obstructive type
- RERA (Respiratory effort related arousal)

### Apnea (Adults)

Score a respiratory event as an apnea when BOTH of the following criteria are met:

1. A drop exists in the peak signal excursion by  $\geq 90\%$  of baseline using an oronasal thermal sensor (diagnostic study), PAP device flow (titration study) or an alternative apnea sensor (diagnostic study).
2. The duration of the  $\geq 90\%$  drop in sensor signal is  $\geq 10$  seconds.

### Classification of Apneas

1. Score an apnea as **obstructive** if it meets apnea criteria and is associated with continued or increased inspiratory effort throughout the entire period of absent air flow.
2. Score an apnea as **central** if it meets apnea criteria and is associated with absent inspiratory effort throughout the entire period of absent air flow.
3. Score an apnea 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.


## Hypopnea Definitions

### AASM Recommended

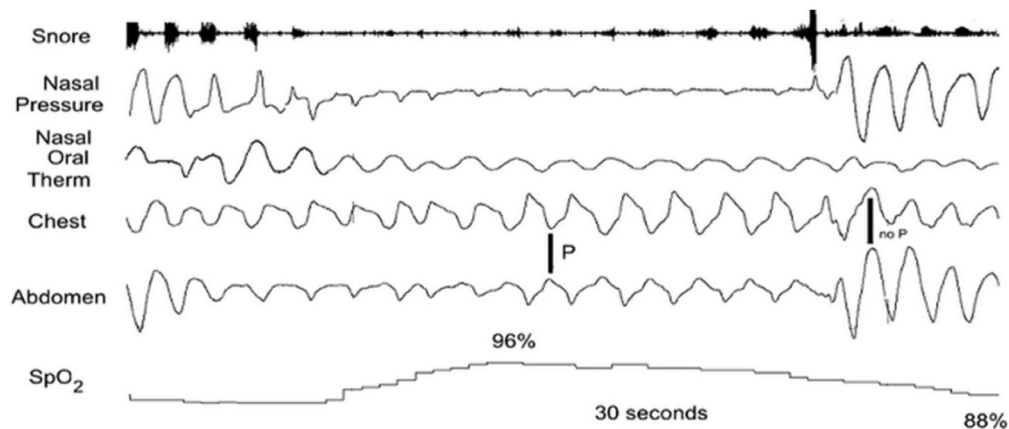
Score a respiratory event as a hypopnea if ALL of the following criteria are met:

1. The peak signal excursions drop by  $\geq 0\%$  of pre-event baseline using nasal pressure (diagnostic study), PAP device flow (titration study), or an alternative hypopnea sensor (diagnostic study).
2. The duration of the  $\geq 30\%$  drop in signal excursion is  $\geq 10$  seconds.
3. There is a  $\geq 3\%$  oxygen desaturation from pre-event baseline or the events is associated with an arousal.

### Obstructive Hypopnea

If electing to score obstructive hypopneas, score a hypopnea as **obstructive** if ANY of the following criteria are met (see Figure F13-3 

1. Snoring during the event.
2. Increased inspiratory flattening of the nasal pressure or PAP device flow signal compared with baseline breathing.
3. Associated thoracoabdominal paradox occurs during the event but not during pre-event breathing.



example of obstructive hypopnea.  
 Snoring  
 Flattening of the nasal pressure  
 thoracoabdominal paradox

## Central Hypopnea

If electing to score central hypopneas, score a hypopnea as **central** if **NONE** of the following criteria is met:

1. Snoring during the event.
2. Increased inspiratory flattening of the nasal pressure or PAP device flow signal compared with baseline breathing.
3. Associated thoracoabdominal paradox occurs during the event but not during pre-event breathing.

Adapted from Berry RB, Brooks R, Gamaldo CE, et al., for the American Academy of Sleep Medicine: *The AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications*, Version 2.1, [www.aasmnet.org](http://www.aasmnet.org), Darien, Illinois, 2014, American Academy of Sleep Medicine.

