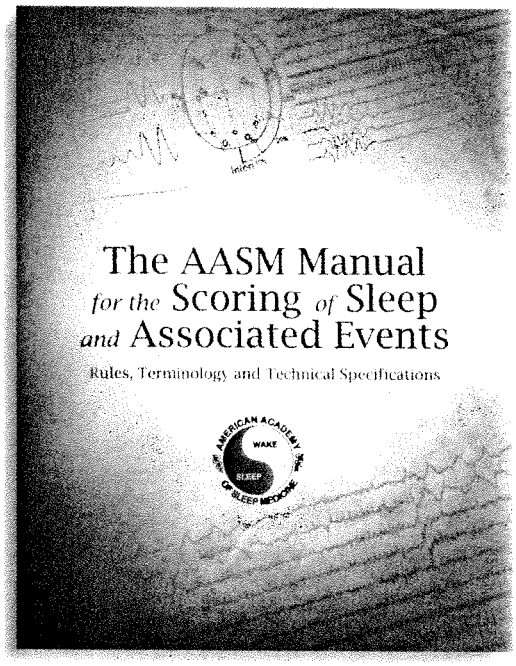
A Technologist's Handbook

for Understanding and Implementing



The AASM Manual *for the* Scoring *of* Sleep *and* Associated Events

Rules, Terminology and Technical Specifications

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Since the publication of the *AASM Manual for the Scoring of Sleep and Associated Events* (the *AASM Manual*), the AASM office has received many telephone calls requesting clarification of the rules and how they were developed. Many of these calls came from technicians and were clearly a result of the fact that the *AASM Manual* was written for physician sleep specialists who came to the *AASM Manual* with the knowledge gained during a sleep fellowship and experience in reading polysomnograms. It has become evident that a supplement to the *AASM Manual* would be useful, and the goal should be to provide the background and explanations needed to make the rules understandable to those just starting out in sleep technology. This *Handbook* reflects experience in training technologists to score polysomnograms, development of classes and lectures in sleep technology, and in researching answers to the questions received since the publication of the *AASM Manual*.

The *Handbook* will briefly review filter settings and electrode placement (parts of the recording process), but the focus is on record scoring. The *Handbook* reviews and expands on the rules as written, with illustrations of key points and tables to summarize scoring strategies. The *Handbook* also includes explanations and decisions made by the AASM Manual Steering Committee. These are frequently updated and are available on the Frequently Asked Questions (FAQ) web page (http://www.aasmnet.org/Resources/PDF/FAQsScoringManual.pdf). References to pages in the *AASM Manual* are in [brackets]. References to the FAQ page are in *italics*.

The *Handbook* follows the order of rules in the *AASM Manual*. Chapter headings are the same as those in the *AASM Manual*. Scoring of polysomnograms does not follow the same order. For example, in order to score some sleep stages you will need to know the rule for scoring arousals. For best results, the Handbook should first be read straight through. The *Handbook* can be used later as a reference for questions as they come up during the scoring of records.

The *AASM Manual* uses 3 sections: definitions, rules and notes. The *Handbook* follows this format.

1. SPECIFICATIONS

The digital specifications for routine sleep studies give the settings for sampling rates, low frequency filter and high frequency filter. We will discuss how to measure frequency when we begin to identify waveforms. For now, these are options in the way that the polygraph records the electrical signals from the sensors. These settings are part of the montage – the recording scheme that is programmed in to your polygraph. The montage includes information about which electrodes are input to the amplifier, the rate at which the signal is sampled, and filter settings. These are "set and forget" rules – once they are programmed into the polygraph you should not have to change them. There are a few occasions when you may want to alter the filter settings, but in general you will want to keep the settings as they are required by the *AASM Manual.*

Impedance. Impedance in polysomnography is a measure of the contact of the electrode with the skin. Your polygraph will have a button or switch to allow you to check the impedance of the electrodes. The *AASM Manual* requires that all electrode impedances should be below 5 KΩ (5 thousand ohms). Often a light or change in color will alert you to an electrode where the impedance is too high. You should then reapply the electrode, cleaning the skin with a mild abrasive to reduce the impedance. If this does not work, you may have to use a different electrode.

Sampling rates. The faster the signal, the faster the sampling rate needed to display the signal. Signals that are fast on the polysomnogram include the EEG, EOG, EMG, ECG and snoring. The *AASM Manual* says that the sampling rate should be at least 200 Hz (200 samples per second), and that 500 Hz is desirable. This is a setting that should be left alone as long as it meets the minimum criterion. Increasing the sampling rate makes the tracings look less "choppy" but it also increases the size of the polysomnogram file. Your center director will have decided the sampling rate for the center to use.

Filter settings. Filters reduce the amplitude of signals that are faster or slower than the signals you want to look at. It's like weeding the garden – you decide which plants you want to keep and try to eliminate the rest. There are some weeds that just keep coming back no matter what you do, and there is some electrical noise that is very hard to filter out. The best way to improve the way the signal looks is to have impedances that are in the recommended range.

Most EEG waves are in the range of 0.5 Hz to 20 Hz, so you will want to keep signals in that frequency range. The filter settings for EEG are to be set at 0.3 Hz for the low frequency filter (it reduces the amplitude of anything slower than 0.3 Hz) and 35 Hz for the high frequency filter (it reduces the amplitude of anything faster than 35 Hz). There are reasons for using settings a little higher and lower than the frequencies you want to see, but these are not important in the routine use of the polygraph. Table 1 gives the recommended filter settings for the polysomnographic signals:

Table 1. Polygraph Filter Settings

Signal	Low Frequency Filter	High Frequency Filter
EEG	0.3 Hz	35 Hz
EOG	0.3 Hz	35 Hz
EMG	10 Hz	100 Hz
ECG	0.3 Hz	70 Hz
Respiration	0.1 Hz	15 Hz
Snoring	10 Hz	100 Hz

When using the low and high frequency filters together, you can think of an open window. As you increase the low frequency and decrease the high frequency you are closing the window. If your polygraph does not have the settings listed, you can open the window slightly more to let in a little more signal (by decreasing the low frequency filter and increasing the high frequency filter) but you should not close the window.

Equipment manufacturers are aware of the *AASM Manual* and are changing settings to match the recommended settings. When your center replaces its equipment, the new equipment should be able to match the required settings exactly.

1. TECHNICAL SPECIFICATIONS

This section of the *AASM Manual* provides recommended and alternative electrode placements for the EEG (brain wave activity), EOG (eye movements) and chin EMG (muscle activity). These 3 parameters are used to determine sleep stages.

There are advantages and disadvantages to each of the placements. Your center can choose the recommended or alternative placements. It is important to include the placements in the sleep study report, and to be consistent from study to study.

2. SCORING OF SLEEP STAGES [P. 24]

Scoring stages in the *AASM Manual* begins with a list of terminology, which is slightly different from the terminology in the Rechtschaffen and Kales manual. N1 replaces NREM 1, N2 replaces NREM 2, and N3 combines NREM 3 and 4. Wake is now W and REM is now R. There used to be a category for movement time, but this has been eliminated. If you see an epoch marked "MT" (movement time) you will know that the scorer is from the old school.

Scoring is done by epochs. An epoch is a chunk of time. A 30-second scoring epoch is used for staging, and each epoch must be given a stage. The rules tell you how to score a 30 second epoch, but you can actually use the rules to score on a second by second basis. W can end after 10 seconds and be replaced by N1 for the last 20 seconds of a 30 second epoch. The *AASM Manual* states that if 2 or more stages occur in a single epoch, the stage that takes up the most time is the one that is given to the epoch. This is easy when there are 2 stages. The stage that takes up more than 15 seconds (half of the 30 second epoch) is the one that is used. However, when there are 3 or more stages, it may be more complicated. This is like an election with 3 candidates; there may not be one that gets more than 50% of the votes, but one of them will usually get more votes than the others. If there are 10 seconds of N1, 8 seconds of N2 and 12 seconds of R in a single epoch, R wins. If 2 stages are close, you can measure more closely. In the case of an exact tie you can flip a coin. Also, the beginning and end of an epoch may be one stage (like W) and the middle part another (N1). As long as the N1 part in the middle lasts more than 15 seconds, the epoch is scored N1. This becomes especially important in scoring sleep onset.

3. STAGE W [P. 25]

Definitions

The definitions sections (gray boxes in the *AASM Manual*) are almost all waveform definitions. Waveform definitions are based on 4 features:

- **Amplitude:** the amount of voltage measured, usually in microvolts (μV); amplitude is measured by how tall a wave is on a polysomnogram
- **Frequency:** the number of waves per second, usually abbreviated Hz (for Heinrich Hertz, a famous physicist) or cps (for cycles per second). Time scrolls across the pages of the polysomnogram from left to right (just like a book). The dividers of seconds in the record examples used in this *Handbook* are marked by either dots or vertical lines. Some of the waveform definitions are based on **duration** rather than frequency. These 2 measures are related. If there are 5 waves per second, then the frequency is 5 Hz. The duration is 1 / frequency. For a 5 Hz waveform, each wave lasts 1/5 second or 0.2 seconds.
- **Waveform:** the shape of the waveform, which can be smooth and sinusoidal (like a sine wave) or sharp, regular (each wave looks the same) or irregular
- **Distribution:** what part of the scalp did it come from? EEG measures come from frontal (F_4), central (C_4) and occipital (O_2) leads. The highest amplitude signals are usually recorded from the area where the activity comes from.

We can determine these 4 features for every EEG waveform. However, not all of the features are used in the definitions provided in the *AASM Manual*.

Alpha rhythm is the first definition in the *AASM Manual*. It uses 3 of the 4 parameters. The rules are summarized in Table 2.

Table 2. Alpha Rhythm Rule

	Alpha Rhythm
Amplitude	Not used
Frequency	8 – 13 Hz
Waveform	Sinusoidal
Distribution	Occipital

Measuring alpha rhythm is usually easy. In Figure 1, the vertical dotted lines are 1 second apart. To determine the frequency, just count the number of peaks between the dotted lines. There are 10 peaks in the sample waveform. This means that the frequency of this waveform is 10 Hz. The waveform is fairly smooth and regular. The distance between the 2 dotted horizontal lines is 75 μV. To measure the amplitude, find the distance between the highest and the lowest point of a wave. Most of these waves are about 75 μV tall.

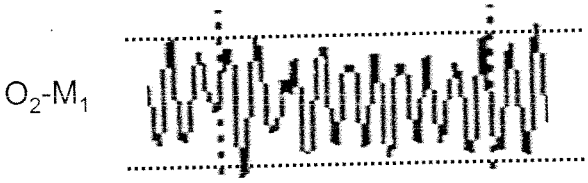

Figure 1. Is it alpha rhythm? Vertical dotted lines are 1 second apart. Horizontal dotted lines are 75 μV apart.

The final piece of information needed for the table is the distribution. Figure 2 shows that the alpha rhythm is largest (biggest amplitude) in the $O_2 - M_1$ channel – the occipital channel.

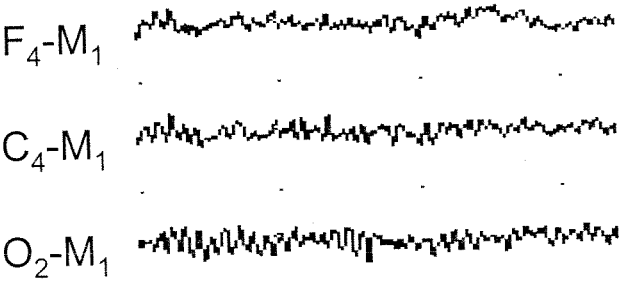

Figure 2. Distribution of alpha rhythm.

Occasionally the alpha rhythm will come from a large portion of the head, which may include the M_1 electrode. In these patients the alpha rhythm will be seen in all 3 EEG channels, and may even be smaller in the occipital channels than in other channels (due to the differential amplifiers).

Table 3 shows that the 4 measures for our sample waveform match the 3 parameters for alpha rhythm. The *AASM Manual* also tells us that alpha rhythm is present when patients close their eyes, and gets smaller or goes away when patients open their eyes. If the waveform meets the definition, is present with eyes closed and goes away with eyes open, then we can be sure that the waveform is alpha rhythm. Most centers include as part of the start-up process asking the patient to close and open their eyes before the sleep study starts. This feature is not part of the scoring rule, but gives you extra confidence in recognizing alpha rhythm activity.

Table 3. Comparing the Alpha Rhythm Sample to the Rule

	Alpha Rhythm Rule	Our Waveform
Amplitude	Not used	75 μV
Frequency	8 – 13 Hz	10 Hz
Waveform	Sinusoidal	Sinusoidal
Distribution	Occipital	Occipital

Eye blinks are recorded from the eye movement electrodes (E_1 and E_2). They are "conjugate," meaning that both eyes move in the same direction at the same time. In virtually all patients, eye movements are always conjugate. The rules are:

Table 4. Eye Blink Rule

	Eye Blinks
Amplitude	Not used
Frequency	0.5 - 2 Hz
Waveform	Vertical
Distribution	EOG Channels

A wave that is 0.5 Hz has half a peak per second or 1 peak every 2 seconds. Figure 3 shows a typical eye blink recording. There are 1 or 2 peaks every second (the dots are 1 second apart), so the frequency is 1 to 2 Hz.

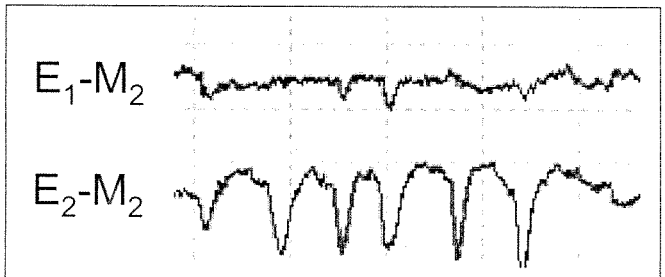

Figure 3. Is it eye blinks? Vertical lines are 1 second apart.

In Figure 3, the waves in the REOG ($E_2 - M_2$; bottom channel) are higher than in the LEOG ($E_1 - M_2$; top channel). The right eye electrode is above the eye and is closer to the signal when the eye moves up. Using the standard EOG electrode placement [p.24] we cannot tell for sure whether the eye movements are vertical or horizontal. This is possible with the alternative placement, where vertical eye movements will produce "in-phase" waveforms (the peaks in the waves point to each other) and horizontal movements produce "out-of-phase" waveforms (the waves point away from each other). This waveform uses the recommended montage. We see a little activity in the LEOG channel indicating that both eyes moved at the same time, so we can be reasonably sure that our waveform is eye blinking.

Table 5. Comparing the Eye Blink Sample to the Rule

	Eye Blink Rule	Our Waveform
Amplitude	Not used	Not used
Frequency	0.5 - 2 Hz	1 - 2 Hz
Waveform	Vertical	Unknown
Distribution	EOG Channels	EOG Channels

A brief explanation: Why does eye blinking cause vertical eye movement? It is not because of the movement of the eyelids. It is because the eyes rotate upward when closed. This is a reflex called Bell's Phenomenon and the upward movement is quite rapid. The eyes return quickly to their original position when opened.

Reading eye movements have a very unusual waveform. They occur when the eye scans from left to right when reading a line, then jumps back to the left to start the next line. The frequency of the waveform depends on how quickly the patient can read the line of text. An example of reading eye movements is shown in Figure 4.

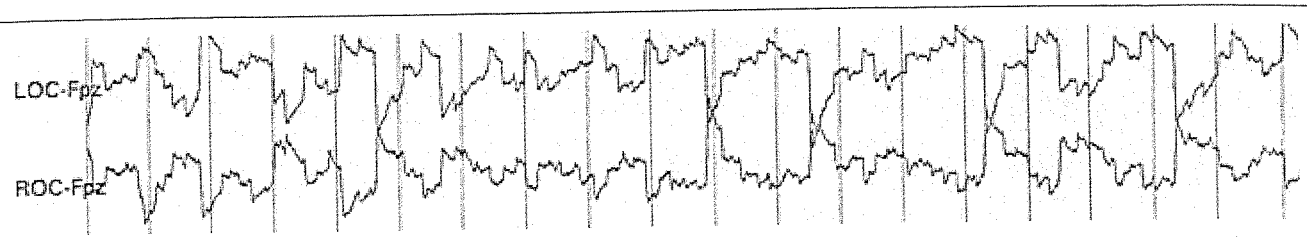

Figure 4. Reading eye movements. Vertical bars are 1 second apart. Alternate eye movement montage.

Rapid eye movements are part of the scoring criteria for R sleep, but you can see them during W as well. The movements are irregular and sharp. The first part of the waveform (either the up part or the down part) must last less than 0.5 seconds. Rapid eye movements during W occur when the patient is looking around the room. The eyes often jump from one object to another during W.

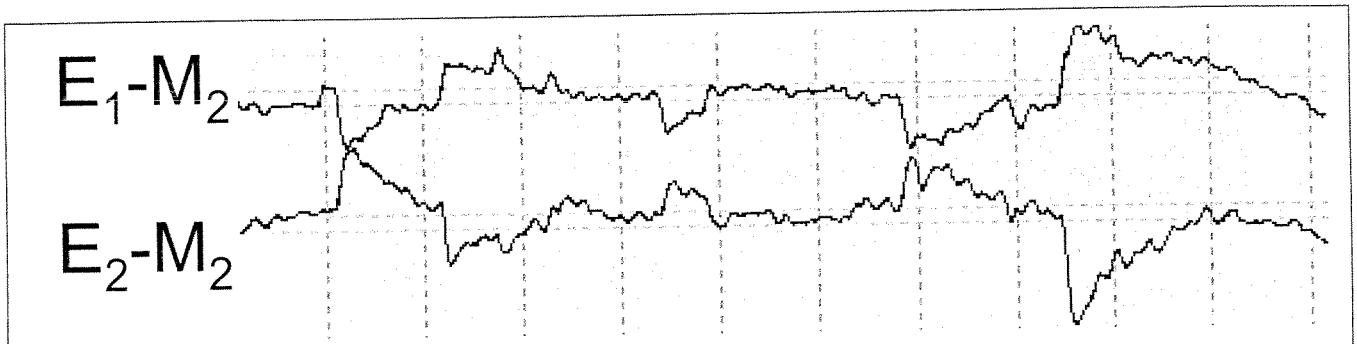

Figure 5. Rapid eye movements in W. Vertical bars are 1 second apart.

RULES

A. Score W when more than half of an epoch has alpha rhythm.
B. Score W in patients who do not have alpha rhythm when:
   1) There are eye blinks
      OR
   2) There are reading eye movements
      OR
   3) There are rapid eye movements with high chin EMG

Rule A is easy to apply. Any epoch with 15 seconds or more of alpha rhythm is scored W. There is one additional case when a score of W is given. According to Section IV.2, an epoch can be W if it is less than half of the epoch but more than any other stage. This is rare, and only happens when there are 3 or more stages in the same epoch.

Rule B uses eye movement markers to score W because the primary marker, alpha rhythm, is not present. None of the 3 eye movement types can occur with the patient asleep. As you will see later, this is thought to be less accurate than the scoring of W in patients with alpha rhythm.

Notes.

1) There are different kinds of W. There is "fully alert, buzzed on caffeine" W, "in the zone can't miss on th basketball court" W, "relaxed, couch potato watching TV" W, and "2 AM driving home can't keep my eye open" W. W often fades slowly into sleep, crossing over into N1 and then back to W. It is very difficult to dra an exact line between W and sleep. The Rechtschaffen and Kales manual and the *AASM Manual* both use alph rhythm as the dividing line for sleep onset in patients who have alpha rhythm. Most people have alpha rhythn If you do not see it, it may be because your occipital electrode placement is wrong. Be sure to measure from th inion (the bump on the back of the head where the neck meets the skull) and go up 10% of the distance from th nasion to the inion. When the placement is too low you may incorrectly assume that the patient does not hav alpha.

During the transition to sleep, some of the features of N1 can be found in W. Do not be distracted. In patient with alpha rhythm, the focus should be on the occipital EEG channel. You should also look for alpha rhythr if there is an awakening during the night. During these conditions, if there is alpha rhythm for more than 1 seconds in an epoch, score W, no matter what else is happening in the record. (But, like most rules, there i an exception. Some patients have "alpha – delta" sleep, with alpha waves mixed in with slow waves. In thes epochs, the slow waves win and the epoch is scored N3.)

One can imagine some epochs where a patient with alpha rhythm would have a different stage score than patient without alpha rhythm. In Figure 6, a 30 second epoch is shown. There is clear alpha rhythm throughou the epoch. Therefore, we score the epoch as W. But if the same epoch were from a recording in a patient withou alpha rhythm, we would not have blinking, reading eye movements or rapid eye movements with high EMC to indicate that the patient was in W. The slow eye movements would lead us to score N1 from the start of th epoch (see section on N1 below).

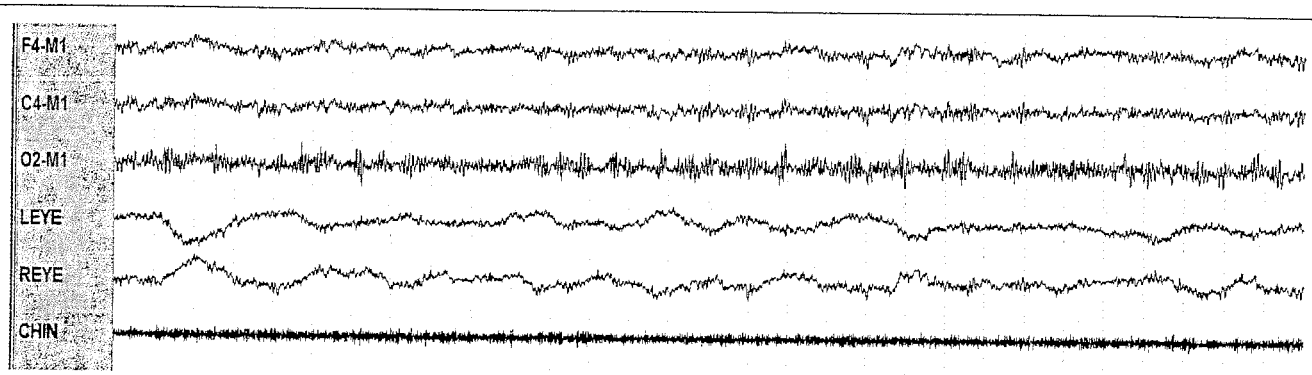

Figure 6. Slow eye movements in W. 30 second epoch.

2) The EEG activity in someone who does not have alpha rhythm is reasonably fast. The usual frequency range is 8 – 30 Hz. EEG waves in the 14 – 30 Hz range are called beta activity. What about the activity in the 8 – 13 Hz range? It is in the alpha frequency range, but unless it is sinusoidal and mostly occipital, it is not alpha rhythm. The alpha frequency activity in patients without alpha rhythm is usually sharp, irregular and low amplitude. One excellent way to be sure that a patient does not have alpha rhythm is to ask them to open and close their eyes. In patients without alpha rhythm, the EEG does not change with eyes open or closed.
3) In patients with no alpha rhythm, we use the EOG to score W. The 3 EOG patterns (eye blinks, reading eye movements, and rapid eye movements with high chin EMG) all occur only during definite W. When they are not present, assume that sleep has started.
4) Chin EMG tone is not a reliable marker of sleep stage. In W it is usually high, although there can be periods of relaxation where the tone drops to levels seen during sleep. It is only a part of the rules for scoring the beginning and end of R.

4. STAGE N1 [P. 25]

Definitions

Slow eye movements are smooth and sinusoidal, with the first part of the wave lasting longer than half a second.

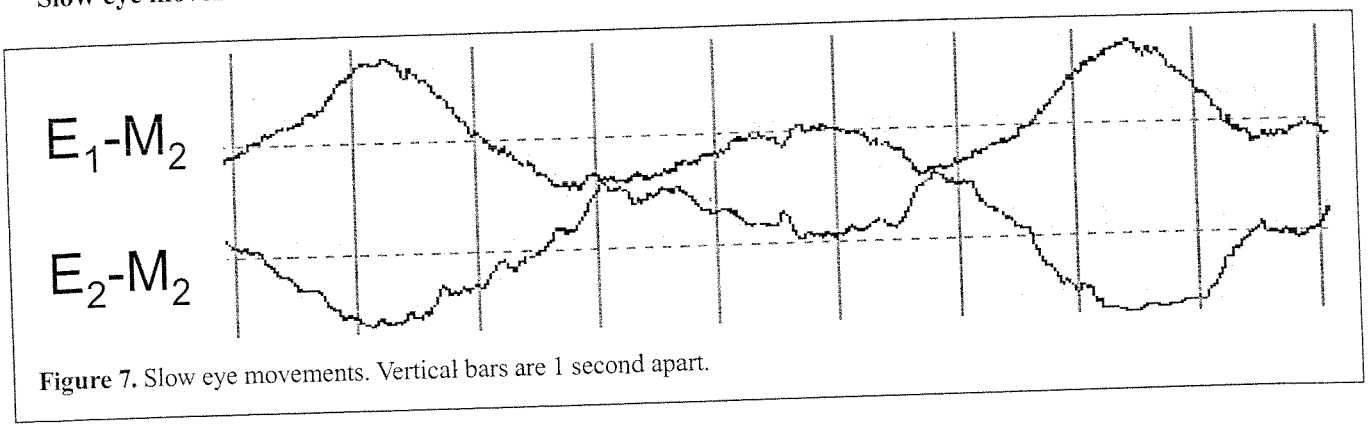

Figure 7. Slow eye movements. Vertical bars are 1 second apart.

Compare Figure 7 to Figure 5. During Figure 5 the waveform jumps quickly from the bottom of the channel to the top. At the beginning of Figure 7 the wave is slowly moving up, with the upward part lasting more than 1 second. The upward part of the wave at the end of Figure 7 lasts almost 2 seconds. The waves in Figure 5 are sharp and choppy – the waves in Figure 7 are smooth and rolling. In most cases you will easily be able to tell the difference between slow and rapid eye movements. If you need to measure to be sure, use the half second rule.

Low amplitude, mixed frequency activity is the uninteresting background of sleep. Most of the EEG activity in N1, N2 and R is low amplitude mixed frequency. Because we will be using the phrase "low amplitude mixed frequency activity" many times throughout this *Handbook*, we will call it LAMF.

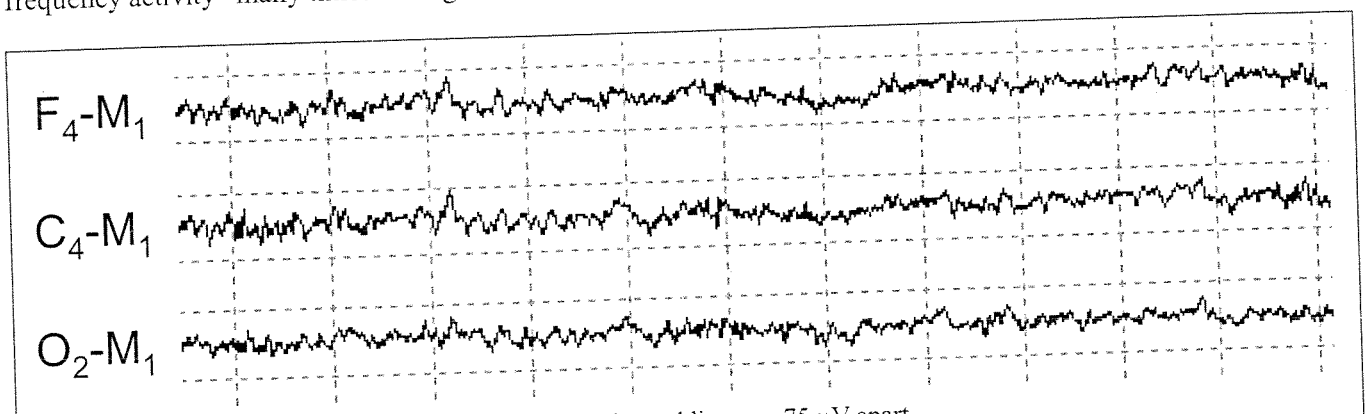

Figure 8. LAMF. Vertical lines are 1 second apart. Horizontal lines are 75 μV apart.

The EEG in Figure 8 is pretty boring. The waves are not well formed, and it's hard to tell what the frequency is because the peaks are irregular. The frequency is mixed – some parts are fast and others are slow. The frontal channel looks pretty much the same as the central and occipital channels. The amplitude is low. When scoring sleep stages, LAMF is the background and the other waveforms will "stick out."

Table 6. LAMF Rule

LAMF – Low Amplitude Mixed Frequency	
Amplitude	Low
Frequency	4 – 7 Hz
Waveform	Mixed
Distribution	All Over

Vertex sharp waves (V waves) are sharp and quick and stick out from the LAMF background. They can occur in trains (several vertex waves in a row), but often they are lonely peaks rising up from LAMF. They can last up to half a second (the frequency is 2 Hz or more). They are biggest in the central channel ($C_4 - M_1$). Here are the rules for scoring:

Table 7. Vertex Sharp Wave Rule

	Vertex Sharp Wave
Amplitude	Not used
Frequency	2 Hz or more
Waveform	Sharp
Distribution	Central

Let's look at an example (Figure 9). This is a 5 second sample from the central channel. Seconds 1, 3, 4 and 5 look boringly similar and are LAMF. Something sticks out from second 2. There is a sharp upward deflection, quickly followed by a downward deflection and then a return to the baseline. The whole wave, from the upward movement at the start to the finish back at baseline, is about 0.4 seconds in duration. The frequency of the wave is 1/0.4 seconds or 2.5 Hz. The amplitude of the wave is measured from the peak (highest point) to the trough (lowest point). The dots are 75 μV apart, and the amplitude of this vertex wave is about 75 μV.

Figure 9. Is it a vertex sharp wave? Vertical lines are 1 second apart.

EEG people have an old saying: "How do you tell if something is a sharp wave? It would hurt to sit on it." The wave in Figure 9 above looks like it would hurt to sit on. Let's measure this wave against the vertex sharp wave criteria.

Table 8. Comparing the Waveform to the Vertex Sharp Wave Rule

	Vertex Sharp Wave	Our Waveform
Amplitude	Not used	75 μV
Frequency	2 Hz or more	2.5 Hz
Waveform	Sharp	Sharp
Distribution	Central	Central

All of the features of the wave in Figure 9 match the criteria for a vertex sharp wave.

Sleep onset has been defined by a lot of different rules in the past. It has been the first epoch of N2, the first appearance of 3 epochs of N1 in a row, and a variety of other rules. The *AASM Manual* uses the first epoch of any stage other than W. That doesn't mean the first time you recognize N1. It has to be a full epoch scored as N1.

RULES

A. In patients with alpha rhythm, score N1 when more than half of the epoch is LAMF.
B. Score N1 in patients who do not have alpha rhythm when:
   1) There is LAMF and the frequency of the EEG has slowed by 1 Hz or more from alpha rhythm.
      OR
   2) There are vertex sharp waves
      OR
   3) There are slow eye movements

For Rule A, remember that for patients with alpha rhythm, the decision to score N1 instead of W is based on the alpha rhythm only. Eye movements and vertex sharp waves don't count.

For Rule B (patients with no alpha rhythm), there are 3 eye movement patterns that always lead to a score of W: eye blinks, reading eye movements and rapid eye movements with high chin EMG. So you really have 6 rules for N1:

1) No eye blinks
   AND
2) No reading eye movements
   AND
3) No rapid eye movements with high chin EMG
   AND
4) Slowing of EEG frequency to the range of LAMF
   OR
5) Vertex sharp waves
   OR
6) Slow eye movements

Notes

1) N1 starts with a choice of 3 markers. Often they happen together, but this is not always the case. Figure 10 is a 30 second epoch with LAMF and slow eye movements, but there are no vertex waves. It is still N1.

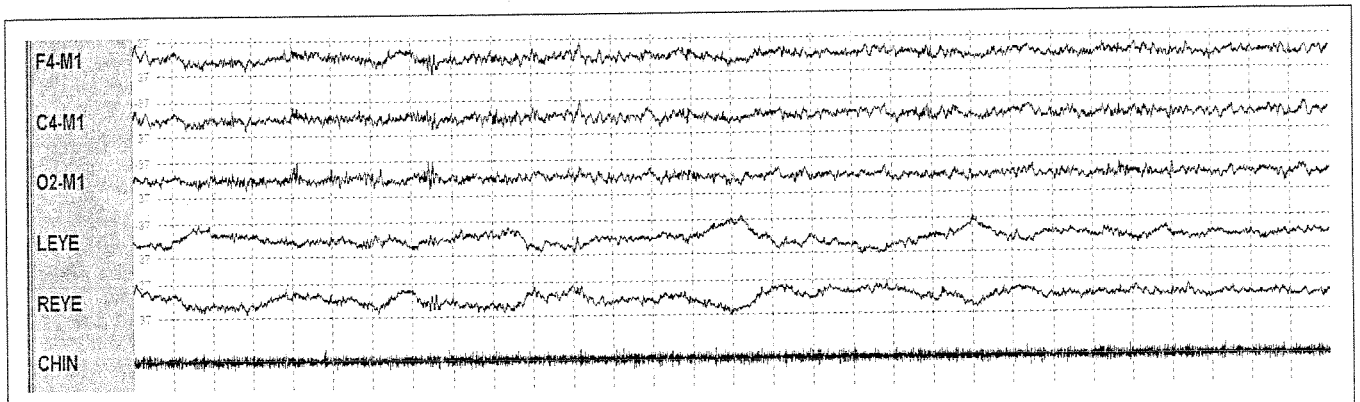

Figure 10. Slow eye movements in N1. 30 second epoch.

2) When you are scoring Figure 10, the beginning of N1 in a patient with alpha rhythm depends only on the change from alpha rhythm to LAMF. This occurs about 8 seconds after the beginning of the epoch. Note that this epoch starts with W and ends N1. If the 10 epochs before this were W and the 10 epochs after this were W, this epoch of N1 would still be counted as sleep onset.
3) The chin EMG amplitude is moderately high in Figure 10, and it does not change with sleep onset. Chin EMG has no role in the scoring of N1.
4) In W just before sleep onset, we sometimes see slow eye movements with alpha rhythm (Figure 6). In patients without alpha rhythm, these epochs would be scored N1 (Rule 3.B.). This has been determined not to be a significant difference.

5. STAGE N2 [P. 26]

Definitions

A K complex picks up where the vertex sharp wave leaves off. Vertex sharp waves last less then half a second; K complexes last at least half a second. This means the frequency is 2 Hz or less. K complexes are usually biggest in the frontal channels. The rules for scoring are:

Table 9. K Complex Rule

	K Complex
Amplitude	Not used
Frequency	2 Hz or less
Waveform	Sharp
Distribution	Frontal

The definition of a K complex includes the rule that the wave go up (negative) first, followed by a downward deflection (positive).

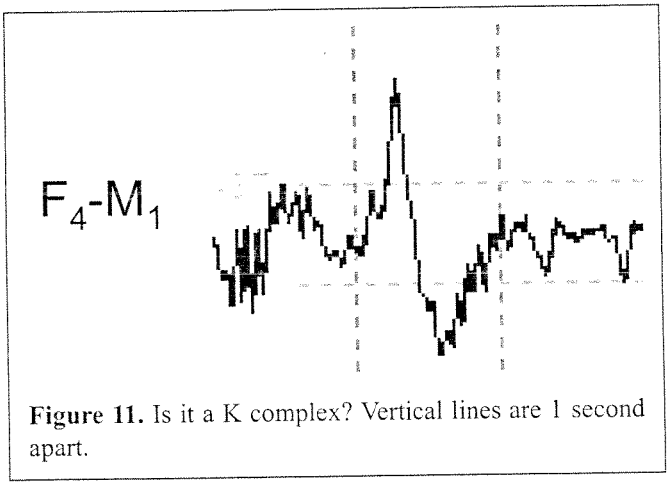

Figure 11. Is it a K complex? Vertical lines are 1 second apart.

The wave in Figure 11 starts off clearly upward. Then there is a deep downward deflection. Looking at the 1 second lines, the whole complex takes about 1 second. The frequency is 1/1 second, which is 1 Hz.

Figure 12 lets you determine the distribution of the waveform. It's a fairly large signal – more than 150 μV. Waveforms this large can be picked up by electrodes that are relatively far away from the source. That is why you can see the same waveform in the central and occipital channels.

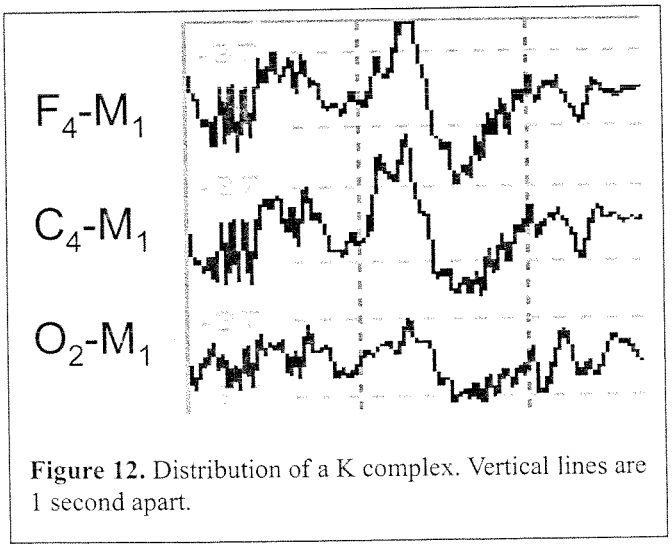

Figure 12. Distribution of a K complex. Vertical lines are 1 second apart.

Our evaluation of the waveform in Figures 11 and 12 is summarized as follows:

Table 10. Comparing the Waveform to the K Complex Rule

	K Complex	Our Waveform
Amplitude	Not used	More than 150 μV
Frequency	2 Hz or less	1 Hz
Waveform	Sharp	Sharp
Distribution	Frontal	Frontal

The waveform clearly meets the rules for a K complex.

K complexes are part of the rules for scoring N2. But if the K complex happens at the same time or within 1 second before an arousal, then it doesn't count. Figure 13 shows a K complex with arousal. When this K complex ends there is fast activity, outside the range of LAMF, which meets the arousal scoring criteria [*AASM Manual*, p. 37]. This arousal should be scored as an arousal. N2 starts only when you see a K complex without arousal; it does not start when you see a K complex with arousal (rule A.1.a., below).

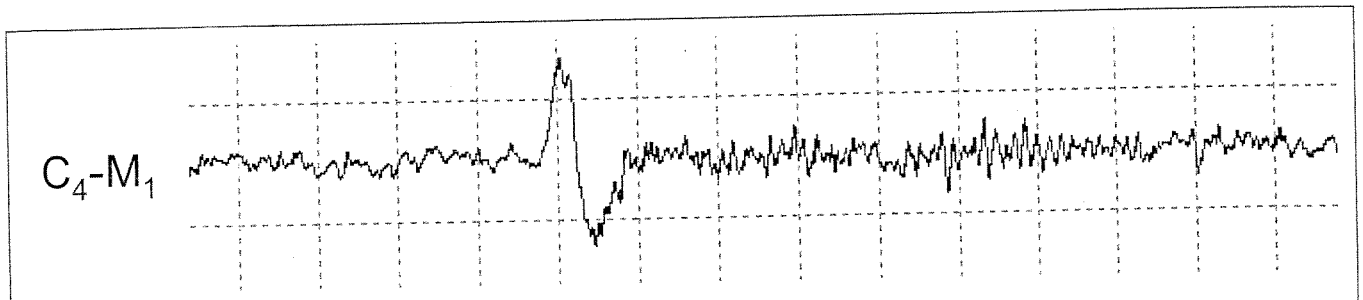

Figure 13. K complex with arousal. Vertical lines are 1 second apart.

Sleep spindles are faster than alpha rhythm but have a similar sinusoidal waveform. They are called spindles because the waveform envelope (the outside edges of the peaks and troughs) often has the shape of a spinning wheel spindle. It goes up slowly and it comes down slowly, with the faster waves inside. The frequency range for spindles is 11 to 16 Hz, but most are in the range of 12 – 14 Hz. They are usually biggest in the central channel. A summary is below:

Table 11. Sleep Spindle Rule

	Sleep Spindle
Amplitude	Not used
Frequency	11 – 16 Hz
Waveform	Sinusoidal
Distribution	Central

In addition, the train of waves in the sleep spindle must last at least a half second.

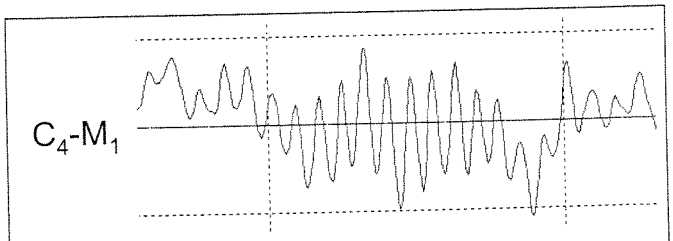

Figure 14. Is it a sleep spindle? Vertical lines are 1 second apart.

The frequency of the waveform in Figure 14 is about 13 Hz. The waveform lasts almost a full second, so it's longer than the required half second. The amplitude is 50 – 75 μV.

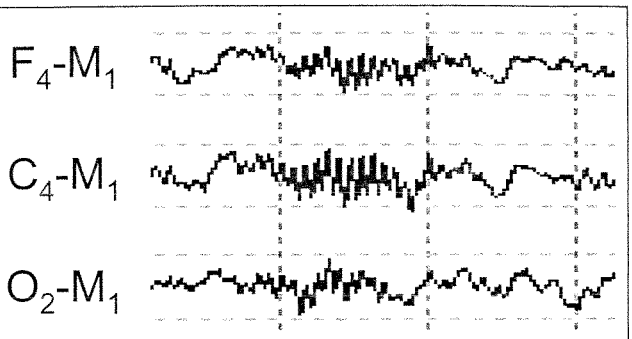

Figure 15. Distribution of a sleep spindle. Vertical lines are 1 second apart.

The biggest signal in Figure 15 is from the $C_4 - M_1$ channel. We're ready to compare our waveform to the rules:

Table 12. Comparing the Waveform to the Sleep Spindle Rule

	Sleep Spindle	Our Waveform
Amplitude	Not used	50 – 75 μV
Frequency	11 – 16 Hz	14 Hz
Waveform	Sinusoidal	Sinusoidal
Distribution	Central	Central

When comparing frequency rules you will note that the alpha rhythm and the sleep spindle frequencies overlap. Waves in the range of 11 – 13 Hz could be either waveform. Both are sinusoidal. Let's compare the rules:

Table 13. Comparing the Sleep Spindle Rule to the Alpha Rhythm Rule

	Sleep Spindle	Alpha Rhythm
Amplitude	Not used	Not used
Frequency	11 – 16 Hz	8 - 13 Hz
Waveform	Sinusoidal	Sinusoidal
Distribution	Central	Occipital

The difference is the distribution: sleep spindles are central, alpha rhythm is occipital. Another big difference does not show up in the table: the context. Alpha rhythm signals W, and is often accompanied by movement and increased chin EMG tone. Alpha rhythm can continue for several minutes at a time. During the night, alpha rhythm usually starts after an arousal, as the patient settles back down. Sleep spindles pop out of a LAMF background. They are usually less than 1 or 2 seconds long. And they are a marker of N2 sleep, so patients are usually quiet and relaxed with low chin EMG tone. They may also appear in the same epoch as K complexes.

Rules

A. The following defines the start of N2:
   1) One or both of these waveforms is seen in the first half of an epoch or the second half of the epoch before it:
      a. A K complex (no arousal)
         OR
      b. A sleep spindle

The rule for N2 is different from the rules for W and N1. For patients with alpha rhythm, W and N1 are scored based on alpha rhythm – it is there (W) or it isn't (N1). N2 is scored based on an event that may last only half a second. These events occur with a background of LAMF. After an event happens, the patient has moved to N2 and stays in N2 until something else is scored. For N2 we will need to have rules for when to start, when to continue, and when to end. An epoch of N2 cannot have 20% or more slow wave activity – that would meet the rule for scoring N3 [*AASM Manual*, p. 27]. Patients who have been sleep deprived or are very sleepy due to a sleep disorder may move into N3 quickly. Normally, however, N2 comes before N3.

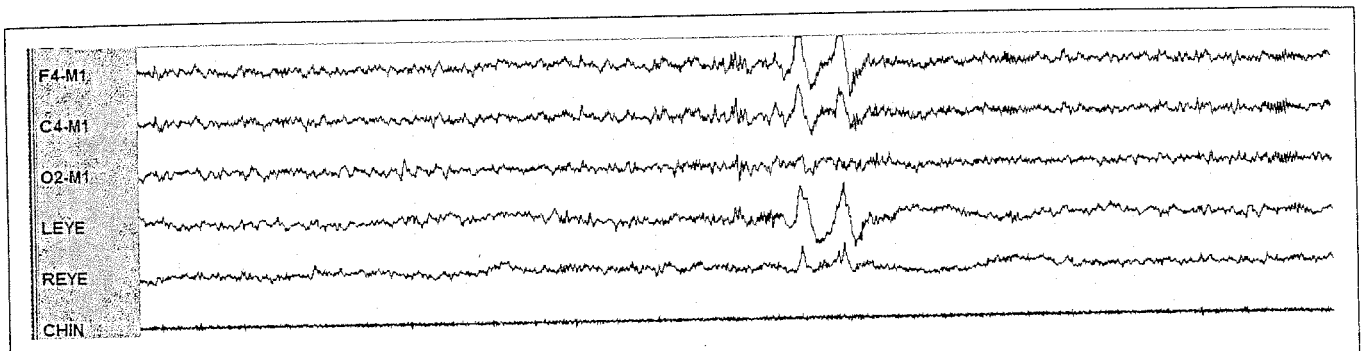

Figure 16. K complex in second half of epoch. 30 second epoch.

Figure 16 illustrates why the rule says if there is a spindle or K complex in the epoch before the one you are scoring, the next epoch will be N2. The first 20 seconds of this epoch is LAMF. No alpha rhythm is seen in the first half of the epoch. The first 16 seconds are scored N1. Then there is a K complex without arousal. This starts N2. Unless there is a change in stage, the next epoch would be N2.

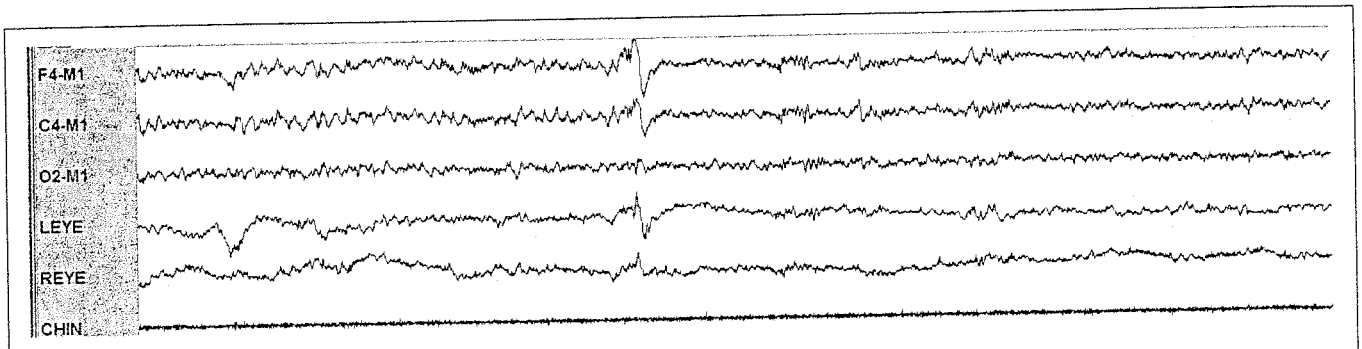

Figure 17. K complex in first half of epoch. 30 second epoch.

Figure 17 has a K complex without arousal in the first half of the epoch (with a spindle later on) and the entire epoch is N2.

Notes

1) The K complexes with arousals don't count for starting N2. If you are in N1, you stay in N1.
2) Standard arousal rules apply for K complexes with arousals [*AASM Manual*, p. 37].

RULES

B. The following defines the continuation of N2:
   1) Continue to score N2 with LAMF and no K complexes or sleep spindles if you have already seen one of the following:
      a. A K complex (no arousal)
         OR
      b. A sleep spindle

C. The following defines the end of N2:

1) End N2 when you see any of the following:
   a. Transition to W
      OR
   b. An arousal [*AASM Manual*, p. 37]
      OR
   c. A major body movement followed by slow eye movements with LAMF and no K complexes or spindles
      OR
   d. Transition to N3
      OR
   e. Transition to R

How do you implement these rules? Keep scoring N2 until you encounter something that meets the rules in C. Let's go through the rules in C one by one.

A. The rule does not say that you must score an epoch as W. The signs of transition to W would be the appearance of alpha rhythm in a patient who has alpha rhythm. In patients without alpha rhythm you might see blinking, reading eye movements, or rapid eye movements and high chin EMG. For the rapid eye movements you are relying on the chin EMG, which is not a reliable marker. Rapid eye movements with low chin EMG would mean a transition to R (see E below).

B. Arousals are brief awakenings. They can be as short as 3 seconds. N2 ends immediately when an arousal is scored. N2 can start up again only when the rules for N2 are met again – this means another K complex or sleep spindle. K complexes with arousals count as arousals, not as K complexes.

C. Major body movements [*AASM Manual*, p. 31] do not, by themselves, end N2. A body movement with alpha rhythm (even a little bit) results in an epoch scored as W. A body movement without alpha rhythm shifts to N1 if slow eye movements occur after the movement. If there is no alpha rhythm and no slow eye movements, the major body movement does not change the stage.

D. Transition to N3 requires that 20% or more of the epoch has slow wave activity. Any epoch that meets this requirement is N3.

E. Transitions from N2 to R are difficult. Both rely on brief events and continue after the event until something happens. This transition is defined in Section 7.D. [*AASM Manual*, p. 30].

Notes

1) There are usually no eye movements during N2. There may be some slow eye movements in the transition from N1 to N2. These do not change scoring.
2) Chin EMG has no effect on N2 scoring. It is usually lower than W, and at times is as low as R.

6. N3 [P. 27]

Definitions

Slow wave activity has a frequency of 0.5 – 2 Hz. It is the only wave with an amplitude criterion. Slow wave activity must be at least 75 μV. Slow wave activity is highest in the frontal channel. The waveform varies – it can be sharp or smooth, and at times faster waves can "ride" on top of the slow wave activity. Slow wave activity is sometimes called delta waves, and N3 sleep is sometimes called delta sleep. Here is the rule:

Table 14. Slow Wave Activity Rule

	Slow Wave Activity
Amplitude	75 μV
Frequency	0.5 – 2 Hz
Waveform	Varies
Distribution	Frontal

During N3 sleep slow waves tend to build up and can cover the entire epoch. Lonely slow waves may be seen in the transition from N2 to N3 (see Figure 18).

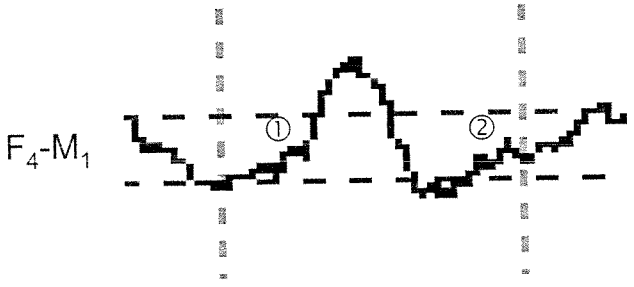

Figure 18. Is it a slow wave? Horizontal lines are 75 mV apart. Vertical lines are 1 second apart. See text for explanation of numbers.

The slow wave is more than 75 μV – it looks to be about 100 μV. The beginning of the wave (number 1) to the end of the wave (number 2) takes about 0.75 seconds. The frequency is 1/0.75 seconds, which is 1.3 Hz.

The distribution in Figure 19 is as expected – the wave is biggest in the frontal channels. There is minimal slow wave activity in the occipital channels. Let's compare our waveform to the rules for scoring slow wave activity.

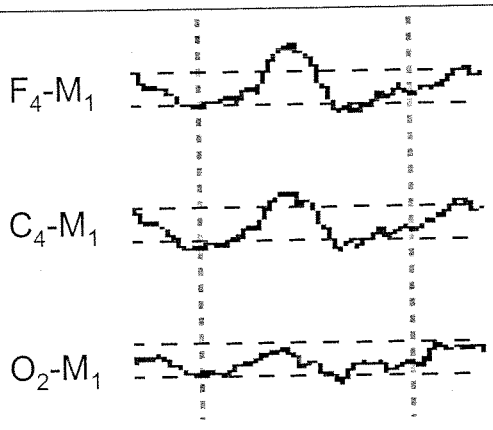

Figure 19. Distribution of the slow wave. Horizontal lines are 75 mV apart. Vertical lines are 1 second apart.

Table 15. Comparing the Waveform to the Slow Wave Activity Rule

	Slow Wave Activity	Our Waveform
Amplitude	At least 75 μV	100 μV
Frequency	0.5 – 2 Hz	1.3 Hz
Waveform	Varies	Not Too Sharp
Distribution	Frontal	Frontal

Keeping in mind that the amplitude and the frequency are measured from the frontal channel. It is clear that our waveform meets the criteria for a slow wave. Looking at this slow wave, you may think this looks just like a K complex. Let's compare the rules for slow wave activity with the rules for K complexes.

Table 16. Comparing Slow Wave Activity and K Complex Rule

	Slow Wave Activity	K Complex
Amplitude	At least 75 μV	Not used
Frequency	0.5 – 2 Hz	2 Hz or less
Waveform	Varies	Sharp
Distribution	Frontal	Frontal

These rules say that all slow waves meet the criteria for a K complex, although usually they are not very sharp. It is in the right frequency range and has the right distribution. But not all K complexes will meet criteria for a slow wave. The K complex does not need to be 75 μV in amplitude. It could be 50 μV as long as it sticks out from the background. And a K complex can be slower than 0.5 Hz. Most K complexes, however, will meet criteria for slow wave activity.

RULE

A. Score N3 when 20% or more of an epoch is slow wave activity.

Scoring N3 requires keeping lots of rules in your mind. You need all of the slow wave activity rules (at least 75 μV, 0.5 – 2 Hz, frontal), and once you have identified the slow waves you need to measure the number of seconds of the epoch they cover. To reach 20% of an epoch you need 6 seconds of slow wave activity (30 seconds x 20% = 6 seconds). If the slow waves are all 1 Hz, then you need 6 of them to reach the 20% mark (1 x 6 = 6). If the slow waves are 0.5 Hz, then they last 2 seconds and you only need 3 of them (2 x 3 = 6). But if the slow waves are 2 Hz, they last 0.5 seconds and you need 12 of them (0.5 x 12 = 6).

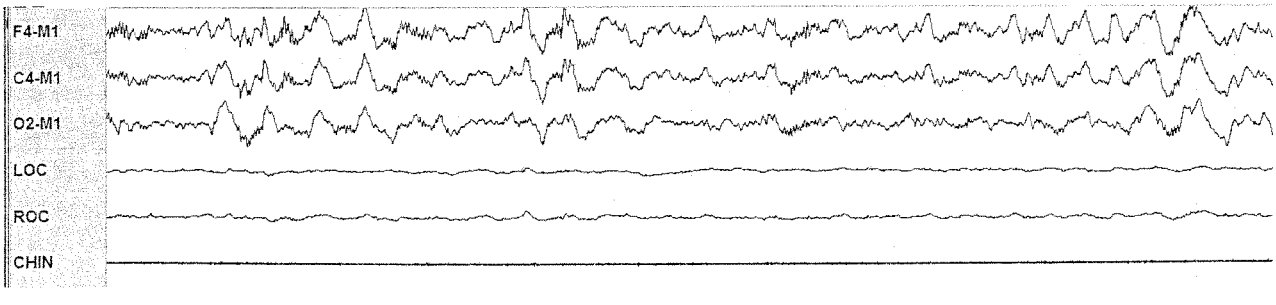

Figure 20. N3. 30 second epoch.

Figure 20 shows a typical epoch of N3. The slow wave activity varies in frequency, so you can't use the simple math above to determine how much of the epoch is slow wave. A simple way to do this is to draw a line on a piece of paper held under each slow wave, then measure the lines until they add up to 6 seconds. Once you have reached 6 seconds you are done and you can stop measuring – there is no extra credit for extra slow wave activity.

Notes

1) There are no rules that say you can't have sleep spindles during N3. Figure 20 has a few spindles hidden in the slow waves. The spindles are biggest in the central channels.
2) There are usually no eye movements in N3. You can see some slow activity in the EOG channels in Figure 20, especially in the right eye channel. It is not actually eye movement – it is the eye leads picking up EEG activity from the frontal lobes.
3) The *AASM Manual* includes the usual warning about chin EMG in the notes to N3. It is unreliable and not part of the scoring for N3.

7. R [P. 27]

Definitions

Rapid eye movements (REM) are fast, irregular eye movements. Figure 5 shows rapid eye movements during W.

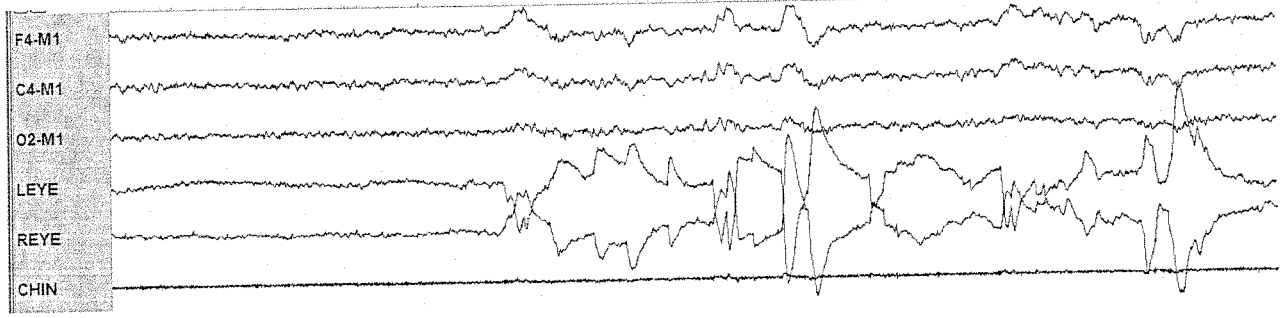

Figure 21. Rapid eye movements during R. 30 second epoch.

Figure 21 shows a large burst of rapid eye movements during R. The eye movement signal is quite large, and in this recording it shows up in the frontal and central leads as well as in the eye movement channels.

Low chin EMG tone. Several entries in the notes section have commented on chin EMG tone. It is not a reliable measure – some people have high tone for much of sleep, and others have low tone from the moment the alpha rhythm disappears. During R the signals from the brain that cause movement are blocked. This is why you can dream of running, but your legs don't move. The blockage is not always complete. Some times little twitches can break through. Babies and dogs have lots of movements break through, and you can see them twitch and move during R. We use the chin muscle as a measure of the blockage because it is a large muscle, easy to put electrodes on and it usually has a lot of activity when you are awake. There are no amplitude criteria for chin EMG – so many microvolts for this stage and so many less for another. We only use chin EMG in a relative way. It should be as low as it gets during R. It may be as low as it gets during N2 – that's OK. We will use changes in the amplitude of the chin EMG to help us decide when R ends. If it goes up, it suggests that the stage is no longer R.

Sawtooth waves. Sawtooth waves have a very distinctive shape. They usually are seen during R just before a burst of rapid eye movements. The rules for R state that sawtooth waves are not part of the criteria. If you see them, it increases the chance that the epoch is R. But if you don't see them it doesn't mean that the epoch is not R. Some people just don't have sawtooth waves.

Table 17. Sawtooth Wave Rule

	Sawtooth Waves
Amplitude	Not Used
Frequency	2 – 6 Hz
Waveform	Triangular, serrated
Distribution	Central

The background activity for R is LAMF. The sawtooth waves stick out from the background and typically have amplitude of 50 μV.

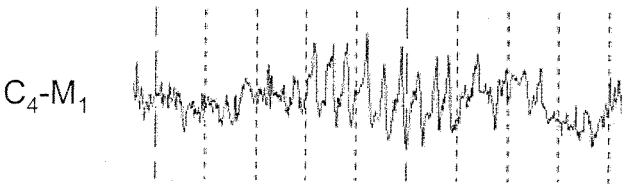

Figure 22. Is it sawtooth waves? Vertical lines are 1 second apart.

The burst of sawtooth waves in Figure 22 lasts 3 seconds. The frequency of the waves is 3 Hz (you can easily count 9 waves in the 3 second burst). LAMF occurs before and after the sawtooth waves. These waves have a jagged upward deflection (negative) and a rapid downward deflection (positive). Draw a line across the bottoms of the waves and you'll make something close to a right triangle. Let's look at the distribution of the waveforms.

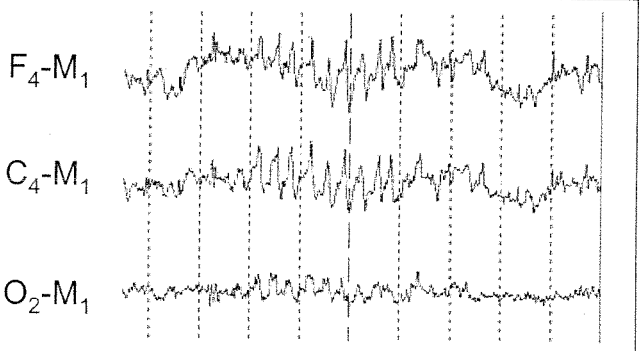

Figure 23. Distribution of the sawtooth waves. Vertical lines are 1 second apart.

The sawtooth waves are largest in the central channel, smaller in the frontal channel and barely visible in the occipital channel.

Table 18. Comparing the Waveform to the Sawtooth Wave Rule

	Sawtooth Waves	Our Waveform
Amplitude	Not Used	50 μV
Frequency	2 – 6 Hz	3 Hz
Waveform	Triangular, serrated	Triangular
Distribution	Central	Central

We can score the waveform in Figure 22 as a run of sawtooth waves. Seeing this activity is evidence in favor of R, but is not part of the scoring criteria.

Transient muscle activity. Twitches during R are recorded by the chin or leg EMG, and can also be seen in the eye movement channels and the EEG channels. There are many muscles around the eye that can twitch during sleep, and the electrodes used to record eye movements are the same type as those used to record the chin EMG. Twitches in the scalp muscles or forehead may be seen in the EEG channels. However, twitches are fast activity, and may be filtered out by the high frequency filter. You may recall that the high frequency filter should be at 100 Hz for the chin and leg EMG channels, but only 35 Hz for the EEG and EOG channels [p. 19]. The burst of muscle activity should last less than a quarter of a second (250 milliseconds) and should stick out from a back-

ground of low chin EMG tone. Figure 24 provides a nice example of transient muscle activity on a background of low chin EMG tone.

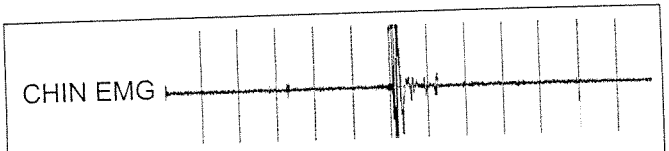

Figure 24. Transient muscle activity in R. Vertical lines are 1 second apart.

Rules

A. Score R for epochs with all of the following:
   a. LAMF
      AND
   b. Low chin EMG tone
      AND
   c. Rapid eye movements

Rapid eye movements are the same kind of event as K complexes and sleep spindles. They are relatively brief. When you see rapid eye movements, you begin to score R. Rapid eye movements and muscle twitches are the "phasic" part of R. The "tonic" part of R has LAMF and low chin EMG tone.

B. The following defines the continuation of R: [p. 28]
   1) Continue to score R with LAMF and no K complexes or sleep spindles if you have already seen rapid eye movements and the chin EMG remains low.

This rule refers to the "tonic" phase or R. This phase is where nothing much is happening. There are no rapid eye movements, but there is also nothing to indicate that another stage has started.

Compare Rule B for R [p.28] with Rule B for N2 [p.26]. Both refer to epochs where the event that leads to the sleep stage score (K complexes or spindles for N2, rapid eye movements for R) is not present. If the chin EMG is at its lowest level, these epochs look identical. If you have entered N2 through the appearance of a sleep spindle or a K complex, these epochs are scored as N2. If you have entered R because of the appearance of rapid eye movements, these epochs are scored as R. Scoring the epochs between N2 and R (a transition that happens frequently) is one of the more difficult decisions for the scoring technologist.

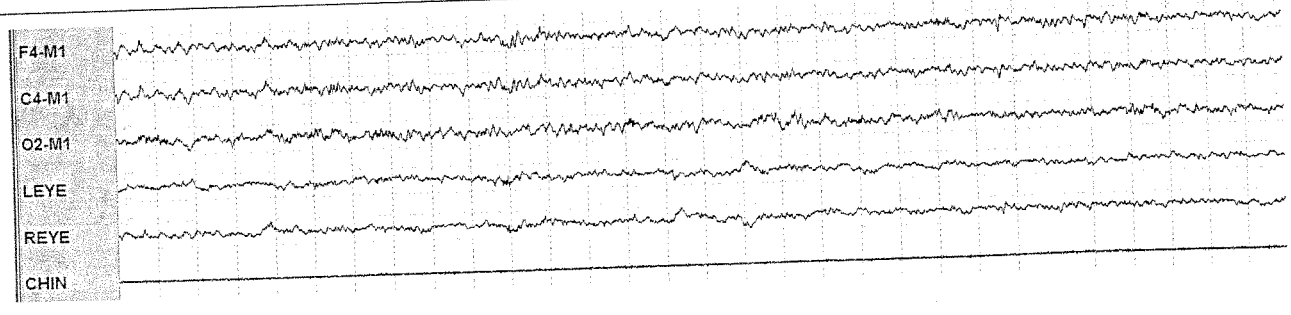

Figure 25. N2 sleep with no K complexes or spindles or "tonic" R sleep? 30 second epoch.

Figure 25 shows one of these epochs. The EEG is LAMF, with a little bit of fast activity at 5 seconds into the epoch (at about 18 Hz when you expand the scale) but nothing else of note. There are no K complexes, spindles or eye movements. It could even be N1 in a patient with good alpha rhythm. This is an epoch that must be scored *in context*. This means that you have to know what came before and what comes after to be able to provide a score. We will return to this later (Rule D below).

C. The following defines the end of R:
   1) End R when you see any of the following:
      a. Transition to W or N3
         OR
      b. An increase of chin EMG with no K complexes or spindles (score N1)
         OR
      c. An arousal followed by LAMF and slow eye movements (score N1)
         OR
      d. A major body movement followed by slow eye movements with LAMF and no K complexes or spindles (score N1)
         OR
      e. There is a K complex or sleep spindle in the first half of the epoch (score N2)

Let's explore each of these rules in turn.

Rule A. If an epoch meets the criteria for W, it is W and it doesn't matter what else is in the epoch. If the epoch is 60% alpha rhythm, it is W. If the patient does not have alpha rhythm and the epoch has blinking, reading eye movements or rapid eye movements with high chin EMG, then it is W. If the epoch has more than 6 seconds of slow wave activity, it is N3. End of story.

Rule B. This is one of the few instances where chin EMG is critical. If the EMG goes up and there are no K complexes or spindles, score N1.

Rule C. Arousals are counted as a bit of W. An arousal might not take up more than 50% of the epoch, so the epoch cannot be scored as W. When a little bit of W happens, it bumps you out of N2 (see rule 5. C. 1. b [p. 26]). But if you are in R, you stay in R unless there are slow eye movements. If there are slow eye movements after an arousal, score N1. We'll learn more about arousals in Section V.

Rule D. Major body movements have different rules depending on the context (see rule 8 below). The *AASM Manual* rules are based on the idea that the patient can roll over in sleep without waking up. You may not be able to tell what stage the patient is in while moving, but what happens before or after can be used to score the epoch. If there are slow eye movements after the major body movement, score both the epoch with the major body movement and the epoch after the body movement as N1. If there are no slow eye movements, continue to score R.

Rule E. Finally, if there are K complexes or sleep spindles in the first half of an epoch, score N2. If there are K complexes or sleep spindles in the second half of the epoch, then more than half of the epoch is still considered R. The next epoch will be scored N2 (see rule 5. A. 1 [p. 26]).

D. Score epochs in between N2 and R as follows:
   1) Score the first epoch after a drop in chin EMG as R, even when there *are no* rapid eye movements, as long as there are no:
      a. K complexes
         OR
      b. Sleep spindles
   2) Score the first epoch after a drop in chin EMG as N2 if there *are*:
      a. K complexes
         OR
      b. Sleep spindles
   3) If there is no drop in chin EMG, score all of the epochs after the last K complex or sleep spindle as R.

This is often called the "look back" rule. Here's how it works: You are happily paging through a record in a long bout of N2. There are K complexes without arousals and spindles, but there are also several epochs with no K complexes or spindles. You score all of these as N2 (rule 5.B.1. [p.26]). Then you see a burst of rapid eye movements. Is this the first epoch of R? It might not be, if the epoch before is one of the epochs you must score in context. These epochs have no K complexes, no spindles and no rapid eye movements. You must "look back" to see whether there has been a change in EMG tone and when the last K complex or spindle occurred. Figures 8 and 9 in the *AASM Manual* [p. 30] are drawings that show the different possibilities and how to deal with them. For patients who have a drop in chin EMG, the drop indicates that R has started. Remember that some patients will be at their lowest chin

EMG level during N2 and will not drop further. If the drop of chin EMG happens in the second half of the epoch, score the stage that the patient was in for the previous epoch (Figure 8B). If the drop happens in the first half of the epoch, score R (Figure 8A). But if you have a drop and then later you see a K complex or spindle, then the patient hasn't left N2 yet (Figure 9A). Score all of the epochs between the drop and the next K complex or spindle as N2. If there is no drop in chin EMG, score all of the epochs between the last K complex or spindle and the first bout of rapid eye movements as R (Figure 9B).

Notes

1) There can be alpha rhythm during R. The alpha rhythm in R is often slower than the alpha rhythm in W. The distribution tends to be the same (highest in the occipital channel). If the alpha rhythm is the same frequency as the alpha rhythm in W and it takes up more than half of the epoch, score W.
2) Remember the definitions of sawtooth waves and muscle twitches? They will increase your confidence when you score R. But they are not part of the scoring criteria. Figure 26 has an epoch that looks like Figure 25, but there are small sawtooth waves at the end. If you were already scoring R, this would support the score. If you were scoring N2, you would keep scoring N2 until you saw rapid eye movements. Then you would use the look back procedure to determine when R starts.

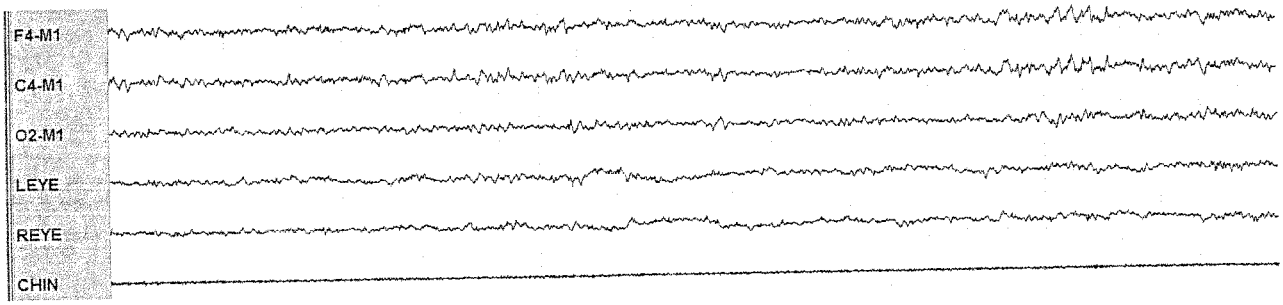

Figure 26. Sawtooth waves near end of epoch. 30 second epoch.

3) When an epoch with low chin EMG tone has both rapid eye movements and K complexes or spindles, score R.

8. MAJOR BODY MOVEMENTS [P. 31]

Definition

Major body movements are epochs that have no readable EEG for more than half of the epoch. This usually happens when the patient turns over or moves around. Movement of the electrodes generates a voltage that can be higher than the EEG signal. It is usually accompanied by EMG activity from the scalp muscles.

RULES

A. If alpha rhythm is seen in any part of the epoch that has a major body movement score W.
B. If there is no alpha rhythm in the epoch and the epoch before or after the major body movement is W, then the epoch with the major body movement is also W.
C. If criteria for A or B are not met, then score the epoch as the same stage as the epoch after the major body movement

Rules A and B tilt the scoring of major body movements toward W. The minimum amount of alpha rhythm is not given, so even a few sinusoidal waves of the right frequency could be used to score W.

Table of Waveform Definitions

	Amplitude	Frequency	Waveform	Distribution
Alpha Rhythm	Not Used	8 – 13 Hz	Sinusoidal	Occipital
Eye Blinks	Not Used	0.5 – 2 Hz	Vertical	EOG Channels
LAMF: Low Amplitude Mixed Frequency	Low	4 – 7 Hz	Mixed	All Over
Vertex Sharp Waves	Not Used	2 Hz or More	Sharp	Central
K Complex	Not Used	Less than 2 Hz	Sharp	Frontal
Sleep Spindle	Not Used	11 – 16 Hz	Sinusoidal	Central
Slow Wave Activity	75 μV or More	0.5 – 2 Hz	Varies	Frontal
Sawtooth Waves	Not Used	2 – 6 Hz	Triangular, Serrated	Central

1. AGES FOR PEDIATRIC RULES

RULES

A. Use the pediatric rules for children 2 months post term or older

"Post term" means at least 40 weeks after conception. For babies born full term, this means use the pediatric rules starting 2 months after birth. For babies born a month premature (36 weeks after conception), use the pediatric rules starting 3 months after birth.

You will notice in the notes that there is no upper limit for using the pediatric rules. Some are in favor of using the adult criteria as soon as there are the key waveforms of adult sleep scoring: alpha rhythm, K complexes, spindles and slow wave activity. For most children this is at 5 – 9 months post term. Others will continue to use the pediatric criteria until a specific age, such as 3 years.

4. SCORING PEDIATRIC SLEEP STAGES [P. 32]

In children under the age of 6 months, scoring of sleep stages may be difficult. This is because the waveforms we rely on for staging have not yet developed. The ages at which K complexes, spindles and slow wave activity develop are listed below:

Table 19. Age when Sleep Waveforms are First Seen

Waveform	Age when First Seen
Sleep Spindles	2 – 3 Months
K Complexes	4 – 6 Months
Slow Wave Activity	5 – 6 Months

RULES

A. If the child is not in W or R and there are no sleep spindles, K complexes without arousals or slow wave activity, score N
B. If there are sleep spindles or K complexes but not slow wave activity, score epochs with sleep spindles or K complexes as N2 and other epochs that are not W or R as N
C. If there are no sleep spindles or K complexes and some epochs have more than 20% slow wave activity, score those as N3 and other epochs that are not W or R as N
D. If there are sleep spindles, K complexes and slow wave activity, score N1, N2 and N3 as in adults.

For children under 2 or 3 months of age it may be difficult to make the distinction between sleep stages. Based on the polygraph recordings alone, it may be difficult to determine if the child is awake or asleep. It may be difficult to tell the difference between N1, N2 and N3. Rule A says that we can lump all of these together as "N" if the patient has no K complexes, spindles or slow wave activity.

As we will see, infants do not have the same kind of alpha rhythm that adults have. This makes scoring of sleep onset very difficult. To further complicate matters, infants often transition from W to R, rather than the adult pattern of W to N to R.

This means that technician notes are not just helpful, they are at times the only way you can tell what stage the infant is in. **Detailed notes on the behavior of the infant are very important.** It is especially important to note if the infant interacts with the environment. But it is easy to be fooled. Infants may smile, make noises and move around a bit during R. The most important observation is eyes open or eyes closed.

The rules above apply to the scoring of stages within N. The rules for N2 and N3 are the same for children as for adults, but gradually take effect as the waveforms appear. The rules for W and N1 are a bit different.

5. PEDIATRIC STAGE W [P. 33]

Definitions

The definitions for pediatric stage W are mostly the same as for adults. Alpha rhythm (when it occurs), eye blinks, reading eye movements and rapid eye movements are all the same as for adults and used in the scoring of W. The new definition is a result of a gradual maturation of the alpha rhythm.

Dominant posterior rhythm (DPR) is the same as alpha rhythm for infants and young children. The frequency changes with age, but 2 things are the same: it is biggest in the occipital channel, and it goes away when the patient's eyes are open. Table 20 shows the relationship between frequency and age.

Table 20. The relationship between dominant posterior rhythm frequency and age.

Dominant Posterior Rhythm	
Frequency	Age
3.5 – 4.5 Hz	3 – 4 Months
5 – 6 Hz	5 – 6 Months
7.5 – 9.5 Hz	3 Years

The DPR is used in infants and children in the same way as alpha rhythm is used in adults.

RULES

A. DPR in children is the same as alpha rhythm in adults
B. Score W in epochs where DPR or alpha rhythm is more than 50% of the epoch
C. If there is no alpha rhythm or DPR, score W when:
   1) There are eye blinks
      OR
   2) There are reading eye movements
      OR
   3) There are rapid eye movements with high EMG tone

Rules A and B are easy. If you are recording a 6 month old infant, you should look for 5 – 6 Hz sinusoidal EEG in the occipital channel (see Table 20). If you see it for more than half of the epoch, score W. Rule 3.C. is the same as rule 3.B. for adults [p. 25]. We know that around 10% of adults will have no alpha rhythm. But almost all infants under 3 months of age will have no DPR or alpha rhythm. This means you would score W when there are eye blinks or rapid eye movements. Not many 3 month old infants are reading, and if they do they are likely to be reading picture books. They won't have the kind of scanning eye movements adults have when reading text. Rapid eye movements may occur in W when tracking a mobile or the face of a parent. Infants often go from W to R, so the rapid eye movements can be misleading. Chin EMG is not a very reliable measure, and may drop only a little bit in the transition to R. What does this mean? **Detailed notes on the behavior of the infant are very important.** The most important observation is eyes open or eyes closed. When you are running a pediatric study, take frequent notes. When you are reading a pediatric study, look at the technician notes frequently.

Notes

1) Note 1 provides some important information on how many children have DPR at different ages, and some amplitude information that is often helpful. This information is summarized in Table 21.

Table 21. Features of DPR and alpha rhythm activity in infants and children.

	Less Than 3 – 4 Months	3 – 4 Months	5 – 6 Months	3 Years	6 – 9 Years	More Than 9 Years
Amplitude	Not Used	50 – 100 μV	50 – 110 μV	Not Used	Average is 50 – 60 μV	Not Used
Frequency	Slow	3.5 – 4.5 Hz	5 – 6 Hz	7.5 – 9.5 Hz	8 – 13 Hz	8 – 13 Hz; Mean is 9 Hz at Age 9, 10 Hz by Age 15
Waveform	Irregular	Sinusoidal	Sinusoidal	Sinusoidal	Sinusoidal	Sinusoidal
Distribution	Occipital	Occipital	Occipital	Occipital	Occipital	Occipital
% Children	100%	75%	70% by 12 Months	82%	~88%	90%

2) When they happen, reading eye movements in children are defined in the same way as reading eye movements in adults.
3) The occipital lobe of the brain is part of the visual system. There are strong connections from the eye to the occipital lobe. In children, blinking can cause some high amplitude activity in the occipital lobe. This is called an evoked potential. It is usually a large amplitude signal (up to 200 μV) that starts a little bit after the eye movement and lasts less than half a second. This is **not** an abnormal EEG pattern. Because the child is blinking, the epoch is scored W.
4) Older children can have an interesting waveform called posterior slow waves of youth (PSW). These are 2.5 – 4.5 Hz and often occur at the same time as the DPR. The PSW is biggest between 8 and 14 years of age. They disappear with eye opening and go away with N1.
5) Infants don't spend a lot of time awake with their eyes closed. If they try to fool you by closing their eyes and thinking quietly about their next bottle, score it as N1 anyway.

6. PEDIATRIC STAGE N1 [P. 34]

Definitions

The definitions for pediatric stage N1 are mostly the same as for adults. Slow eye movements, LAMF, vertex sharp waves and sleep onset are all defined in the same way. Two new waveforms are used:

Rhythmic anterior theta activity (RAT) is runs of 5 – 7 Hz activity biggest in the frontal channel.

Hypnagogic hypersynchrony (HH) is a burst of very large waves that look abnormal. The frequency is 3 – 4.5 Hz, they are very sinusoidal, and the amplitude can be as high as 350 μV. Because they are so large, they are seen in all channels but they are usually smallest in the occipital channel.

Table 22. RAT and HH

	Rhythmic Anterior Theta Activity	Hypnagogic Hypersynchrony
Amplitude	Not Used	75 – 350 μV
Frequency	5 – 7 Hz	3 – 4.5 Hz
Waveform	Sinusoidal	Sinusoidal
Distribution	Frontal	Frontal and Central

RULES

A. Score N1 in epochs where DPR or alpha rhythm is less than 50% of the epoch
B In infants and children without DPR or alpha rhythm, score N1 when you first see:
   1) LAMF that is slower than the W activity
   OR

2) Slow eye movements
   OR
3) Vertex sharp waves
   OR
4) RAT
   OR
5) HH
   OR
6) High amplitude 3 – 5 Hz activity either all over or in the occipital channel

This is similar to 4.B. in adults [p. 25] with the addition of the 2 new waveforms defined above and the high amplitude occipital slow wave activity.

Notes

1) The high amplitude diffuse or occipital slow wave activity (Rule 6) is at 3 – 4 Hz in infants from 6 – 8 months old with amplitude of 75 – 200 μV. It is usually 1 – 2 Hz slower than activity in W.
2) In children 8 months to 3 years the high amplitude slow wave activity may also move to the frontal or central channels at 4 – 6 Hz with very high amplitude (more than 200 μV).
3) After 3 years of age sleep onset can be scored by a slowing of the DPR and gradual replacement by LAMF. Deciding the precise moment when N1 starts may be very difficult.
4) In infants under 3 months of age the first stage of sleep is often R. This makes the scoring of sleep onset even harder. Behavioral notes from the technician are very, very important.
5) RAT usually appears around 5 years of age and disappears in adulthood.
6) Vertex waves can be seen but are not very well formed between 6 – 16 months. Vertex waves that look like those of adults are seen after 16 months.
7) HH is a pattern of sleep onset. About 30% of infants 3 months of age have it, 95% of normal children between 6 – 8 months have it, but only 10% of children at age 11 years have it. It is usually gone by 12 years of age.

One more time: **Detailed notes on the behavior of the infant are very important. If you are running a study, take lots of notes**. If you are reading the study, look at the notes often. In adults it can sometimes be difficult to tell when sleep onset happens. In children it is much harder and in infants it can be close to impossible.

1. SCORING AROUSALS

Rules

A. Arousals from N are an "abrupt shift" of EEG frequency (except sleep spindles) that lasts at least 3 seconds. Arousals from R are an abrupt shift of EEG frequency that lasts at least 3 seconds and an increase of chin EMG that lasts at least 1 second.

The scoring of arousals has a minimum duration (3 seconds) but it does not have a maximum duration. The beginning of a bout of W is considered an arousal.

Notes

1) When looking for the abrupt shift of EEG frequency you can use either the central or occipital channel.
2) You can increase your level of confidence in scoring an arousal by looking at other channels – EMG, respiration and ECG. However, these channels cannot be used to score arousals. You must score the arousal only when there is an increase of EEG frequency.

What does an "abrupt shift" of EEG frequency mean? This is the critical decision in scoring an arousal. The shift can include alpha, theta or frequencies faster than 16 Hz, but does not include sleep spindles. To understand the shift, we need to understand the background EEG activity of sleep. The background for N1, N2 and R is LAMF. Yes, there are K complexes and spindles in N2, but these don't count in scoring an arousal. The K complexes are slower than LAMF, and spindles are specifically excluded. The background activity for N3 is slow wave activity.

Because arousals are a "lightening" of sleep stage, the "abrupt shift" is typically an increase in EEG frequency. Since the background EEG in N1, N2 and R is LAMF, an increase in frequency would require a shift to alpha activity or higher EEG frequencies (greater than 16 Hz). The term alpha activity is used because the increase in frequency may be in the central channel, but it could also be the appearance of alpha rhythm if it happens in the occipital channel and is sinusoidal. The background activity in N3 is slow wave activity (0.5 – 2 Hz). An increase in frequency could be a shift to theta activity (4 – 7 Hz), to alpha, or to higher frequencies.

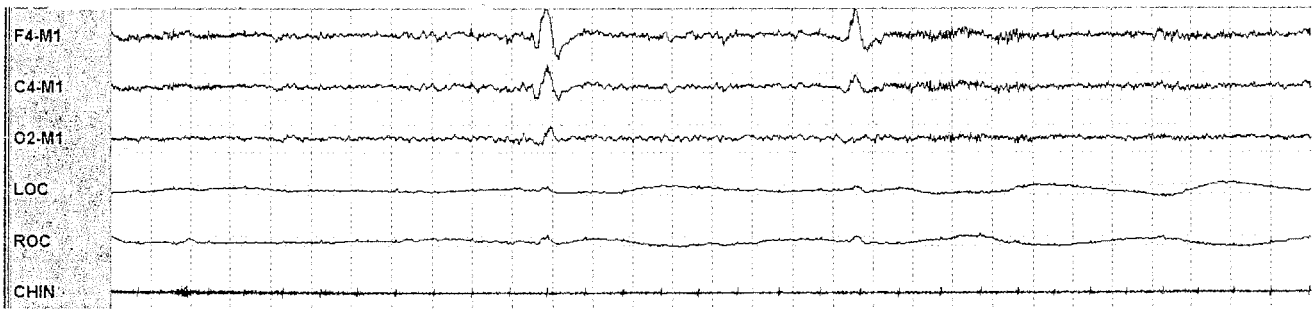

Figure 27. Arousal from N2. 30 second epoch.

Figure 27 shows an arousal from N2. A K complex occurs in the first half of the epoch. Approximately 2/3 of the way into the epoch there is another K complex and afterward the EEG frequency shifts from LAMF to alpha frequency. The alpha activity is highest in the frontal channel, so it is probably not alpha rhythm. This shift in frequency lasts for more than 3 seconds, so it meets the criteria for an arousal.

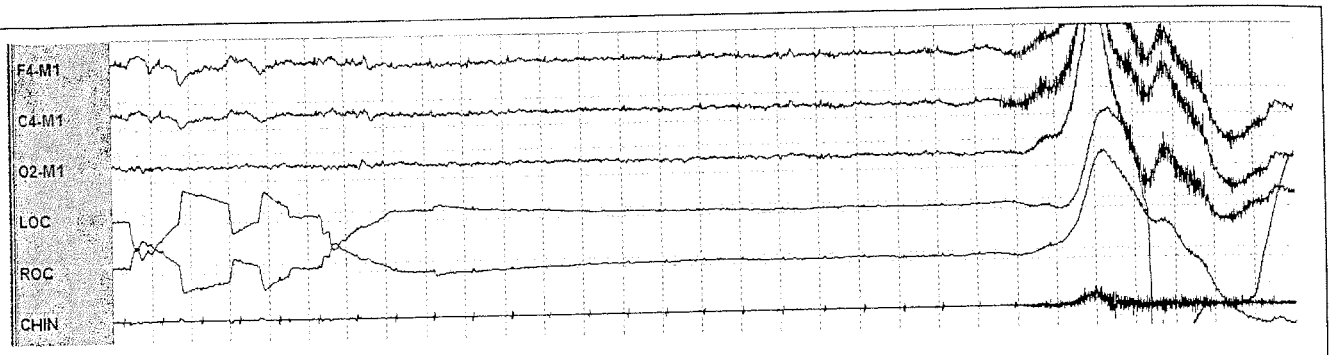

Figure 28. Arousal from R. 30 second epoch.

Figure 28 shows a typical arousal from R. Note the eye movements and LAMF in the first part of the epoch. About 25 seconds into the recording the chin EMG increases in amplitude. The EEG frequency shows an abrupt shift from LAMF to about 20 Hz (you will need to use a 5 or 10 second window to see this). The abrupt shift in EEG frequency lasts more than 3 seconds and the increase in chin EMG lasts more than 1 second. This is an arousal.

This is from the Frequently Asked Question page:

Can you score AROUSALS IN AN AWAKE EPOCH if 10 seconds of sleep precedes the event and all other criteria are met?

Yes. 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.

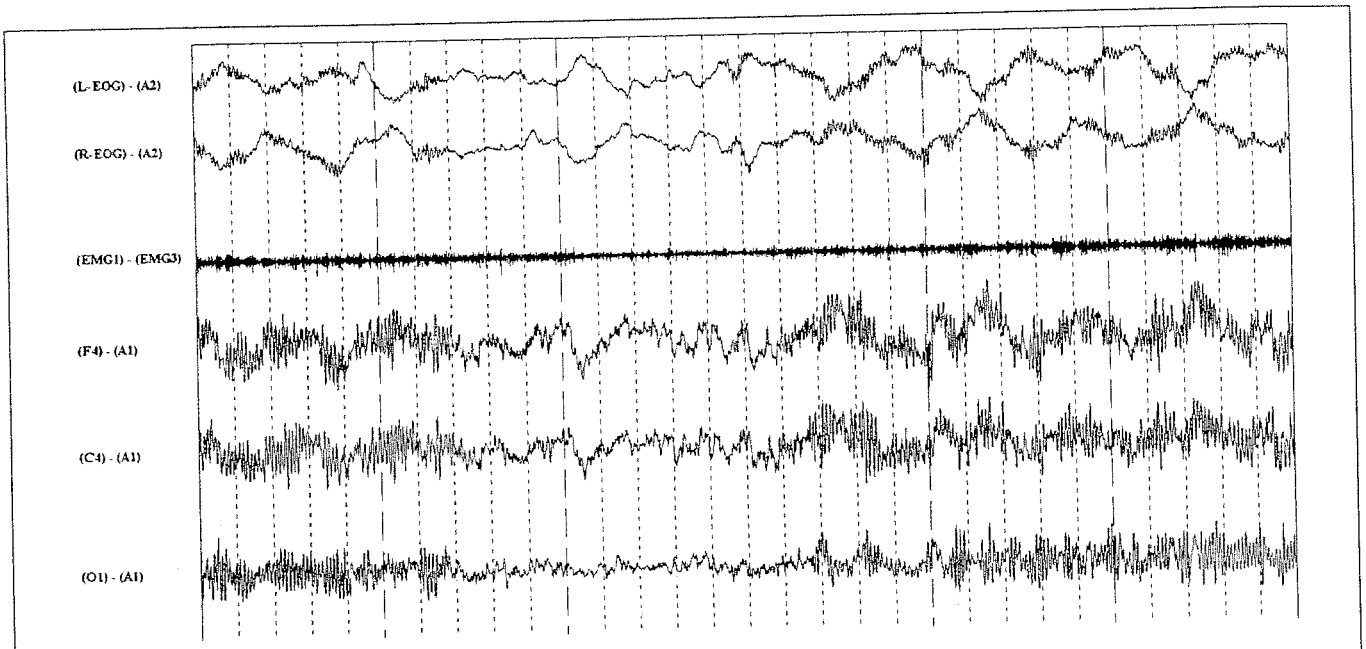

Figure 29. Arousal during an epoch of W. 30 second epoch.

Figure 29 shows an epoch of W. There is huge alpha rhythm in all 3 EEG channels for 20 seconds of the epoch (7 at the start and 13 and the end). In between is a drop out of alpha rhythm and replacement with LAMF. This is N1 and lasts 10 seconds. The start of alpha rhythm after the bout of N1 is an arousal. It is an abrupt shift of EEG frequency lasting more than 3 seconds. The shift is back to alpha rhythm.

1. LEAD PLACEMENT

RULES

A. The ECG leads should be placed on the right shoulder and the left hip.

Notes

1) Use additional cardiac leads if a physician requests them.
2) You may need to increase the size of the display to see ECG waveforms.
3) These electrode placements are not standard for ECG, but are similar and not likely to fall off.
4) Disposable sticky ECG electrodes have fewer artifacts than EEG electrodes applied with paste and used to record the ECG.

The Task Force had to decide between using a standard 12 lead ECG (which would use up lots of channels) and a 1 channel ECG. They chose to recommend the single channel, and they settled on Lead II (right arm to left hip) as the best signal. They went a step further and suggested moving the electrodes to the torso (chest and stomach) so that they would be less likely to fall off.

Some ECG abnormalities produce different changes in different standard ECG channels. Limiting the recording to a single channel makes it impossible to see some of these abnormalities. It also limits the ability to know where some of the abnormalities come from. But it produces an excellent measure of the number of heart beats per minute. The signal should contain all 3 elements of the ECG: a P wave, a QRS complex and a T wave.

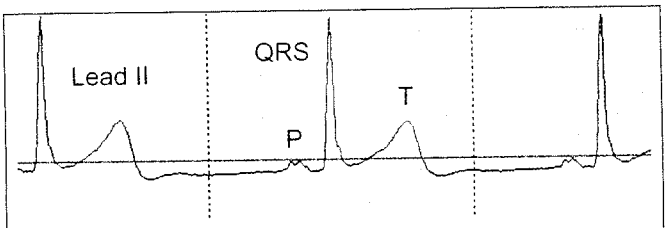

Figure 30. Elements of the normal ECG. Vertical lines are 1 second apart

The manual does not have a definitions section for cardiac rules, but some terms need explanation:

- **Tachycardia:** A heart rate that is faster than normal.
- **Bradycardia:** A heart rate that is slower than normal.
- **Asystole:** A period of time with no heart beat.
- **Fibrillation:** Fluttering movements of the heart that do not push blood through the blood stream.

2. SCORING RULES

RULES

A. Score sinus tachycardia when the heart rate is faster than 90 beats per minute.
B. Score bradycardia when the heart rate is slower than 40 beats per minute in patients older than 6 years.

Sinus tachycardia means that the heart rhythm starts in the sino-atrial node, which is the normal place for a heart beat to start. The sino-atrial node produces the P wave. If you can see a P wave before each heart beat, you know the heart is in a sinus rhythm.

How long does the tachycardia or bradycardia have to last before you score it? This question was submitted as a Frequently Asked Question and the answer was:

Sustained sinus bradycardia or tachycardia is defined by more than 30 seconds of a stable rhythm to distinguish it from transient responses associated with sleep disordered breathing events or arousals.

The heart rate slows during episodes of apnea and speeds up during arousals. If these changes are brief they are considered normal and should not be scored. Children under 6 years of age have faster heart rates, but the Task Force felt that there wasn't enough data to say what is normal and what is abnormal.

C. Score asystole when there is no heart beat for more than 3 seconds in patients older than 6 years.

This is the same as the American Heart Association recommendation. You should score asystole of 3 seconds. Your center's emergency procedures should tell you when an asystole becomes an emergency.

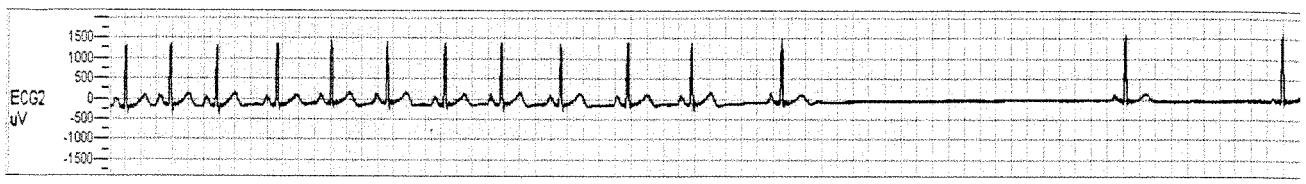

Figure 31. Asystole of 4.25 seconds. Vertical lines are 200 milliseconds apart.

D. Wide complex tachycardia is at least 3 beats in a row, a rate of at least 100 beats per minute, and a QRS interval of at least 120 milliseconds.
E. Narrow complex tachycardia is at least 3 beats in a row, a rate of at least 100 beats per minute, and a QRS interval of less than 120 milliseconds.

Measure the QRS interval from the beginning of the Q to the end of the S. You will need to expand your time base and increase the display of the ECG to make these measurements.

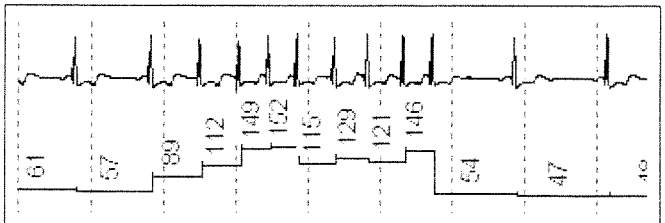

Figure 32. Tachycardia. Vertical lines are 1 second apart.

Figure 32 shows a portion of an epoch from an 82 year old man with heart disease. The upper channel is the ECG. The lower channel measures the time between the R parts of the QRS complexes. His usual heart rate is 60 beats per minute. During this episode the rate climbs to as high as 152 beats per minute, and stays above 100 beats per minute for 8 beats. This is tachycardia. To determine the type, we need to expand the time base.

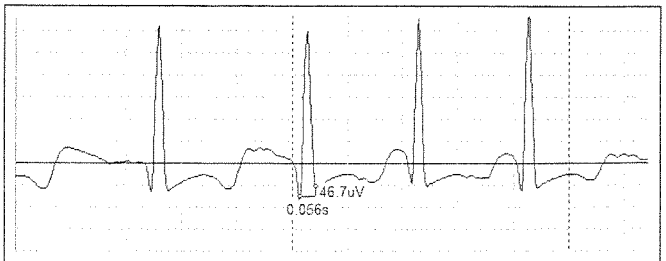

Figure 33. Measuring QRS interval in tachycardia. Vertical lines are 1 second apart.

In Figure 33 we are able to expand the ECG tracing and use a measuring tool to determine the QRS interval. The interval is 0.056 seconds, which is 56 milliseconds. This is less than 120 milliseconds and meets the definition of narrow complex tachycardia.

F. Score atrial fibrillation with an irregularly irregular rhythm and the P waves are replaced by rapid waves with no consistent waveform.

An irregularly irregular rhythm means that the QRS complexes happen with a constantly changing rate. Some arrhythmias cause the rate to slow a little bit more with each beat. Atrial fibrillation is not like this. It causes some narrow and some wide intervals between QRS complexes with no particular pattern. In addition, the P wave disappears. This means that the sino-atrial node is no longer pacing the heart beat. When that happens, other parts of the heart try to start a heart beat. The electrical discharge from many atrial pacemakers firing at different times causes rapid waves in the ECG. Some of these waves are large and others are small. There is no pattern to the rapid waves.

Notes

1) Heart block is when the pacemaker signal does not cause the heart to beat. If you can see a clear P wave and it is not followed by a QRS complex, you can score heart block. This may not be very clear with a single ECG lead.
2) Ectopic or premature beats are when another pacemaker sneaks in after a QRS complex and before the sino-atrial node is ready to start another heart beat. They can come from the atrium and look like a P wave with a slightly different shape, or they can come from the ventricle and have a very different QRS shape. Many people have premature beats during sleep. If they are very frequent, they should be reported.

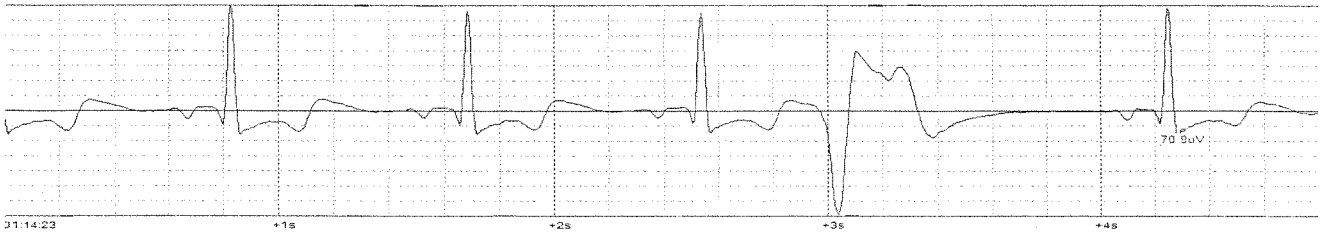

Figure 34. Ectopic beat. Vertical lines are 1 second apart.

Figure 34 shows an ectopic beat at +3 seconds. The normal interval between beats is about 1 second (for a heart rate of 60 beats per minute). There are 3 normal beats. Then, after only half a second, a beat with a very different shape is seen. It is probably from the ventricle. A few beats like this during the night are normal. If abnormal beats occur frequently, you should make note of it in your report.

3) These rules don't apply to children under 6.

1. SCORING PERIODIC LIMB MOVEMENTS IN SLEEP (PLMS)

The Task Force writing the movement rules uses a lot of acronyms (for example, leg movements are LMs, hypnogenic foot tremor is HFT). The full names are descriptive – they tell you a lot about what you are looking for in the recording. The acronyms are difficult to keep straight. If you forget what an acronym stands for, you should look it up.

RULES

A. The rules for scoring a limb movement (LM) are:
   1) The LM must last at least 0.5 seconds
      AND
   2) The LM must last less than 10 seconds
      AND
   3) The minimum amplitude of the LM is 8 μV higher than baseline
      AND
   4) The start of the LM is when the amplitude meets the 8 μV requirement
      AND
   5) The end of the LM is when the amplitude goes below 2 μV above baseline for more than half a second

Don't worry that you will be doing a lot of measurement of LMs. Most LMs easily meet the requirements for amplitude because electrical activity from the muscle is a large signal. You will often be able to tell by eye that the duration of the burst of activity meets the duration requirements. This means that only rarely will you have to measure a LM, which is a good thing because some patients may have as many as 400 – 500 LMs in a single night.

Table 23. Limb Movement Rule

	Limb Movement
Amplitude	More than 8 μV Above Baseline
Frequency	Fast
Waveform	Spiky
Duration	0.5 – 10 Seconds

Table 23 shows the rules for scoring a LM. The amplitude criterion depends on the amplitude of the signal before the LM starts. This means it is a *relative* measure and not an *absolute* measure. The amplitude criterion for slow wave activity is absolute – the waves must be 75 μV no matter what the amplitude before or after. The limb EMG is made up of the electrical activity of muscle fibers. The fibers don't fire all at once, but when they do the signal is very brief. This means that the frequency of the EMG signal is fast. The high frequency filter should be set at 100 Hz [p. 19] so that the muscle signal is not filtered out. You will note in Table 23 that we have replaced the usual distribution measure with duration. The distribution of a LM is whatever muscle you are recording from. LMs can be recorded from the leg, and they can also be recorded from the arm or fingers or neck. The duration of the movement is the more important measure for defining the LM. Use the rules for the start and finish of the LM provided in rules 4 and 5.

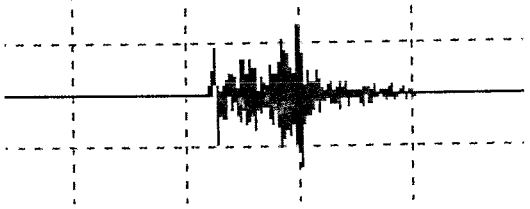

Figure 35. Left leg EMG. Vertical lines are 1 second apart. Horizontal lines 75 μV apart.

Figure 35 shows muscle activity from the anterior tibialis muscle of the left leg. The baseline is about 2 μV. The muscle activity reaches the criteria of 8 μV over baseline (10 μV) with the first burst of activity. The amplitude of the signal goes up by about 20 μV and increases until it is about 80 μV from top to bottom. It decreases gradually and stays above 2 μV above baseline for 1.5 seconds. Is this a LM?

Table 24. Comparing our Event to a LM

	Limb Movement	Our Event
Amplitude	More than 8 μV Above Baseline	About 50 μV
Frequency	Fast	Fast
Waveform	Spiky	Spiky
Duration	0.5 – 10 Seconds	1.5 Seconds

It looks like we meet all of the criteria, and the event is a LM. Now let's score the periodic part of periodic limb movements.

B. The rules for scoring a periodic limb movement (PLM) series are:
   1) The series must include at least 4 LMs
      AND
   2) The time between the start of one LM and the start of the next LM must be at least 5 seconds
      AND
   3) The time between the start of one LM and the start of the next LM must be less than 90 seconds
      AND
   4) If you have LMs on both legs, score them as 2 LMs only when the time between the start of one LM and the start of the other LM is more than 5 seconds

In order to score a PLM, an event must meet all of the rules in A and all of the rules in B. The time between the start of one LM and the start of the next LM is usually between 20 and 40 seconds. In order to measure this, you need a compressed time scale on your display. Figure 36 uses a 3 minute screen.

Figure 36. PLM series. Vertical lines are 30 seconds apart. Horizontal lines 75 μV apart.

There are 8 limb movements in 3 minutes. That calculates out to 2.67 movements per minute. To find the frequency in seconds, it is 1/2.67 x 60 or a frequency of one every 22.5 seconds. The frequency of PLMs is not exact – some of these leg movements are a little farther apart than others. But the distance between movements in this sample is always more than 5 seconds and less than 90 seconds. Since there are more than 4 movements, this qualifies as a PLM series.

Notes

1) Do not score PLMS that occur 0.5 seconds before, at any time during, and 0.5 seconds after an apnea or hypopnea.
2) Score PLMS with arousals if the arousal occurs within 0.5 seconds before or after the LM. This means that the arousal can come after the leg movement or **before** the leg movement. The *AASM Manual* requires that you count up the number of PLMS **and** the number of PLMS with arousal [p.18] for your sleep study report.

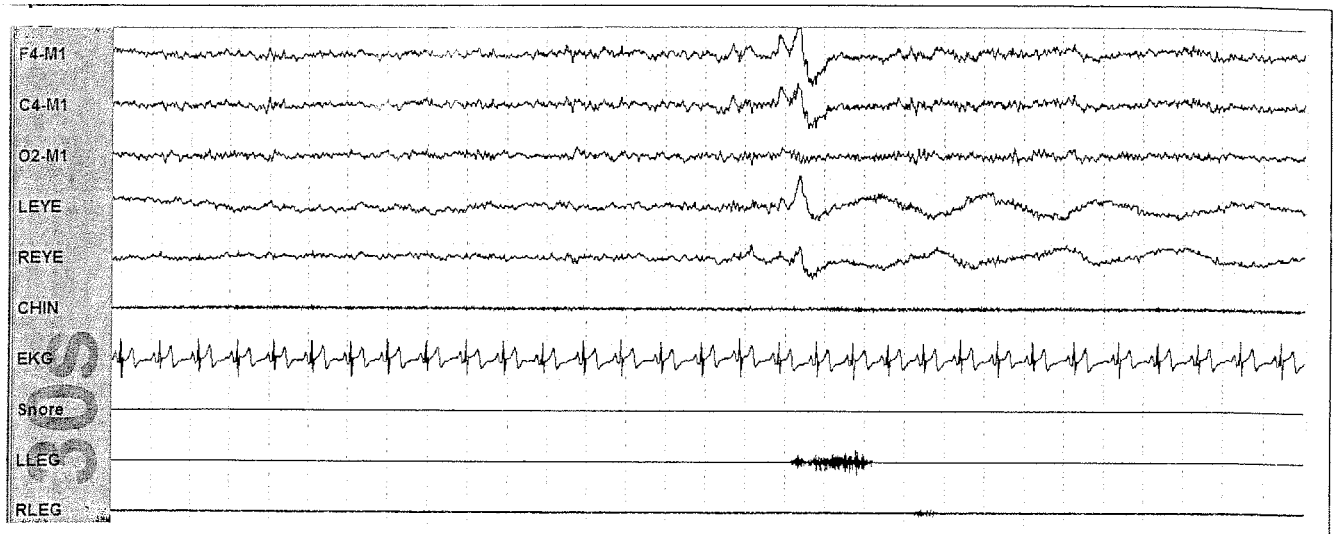

Figure 37. Leg movement with arousal. 30 second epoch.

The left leg burst in Figure 37 lasts about 2 seconds and meets amplitude criteria for a leg movement. It happens about the same time as a K complex. The K complex is followed by 6 seconds of faster frequency EEG, meeting criteria for an arousal [Section V, p. 37]. This is a LM with arousal.

3) Where do you put the electrodes for recording PLMS? It's the muscle in the front of the leg below the knee. Put the electrodes 2 – 3 cm apart (about 1 ½ inches). The electrodes should be halfway down the muscle, usually the part of the muscle that is the widest. Don't put the electrodes on the bone. You will need to feel the muscle. It is usually a bit to the outside of the leg. This note says that it is strongly preferred that you record from both legs. It says you can have a single channel that records from one electrode on each leg. It is much better to record the legs separately – it gives you a much more accurate measure of PLMS.
4) The baseline is very important in the scoring of PLMS. The *AASM Manual* recommends that the baseline should be less than 10 μV. What do you do if the baseline is more than 10 μV? The first thing you can do is check the impedance on the electrode. High impedance can cause artifact that increases the amplitude of the signal. This should be less than 5 kΩ. If the electrode contact is good, there really isn't much else that you can do.
5) The EMG signal is fast. If you use filters that reduce fast activity, you will also reduce the signal. This includes the 60 Hz "notch" filter, often used to eliminate electrical noise from power outlets.

2. SCORING ALTERNATING LEG MUSCLE ACTIVITY (ALMA) [P. 41] [SCORING ALMA IS OPTIONAL]

Rules

ALMA is the first rule that we have encountered that is optional. Your center must decide if you are to score ALMA. It is not a pattern that you will see very often.

A. The rules for scoring ALMA are:
   1) ALMA must have at least 4 muscle bursts
      AND
   2) The minimum ALMA frequency is 0.5 Hz
      AND
   3) The maximum ALMA frequency is 3 Hz

ALMA is like the leg movements you make while riding a bicycle. First one leg moves, then the other. The movements can be slow. A frequency of 0.5 Hz means one movement every 2 seconds. So there could be a leg movement on the left, then 2 seconds later a movement on the right, then 2 seconds later a movement on the left. A frequency of 3 Hz means one movement every 0.3 seconds. Left – right – left can occur in 1 second.

Notes

1) You won't be able to tell if a patient has ALMA unless you are recording the leg EMGs separately.
2) The EMG bursts in ALMA usually last between 0.1 and 0.5 seconds. This means they are shorter than PLMS.
3) There has been no research to connect ALMA with another disorder or any problems during the day. It may just be an interesting EMG pattern.

3. SCORING HYPNAGOGIC FOOT TREMOR (HFT) [P.42]

[SCORING HTF IS OPTIONAL]

RULES

HFT is the second rule that is optional. Your center must decide if you are to score HFT. It is not a pattern that you will see very often.

A. The rules for scoring HFT are:
   1) HFT must have at least 4 muscle bursts
      AND
   2) The minimum HFT frequency is 0.3 Hz
      AND
   3) The maximum HFT frequency is 4 Hz

HFT occurs in one leg. Have you ever seen someone jiggling their leg up and down when they are nervous? HFT is that leg jiggling during sleep.

Notes

1) The EMG bursts in HFT usually last between 0.25 and 1 second.
2) There has been no research to connect HFT with another disorder or any problems during the day. It may just be an interesting EMG pattern.

4. SCORING EXCESSIVE FRAGMENTARY MYOCLONUS (EFM) [P.42]

[SCORING EFM IS OPTIONAL]

RULES

EFM is another optional finding.

A. The rules for scoring EFM are:
   1) EFM bursts last less than 150 milliseconds
      AND
   2) At least 20 minutes of N sleep with EFM must be recorded
      AND
   3) There must be at least 5 bursts per minute

Notes

1) The EMG bursts in EFM have not been connected with any daytime problem or other disorders.
2) Most of the time there are no movements with EFM. If there are, they are the tiny kinds of movements that people usually have during R. The movements are usually in the fingers, toes and the corner of the mouth.
3) The bursts are usually 150 milliseconds long, but they can be longer in people with EFM who have movements.

An example of EFM is shown in Figure 38. This is a 5 minute screen. The right leg channel has frequent bursts of EMG activity that meet the criterion of at least 5 per minute.

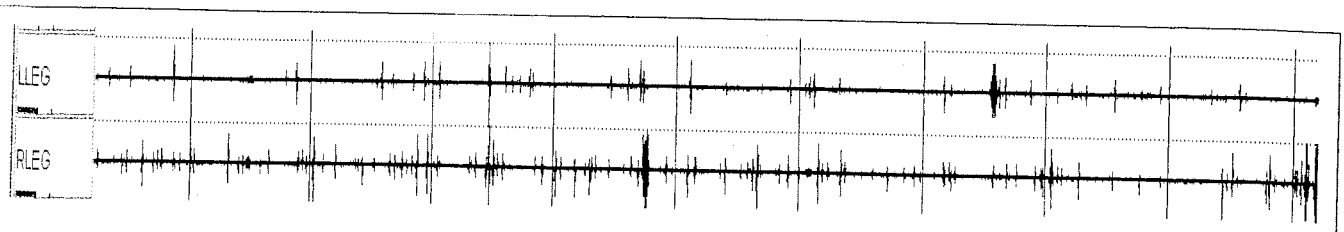

Figure 38. Excessive fragmentary myoclonus. Vertical bars are 30 seconds apart.

5. SCORING BRUXISM [P.42]

Bruxism is tooth grinding, and many people grind their teeth at night. This is often discovered by dentists when they see excessive wear on the teeth. It can be very severe, with some people grinding their teeth to nubs. Often it is linked to an eerie, creaking sound as the teeth move back and forth. Scoring of bruxism is not optional.

Rules

A. The rules for scoring bruxism are:
   1) Bruxism can be brief (phasic) bursts of chin EMG or longer (tonic) periods of increased EMG with amplitude 2 times the baseline amplitude
      AND
   2) The bursts last between 0.25 and 2 seconds and you must have at least 3 bursts in a row
      AND
   3) The sustained activity must last more than 2 seconds.
      AND
   4) There must be at least 3 seconds of baseline activity between episodes of bruxism
      OR
   5) You can make the diagnosis based on sound recordings if there are 2 episodes in a night and the patient has no signs of epilepsy

Notes

1) At times the bursts are very rhythmic, like chewing movements. This is called rhythmic masticatory muscle activity (RMMA).
2) The diagnosis is helped by adding electrodes on the muscles that close the jaw (the masseter). The muscles attach to the jaw about half way between the chin and the ear. If you clench your teeth you can feel the muscle.

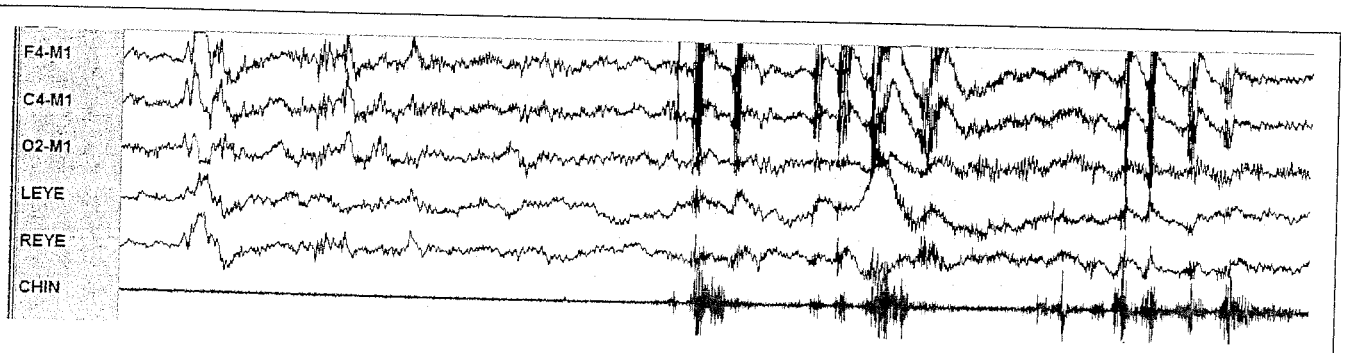

Figure 39. Bruxism. 30 second epoch.

Figure 39 contains a mix of bursting and sustained bruxism. Some of the muscles involved in bruxism attach to the skull. This means that the frontal and central EEG electrodes can also pick up muscle activity during bruxism. However, your decision should be made based on the chin EMG.

6. SCORING THE POLYSOMNOGRAPHIC FEATURES OF REM SLEEP BEHAVIOR DISORDER (RBD) [P.42]

RBD is a disorder of acting out dreams. The system that normally keeps you in bed when you dream of playing football or running from a dinosaur doesn't work. This leads to people leaping out of bed at times and occasionally injuring themselves. On a sleep study, the key feature of RBD is that the muscle tone is high during R. The recording shows LAMF and rapid eye movements, as it would normally during R, but the EMG is high.

Definitions

Like bruxism, RBD can come in 2 forms: tonic and phasic. Definitions of abnormal EMG activity are provided for both.

Sustained (tonic) activity in R is when the EMG is higher than it is in N (N1, N2 or N3) for at least half of an epoch.

Excessive burst (phasic) activity in R is measured in a complicated way. First you divide the 30 second epoch into 10 "mini-epochs" each lasting 3 seconds. Then you look for bursts in each of the mini-epochs. If you see 5 or more mini-epochs with EMG bursts, then the epoch is scored as having increased EMG. The bursts last 0.1 – 5 seconds and are 4 times higher than the baseline activity.

Rules

A. The rules for scoring abnormal EMG activity in R are:
   1) Sustained muscle activity in the chin during R
      OR
   2) Excessive phasic muscle activity in R. This can be in the chin or leg EMG channels

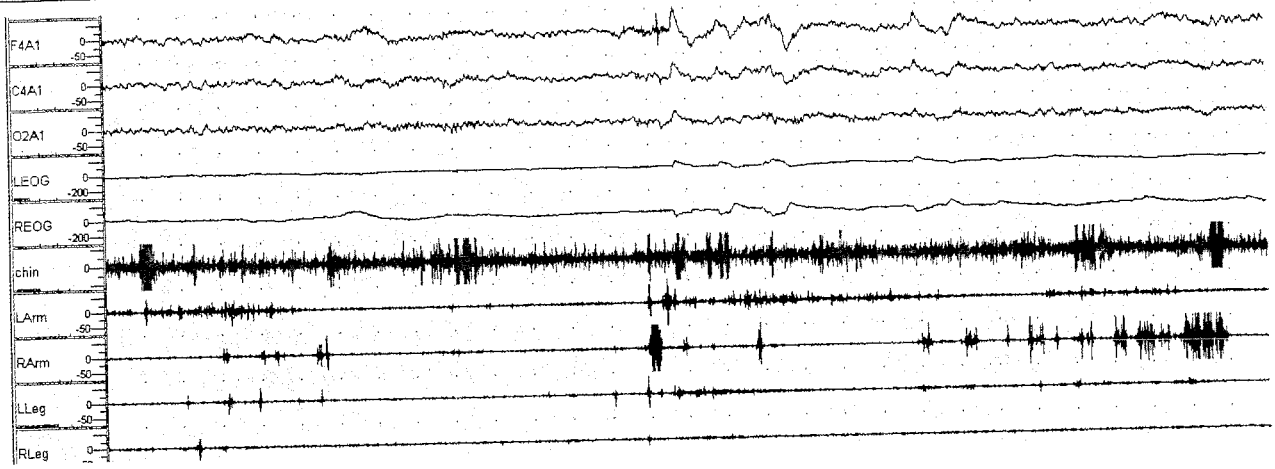

Figure 40. Sustained chin EMG activity in R. 30 second epoch.

Figure 40 is a recording from a patient with RBD. The patient was suspected of RBD prior to the test, and the ordering physician requested the addition of left and right arm EMG recordings. The EEG is LAMF; there are rapid eye movements in the middle of the epoch. The epoch is scored R. However, the chin muscle tone is high throughout the epoch. Bursts of muscle activity are recorded from the right arm, with more sustained activity from the left arm. Some activity is seen in the leg channels as well. This meets criteria for an abnormal epoch.

Notes

1) Video monitoring is very important with RBD patients. If you are lucky you will see the patient act out dreams. This may include singing, hitting the pillow or leaping out of bed and ripping off all of the electrodes. Other instances of RBD are less exciting, and may include mumbling, gesturing or rolling back and forth in bed. It is important to stay alert when recording patients suspected of RBD.
2) Some muscle activity during R is normal. There is much more twitching in RBD than in normal R. In addition, patients with RBD will have more complicated movements than simple twitching.

3) Many patients have a background of increased EMG tone and twitching. The abnormal behaviors usually pop out of this background.
4) The baseline EMG does not usually drop in the transition from N to R in patients with RBD. In fact, it is usually higher in RBD patients during R.

RBD is one of the disorders where "you'll know it when you see it." Acting out of dreams is no laughing matter – it can be dangerous and has been associated with severe injuries. Documentation of the behavior by the technologist is very important in RBD.

7. SCORING THE POLYSOMNOGRAPHIC FEATURES OF RHYTHMIC MOVEMENT DISORDER (RMD) [P.43]

Rhythmic movement disorder is body rocking, head rolling or head banging. It is more common in children than in adults. The movements can be forward and backward or side to side. It is most often seen in N2.

Rules

A. The rules for scoring RMD are:
   1) The minimum frequency of movements is 0.5 Hz (1 every 2 seconds)
      AND
   2) The maximum frequency of movements is 2 Hz (2 every 1 second)
      AND
   3) In order to be scored there must be at least 4 movements
      AND
   4) The EMG bursts should be at least 2 times higher than the background EMG activity.

Notes:

1) It may help to put electrodes on the muscles that are active during RMD. Putting electrodes on the muscles of the neck (for example, the sternocleidomastoid) will often give a nice tracing of bursts of activity in patients with headbanging.
2) Video monitoring is important in the diagnosis of RMD.

The rhythmic movements are reported to be soothing by patients. RMD is usually a temporary problem and causes no trouble. However, at times the movements may be very vigorous and may cause injury. Padding the headboard may be a solution for some patients. RMD is usually pretty clear and is not often confused with other diagnoses. Documentation of the behavior by the technologist is very important in RMD.

1. TECHNICAL CONSIDERATIONS

Technical considerations for respiratory monitoring are important. You need at least 4 signals: a thermal sensor, a nasal pressure transducer, a measure of effort to breathe (usually a respiratory inductance plethysmograph or RIP) and a pulse oximeter.

A. Use the thermal sensor to score apnea

The thermal sensor measures temperature. The air going into the lungs is cold. It is warmed in the lungs. The in and out of air can be measured by the thermal sensor placed in or near the nose and mouth. It can measure air from both the nose and mouth, which is important in patients who are mouth breathers.

B. Use the nasal pressure transducer to score hypopnea

The nasal pressure transducer measures a change in pressure as air passes over tubing placed in or near the patient's nose. Very small changes are detected. The nasal pressure transducer only measures air flow from the nose.

C. Use either an esophageal manometer or RIP belts to detect effort

It is important to know whether or not the patient is trying to breathe during an episode of apnea. If the patient does not make an effort to breathe, the apnea is called a central apnea. If the patient is trying to breathe but no air is flowing, the apnea is called obstructive. There are several ways to measure effort. One is to place a balloon in the esophagus and connect it to a pressure transducer. When the patient makes an effort to breathe there are changes in the pressure in the chest. The esophageal manometer measures this. There are also movements of the chest and abdomen during effort. The RIP belts are placed around the chest and abdomen and provide an indirect measure of the volume of the lungs. Most centers use RIP belts.

D. Use a pulse oximeter to measure blood oxygen levels

The pulse oximeter takes advantage of the change in the wavelength of the blood that happens when there are changes in the amount of oxygen in the blood. A probe shines a light through the skin, usually of the finger, and a sensor measures how much red light passes through the tiny blood vessels (capillaries). The scoring of hypopneas relies on the pulse oximeter to measure blood oxygen.

Notes:

1) If a sensor stops working during the night you can use one of the alternative sensors listed below.
2) If the thermal sensor is not working, use the nasal pressure transducer.
3) If the RIP belts are not working, use intercostal EMG recordings.
4) If the nasal pressure transducer is not working use the RIP belts or the thermal sensor.
5) Using a square root transformation on the nasal pressure transducer helps to increase the accuracy of scoring by reducing scoring of hypopneas that have only minimal flow reduction.

It is better to relocate or replace a sensor if it stops working than to switch to another sensor. The accuracy and reliability of the secondary sensor is less than the primary sensor. For example, adequate intercostal EMG recordings are difficult to get in patients who are overweight. When they work, they provide a good alternative to RIP. But when they don't, which may happen when the patient rolls over, you are left with no indication of effort.

2. EVENT DURATION RULES [P. 45]

A Apneas and hypopneas are measured from the lowest point of the last normal breath to the beginning of the first normal breath after the apnea or hypopnea.

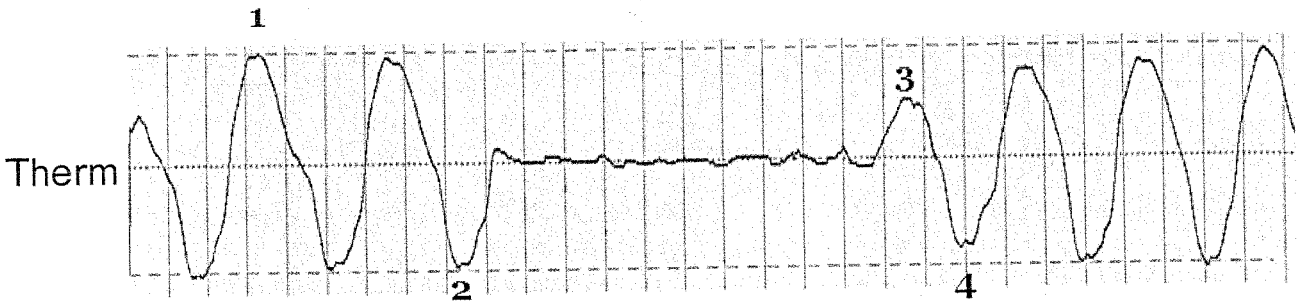

Figure 41. Measuring the duration of an apnea. Vertical lines are 1 second apart. See text for explanation of numbers.

Figure 41 shows how to measure an apnea. Number 1 is a normal breath. The dotted horizontal lines show the amplitude of this "baseline" breath. The first abnormal breath starts at number 2. Number 2 is at the low point of the breath – this is called the nadir (the high point is called the zenith). The nadir is where you start to measure the duration of the apnea. Number 3 is at the zenith of a small breath. This is not a normal breath, and does not end the apnea. Number 4 is at the nadir of the first normal breath. This means that the duration of the apnea is from 2 to 4. It is a little more than 12 seconds.

B. For patients who do not have regular breathing, end the apnea or hypopnea when the breathing amplitude increases or when there is a 2% increase in blood oxygen level.

Patients with severe sleep apnea may have very irregular breathing throughout sleep. They may go from one apnea to another with a few gasping breaths in between. It will be easy to tell the end of an apnea because the thermal signal goes from almost zero to something. It will be harder to tell when a hypopnea ends. The use of blood oxygen level to determine the end of an event is complicated. The reduced level usually starts to show up on the polygraph 10 to 12 seconds after the start of the apnea. Any increase in blood oxygen level at the end of the apnea would also be delayed by a similar amount.

3. SCORING APNEAS [P. 45]

A. Score an apnea when:
   1) The thermal signal goes down by 90% or more
      AND
   2) The event lasts more than 10 seconds
      AND
   3) At least 90% of the apnea has a thermal signal reduced by 90%

The first sleep related breathing event in the *AASM Manual* is the apnea. Apnea means that the airflow has stopped or nearly stopped. The sensor to measure apnea is the thermal mouth and nose sensor. To score apnea, the thermal signal must go down by 90%. Why isn't this 100%? It is because the measure doesn't really measure air flow – it measures temperature changes. With a full breath, the relatively cold room air is drawn into the lungs, warmed up by the body, and exhaled. This temperature change is a reliable indicator of apnea. During apnea the airway is closed but some air may move in and out of the nose and mouth. It warms up a bit when it is inside the body, resulting in a small signal in some patients. The 90% rule means that in addition, some patients who do not have complete airway closure may be scored with apnea. This has very little effect on the accuracy of scoring of respiratory events. It turns out that these partial closures may have the same effect as the complete closures.

You will measure duration using rule A.2. above. Less than 10 seconds is not an apnea (except in children).

Rule 3.A.3. caused some confusion and resulted in several entries in the Frequently Asked Questions web page. Here is the text of the most recent Frequently Asked Question:

Respiratory events require a minimum duration of 10 seconds in adults and 2 breaths in children. The abnormality must last this specified duration though amplitude criteria are required for only 90% of the duration. Any event that does not have an abnormality lasting a total of 10 seconds [or 2 breaths in children] cannot be defined as an apnea or hypopnea. Abnormalities lasting only 9 seconds are not scored as respiratory events in adults. The published FAQ R12 states "Scoring of hypopneas and apneas requires a minimum duration of 10 seconds. If the amplitude criteria are met during any contiguous 9 seconds of an event that lasts 10 seconds or longer then the event should be scored even if the duration of the amplitude reduction does not constitute 90% of the total event duration." Thus relatively rare events that incorporate only 7 or 8 seconds meeting amplitude criteria will not meet criteria for an event.

Here's the problem: The apnea begins with the nadir of the last normal breath. The apnea ends with the beginning of the first normal breath. What happens if the first abnormal breath is only 10% of normal amplitude, the amplitude stays down for 9 seconds, at 10 seconds it goes up to 50%, and the apnea really ends one breath later, at 13 seconds? This is exactly what happens in Figure 41. The event starts at number 2. The amplitude stays low until the beginning of the breath marked as 3. This is about 9 seconds. Breath 3 is not a normal breath – it's only around 50% of normal. So the event continues until the beginning of the first normal breath at number 4. The event is 13 seconds, but only 9 seconds meets the criterion for apnea. The whole event is counted as an apnea, including the 50% breath. The Frequently Asked Question page uses the word "contiguous" in the answer. This means that the 9 seconds has to occur in one solid block of time. It isn't enough to have 3 seconds at the beginning and another 6 seconds at the end – it has to be one 9 second block of time.

B. There are 3 types of apnea:
   1) **Obstructive** apneas have effort throughout the apnea
      OR
   2) **Central** apneas have no effort throughout the apnea
      OR
   3) **Mixed** apneas are central at the beginning and obstructive at the end.

Use the thermal sensor to determine if there is an apnea. If there is, the next step is to determine what type of apnea it is. This requires looking at the effort channels – the RIP signal (or esophageal manometry if that is what your center uses). If the RIP activity continues throughout the apnea, the type is obstructive. If the RIP signal goes flat, it's central. And if it's some of each it's mixed.

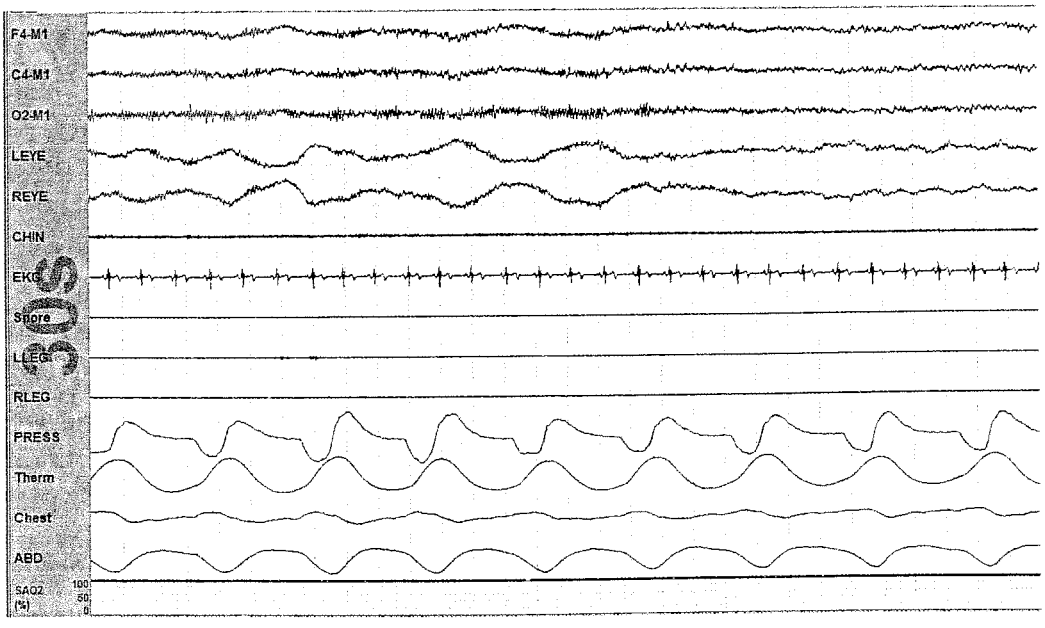

Figure 42. Normal breathing at sleep onset. 30 second epoch.

Let's start our review of breathing with a normal epoch. Figure 42 has the usual EEG, eye movement and chin EMG channels at the top. This is followed by an ECG (or EKG) signal at the top. The next channel is a snoring microphone. (The type of snoring sensor to be used is not specified in the AASM Manual. Other technologies may be used.) Then there are left and right leg channels. "Press" is the nasal pressure transducer and "therm" is the thermal sensor. Chest and abdomen are next – these are the RIP belt signals. Finally, blood oxygen levels are shown as SaO_2. There are 9 breaths in this 30 second epoch, so the respiratory rate is 18 breaths per minute. Blood oxygen level is close to 100%. Breathing during N1 is often nice and regular.

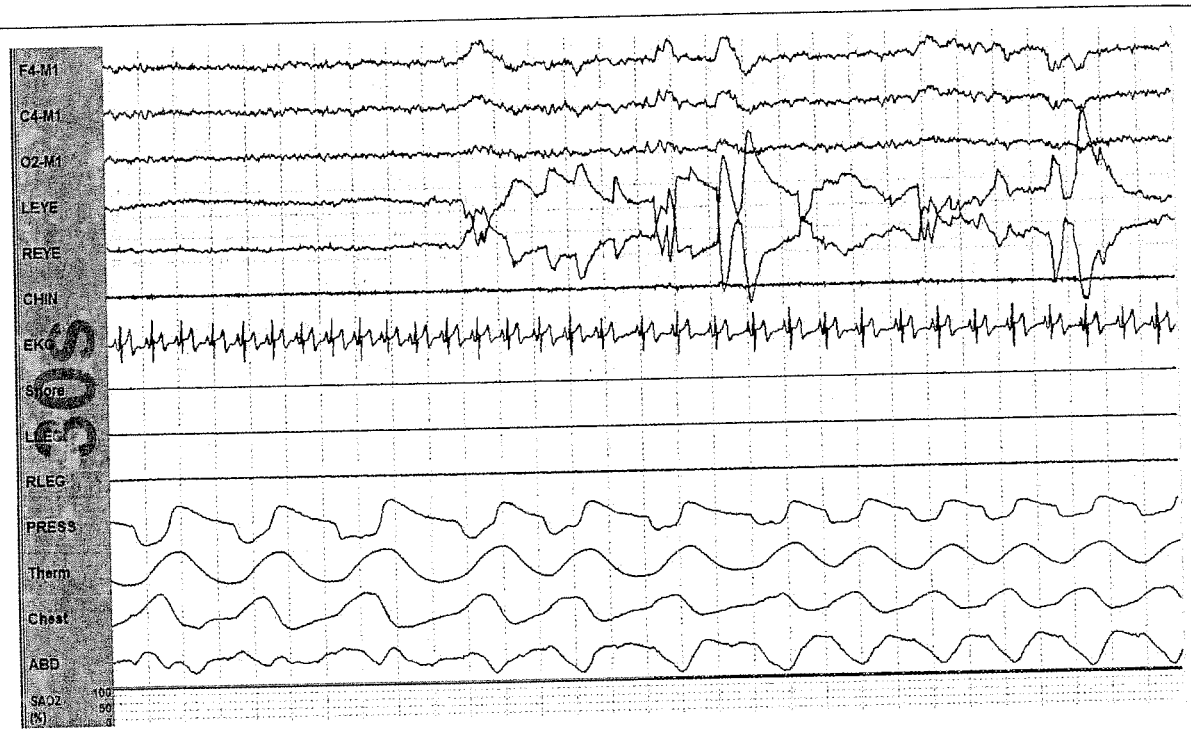

Figure 43. Normal breathing in R. 30 second epoch.

Figure 43 shows breathing in R. The respiratory rate changes about 2/3 of the way through the epoch. It becomes faster and the amplitude of the thermal and pressure sensors go down. Changes in respiratory rate, sighs and brief interruptions of breathing are normal in R.

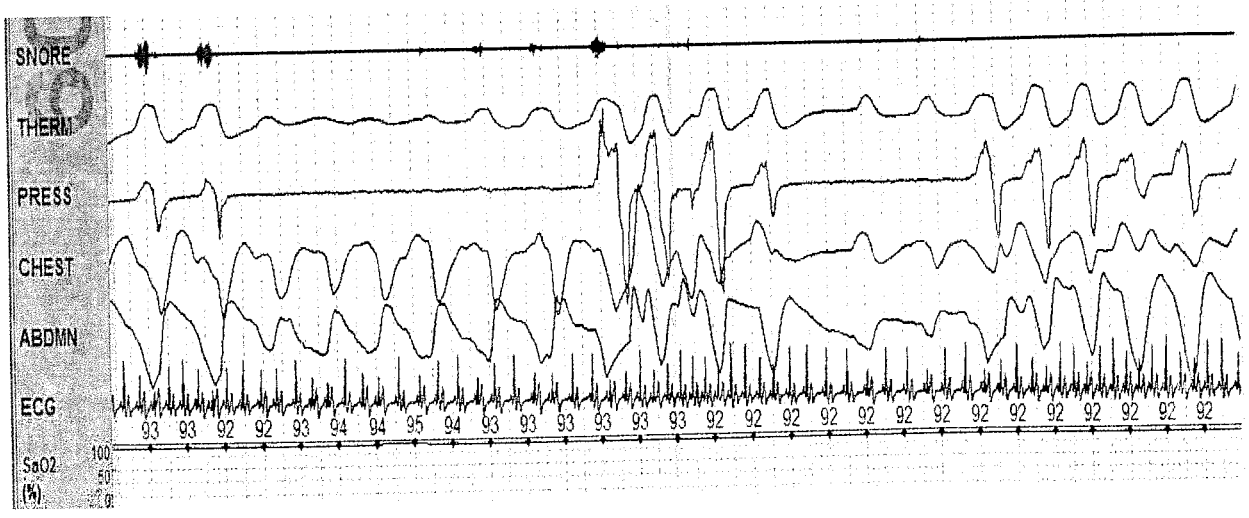

Figure 44. Obstructive apnea. 60 second epoch.

The episode on the left of Figure 44 is an obstructive apnea. The thermal signal is reduced by 90% for much of the episode. There are 2 small breaths at the end of the event, but there is a clear block of 9 seconds meeting the amplitude criterion. This means the episode is an apnea. The nasal pressure transducer goes flat for the entire episode, but this has no bearing on the scoring of an apnea. Next, look at the chest and abdominal recordings at the very start of the epoch. There are 2 breaths where the chest and abdomen go up at the same time and go down at the same time. Now look at the chest and abdomen during the apnea. The chest goes up when the abdomen goes down, and the chest goes down when the abdomen goes up. This is called paradoxical effort, or "paradoxing." During paradoxing, the amount of air in the lungs does not change. This happens when the airway is closed. The paradoxing indicates that the patient is making an effort to breathe, but there is no air flow. This is obstructive apnea.

There are some other features of the episode in Figure 44 that are worth noting. Snoring occurs during the first 2 breaths of the epoch. Then the snoring stops. Snoring cannot happen when the airway is closed. Toward the end of the apnea, the snoring starts up again, and we can see some air movement in the thermal sensor channel. The apnea ends with a loud snore, probably a gasp, as the airway opens completely. The oxygen saturation goes down somewhat during the apnea. There is a delay in the time between the start of the apnea and the start of the desaturation. The high value for this apnea is 95% and the low value at the end of the apnea is 92%. Oxygen saturation is not part of the criteria for scoring obstructive apnea. Finally, the ECG shows a pattern of slowing during the apnea and speeding up at the end of the apnea. This is a normal response to a closed airway.

In contrast to the other apneas, central apneas have no effort throughout the entire epoch. Figure 45 is an example. Effort ends with the last good breath, and does not resume until airflow starts again. Central apneas often happen at sleep onset and after arousals.

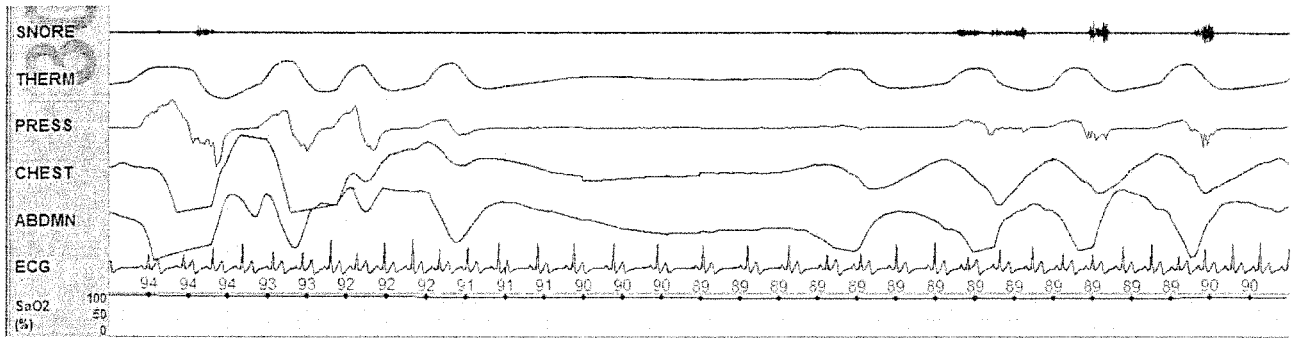

Figure 45. Central apnea. 30 second epoch.

Figure 46, a mixed apnea, shows many of the features of an obstructive apnea. The thermal sensor signal goes flat (as does the pressure transducer signal). There is some oxygen desaturation and moderate ECG slowing. The difference is in the effort measurement. In this mixed apnea, effort is absent in the first half of the apnea, but resumes half way through the apnea.

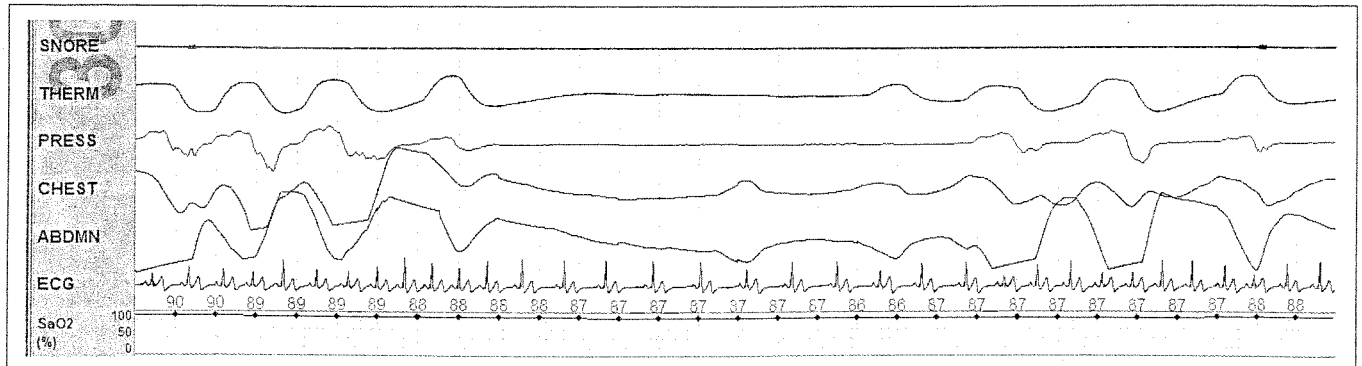

Figure 46. Mixed apnea. 30 second epoch.

Notes:

1) Blood oxygen level is not used in the definition of apnea.
2) Always use the rule for measuring apnea duration.

4. HYPOPNEAS [P. 46]

Hypopneas are caused by partial closing of the airway. In the polysomnogram, this shows up as a decrease of the amplitude of the nasal pressure signal. The thermal signal may also go down, but if it reaches 90% for 9 seconds the event is an apnea and cannot be scored as a hypopnea. There are 2 rules for hypopnea, one recommended and one alternative. Your center must choose which rule to follow. You can follow only A, you can follow only B, or you can follow A and B if you report them separately. You cannot score the record using A or B at the same time.

A. The rules for scoring hypopnea are:
   1) The nasal pressure amplitude decreases by 30% or more
      AND
   2) The event lasts at least 10 seconds
      AND
   3) The blood oxygen level drops by 4% or more
      AND
   4) At least 90% of the hypopnea meets the amplitude decrease

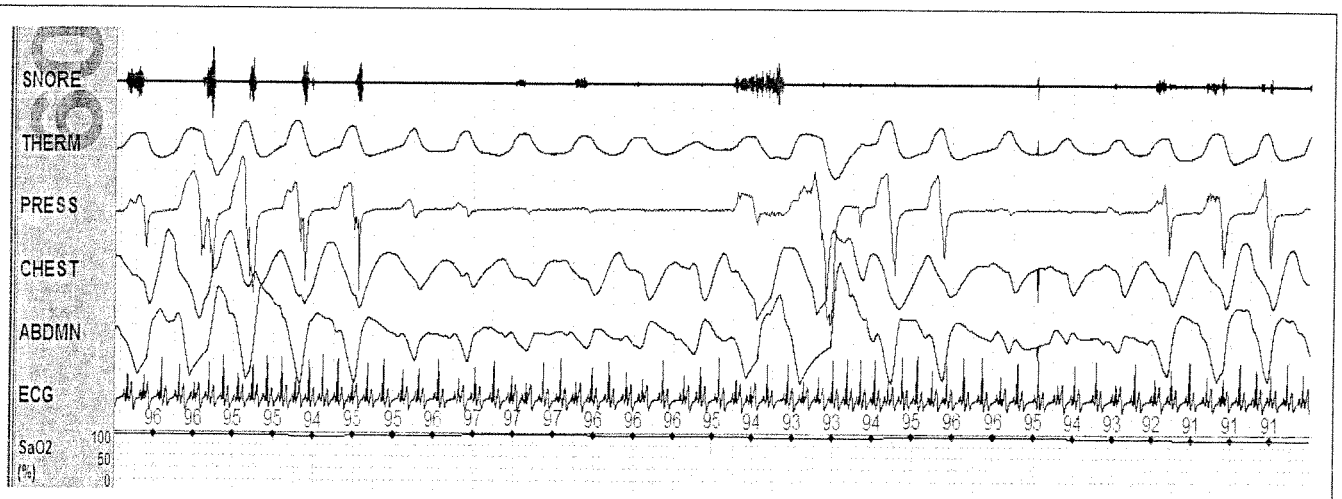

Figure 47. Hypopnea. 60 second epoch.

The first decision on reviewing a breathing event is whether or not it is an apnea. The thermal sensor channel is used for scoring apnea. In Figure 47, the thermal sensor signal goes down, but not by 90%. It is reduced by 40-50%. Once you have determined that the event is not an apnea, move your attention to the pressure transducer channel. Does the nasal pressure signal decrease by 50% or more? In Figure 47, it clearly does. In fact, the latter portion of the event has a flat pressure transducer signal. Next, does the event last more than 10 seconds? This event lasts a bit more than 21 seconds. Does the blood oxygen drop by 4% or more? The high value is 97% and the low is 93% -- the event reaches criteria for oxygen desaturation. Does the decrease in amplitude of the pressure transducer signal occur for 90% of the event? It is hard to determine the baseline, but in this event the pressure transducer signal is very low for almost the entire event.

There are many similarities between Figure 47 and Figure 44. There is paradoxing of the chest and abdominal signals. Snoring occurs before and at the end of the event. There is oxygen desaturation. There is ECG slowing during the event and a speed up at the end. The only difference is that the thermal signal does not decrease by 90% with the hypopnea. Rule 4A is the rule for scoring hypopnea that is accepted by Medicare.

B. The alternative rules for scoring hypopnea are:
   1) The nasal pressure amplitude decreases by 50% or more
      AND
   2) The event lasts at least 10 seconds
      AND
   3) The blood oxygen level drops by 3% or more OR the event causes an arousal
      AND
   4) At least 90% of the hypopnea meets the amplitude decrease

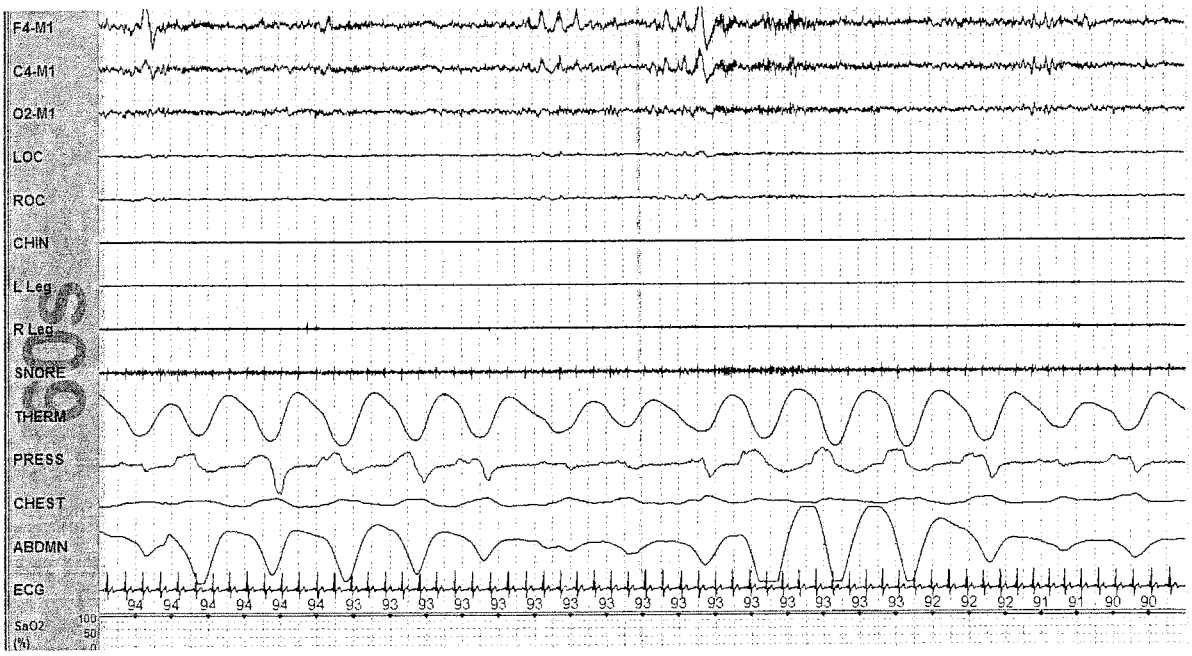

Figure 48. Hypopnea. 60 second epoch.

There is a 12 second hypopnea in the middle of Figure 45. The thermal signal decreases slightly and the nasal pressure signal goes down by more than 50%. The oxygen saturation goes from 93% at the start of the event to 90% at the end. A 3% desaturation meets the criteria for a hypopnea using rule 4.B. There is also an arousal at the end of the hypopnea, just after a K complex. The EEG speeds up for more than 3 seconds – an arousal should be scored. The rules for 4.B. require a 3% desaturation or an arousal. The hypopnea in Figure 45 has both.

Notes:

1) Your report should include which rule you used to score hypopnea.
2) Some centers score hypopnea type, just like apnea, using obstructive, mixed or central. Since there is only partial closing of the airway respiratory effort continues throughout all hypopneas. If your center scores hypopnea type, you will be given rules for doing so.

5. RESPIRATORY EFFORT RELATED AROUSALS [P. 46] [SCORING RERAS IS OPTIONAL]

A. The rules for scoring respiratory effort related arousals (RERAs) are:
   1) A period of 10 seconds or more of increasing effort or flattening of the nasal pressure signal leading to an arousal from sleep. An event that meets criteria for an apnea or hypopnea cannot be a RERA.

Notes:

1) The best transducer for determining increasing effort is an esophageal manometer. Nasal pressure and RIP belts can also be used.

6. HYPOVENTILATION [P. 46]

[SCORING HYPOVENTILATION IS OPTIONAL]

A. The rules for scoring hypoventilation are:
   1) Score hypoventilation during sleep if the $PaCO_2$ increases by 10 mm Hg or more over baseline

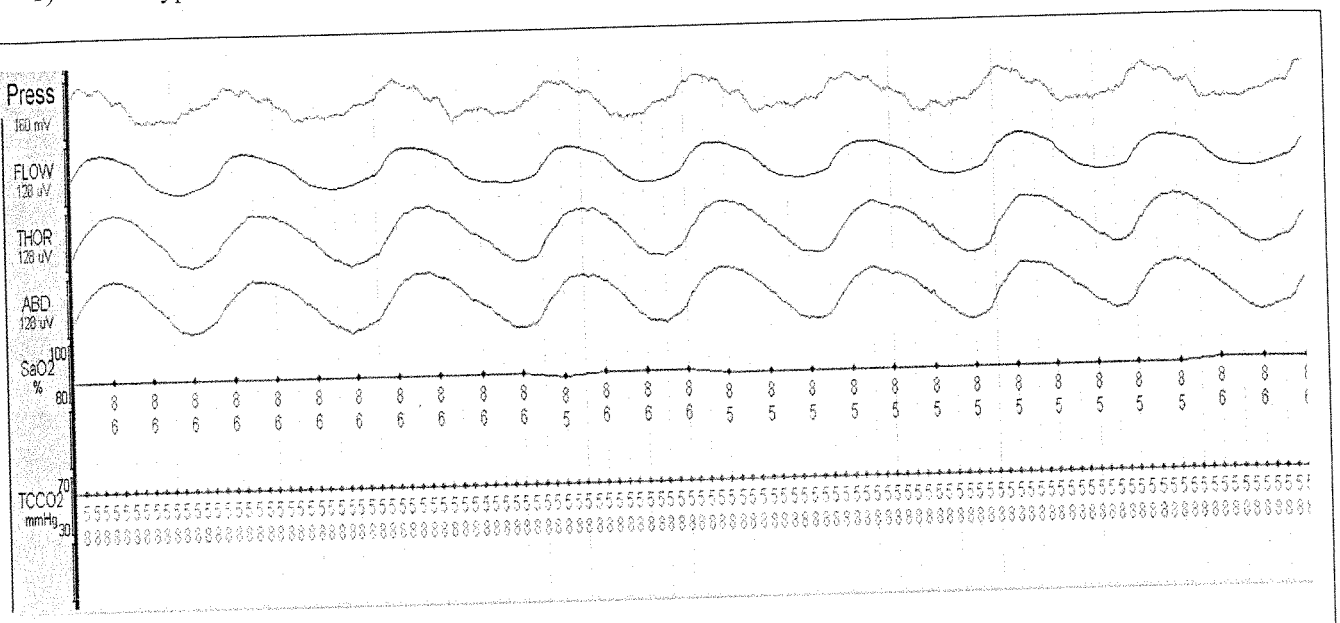

Figure 49. Hypoventilation. 30 second epoch.

The bottom tracing in Figure 49 is transcutaneous CO_2 ($TCCO_2$). This reads 58 mm Hg throughout the epoch; the $TCCO_2$ was at 32 mm Hg during waking. Oxygen saturation is also abnormal, at 85 – 86% during sleep, but this is not included in the rule for scoring hypoventilation. Hypoventilation usually occurs in patients with lung disease or weakness of the breathing muscles.

Notes:

1) Do not score hypoventilation using oxygen desaturation.
2) You can't score hypoventilation but if the $PaCO_2$ by analyzing arterial gas is high when the patient first wakes up it is "suggestive" of hypoventilation.
3) End tidal CO_2 and transcutaneous CO_2, when reliable, can be used as alternative measures for $PaCO_2$.
4) Hypoventilation episodes should be long enough to convince the scorer that they are not artifact.

7. CHEYNE STOKES BREATHING [P. 47]

A. Score Cheyne Stokes breathing if there are 3 cycles of increasing and then decreasing breathing amplitude and:
   1) Five or more central apneas or hypopneas per hour of sleep
      OR
   2) At least 10 consecutive minutes of breathing cycles

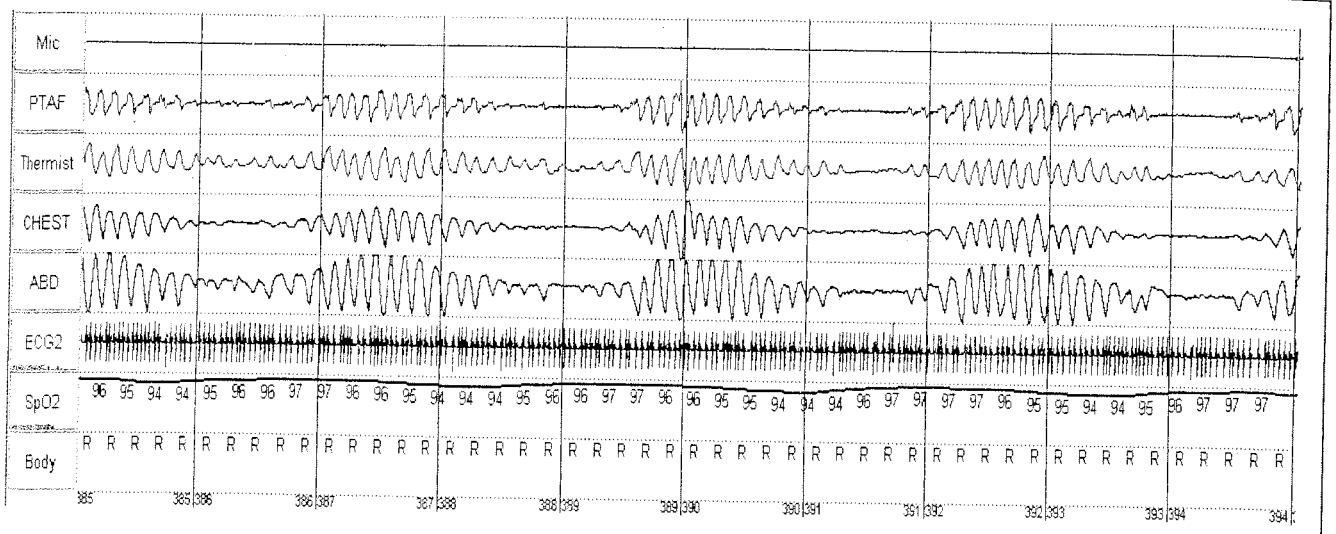

Figure 50. Cheyne Stokes breathing. Vertical lines are 30 seconds apart.

Figure 50 shows a typical Cheyne Stokes breathing pattern. All of the breathing signals show the same pattern – thermal sensor, pressure transducer and effort channels. The pattern is a gradual increase of breathing amplitude, a peak of breathing amplitude, and then a decrease of breathing amplitude. During the first cycle on the left of Figure 50, the signal gets very small but does not stop. This means that a central apnea cannot be scored. In the final cycle of this sample on the right of Figure 50, the signal goes completely flat. The flat period lasts for more than 10 seconds. This episode meets all of the rules for scoring central apnea [p. 45]. Oxygen saturation increases and decreases a little bit with the breathing pattern, but this is not part of the scoring rule. To meet all of the criteria, the pattern in Figure 50 must be associated with 5 or more central apneas per hour or a total of 10 minutes of the cyclic breathing pattern.

Note:

1) The cycle length for Cheyne Stokes breathing is usually around 60 seconds.

Measure the cycle length from the beginning of one episode of increasing and decreasing to the beginning of the next episode. The cycle length in Figure 50 is approximately 80 seconds. The length of the cycles is usually similar from cycle to cycle in the same patient, but may be different from patient to patient.

1. TECHNICAL CONSIDERATIONS

Technical considerations for children are the same as for adults [p. 45]. Hypoventilation in adults requires monitoring of CO_2, but scoring of hypoventilation is optional. Therefore, CO_2 monitoring is not required for adult sleep studies. The technical considerations for children include a specific rule for assessing hypoventilation in children, and scoring of hypoventilation is required in children. Therefore, CO_2 monitoring is required for pediatric sleep studies.

E. Use transcutaneous or end tidal PCO_2 monitoring for scoring hypoventilation in children.

Notes:

There is one note that is different from adults:

3) End-tidal PCO_2 or summed calibrated inductance plethysmography can be used as an alternative signal for scoring apnea in children.

Remember that alternative sensors are to be used when the primary sensor is not functioning. Measurement of airflow in children can be difficult – they tend to push sensors out of their noses and move around a lot in sleep. This note gives the scorer additional options.

3. APNEA RULES [P.48]

The rules for scoring pediatric apnea are similar to those in adults [p. 45] with the exception of the duration of an event. There are different rules for obstructive and central apneas.

A. Score an obstructive apnea in children when:
   1) The event lasts at least 2 missed breaths
      AND
   2) The thermal sensor amplitude drops by more than 90% for more than 90% of the respiratory event
      AND
   3) There is respiratory effort throughout the event
      AND
   4) The event duration is measured in the same way as in adults

Why is the duration criterion for obstructive apnea different in children? Obstructive apneas tend to be shorter in children but have more of an effect on blood oxygen level. This is because children have smaller lungs and less of a reserve of oxygen to draw on. The lungs grow as the child ages, so it would be useful to have a measure that changed with age in the same way as the size of the lungs change. The breathing rate is very fast in infants and gradually slows with age.

Table 25. Age related changes in breathing rate. From the New York State Department of Health.

Age	Rate (breaths per minute)
Infant (birth–1 year)	30–60
Toddler (1–3 years)	24–40
Preschooler (3–6 years)	22–34
School-age (6–12 years)	18–30
Adolescent (12–18 years)	12–16

Two breaths is a good measure to use for obstructive apnea duration. In infants with a rate of 45 breaths per minute, 2 breaths lasts 2.67 seconds (1 / 45 breaths per minute = 0.02 minutes per breath; 0.02 minutes per breath * 60 seconds = 1.33 seconds per breath). If the breathing rate is 24 breaths per minute in a preschooler, 2 breaths would last 5 seconds (1 / 24 breaths per minute = 0.04 minutes per breath; 0.04 minutes per breath * 60 seconds per minute = 2.5 seconds per breath). A breathing rate of 12 breaths per minute equals 5 seconds per breath or the adult criterion of 10 seconds for 2 breaths.

B. Score a mixed apnea in children when the event lasts at least 2 missed breaths, the thermal amplitude drops more than 90% for more than 90% of the event, and the first part of the event has no respiratory effort and the second part has respiratory effort.

With the exception of the duration criterion, this rule is the same as for adults [p. 45].

C. Score a central apnea in children when there is no respiratory effort during the event AND:
   1) The event lasts 20 seconds or longer
      OR
   2) The event lasts at least 2 missed breaths and has an arousal, an awakening or at least 3% oxygen desaturation

A study of breathing in children showed that 30% of normal children had at least 1 central apnea lasting more than 10 seconds. These central apneas usually happen after a movement or a sigh. They are thought to be the result of a reflex and have no harmful effects. The rule of 20 seconds or longer is not supported by data, but results in a small percentage of children having events that are scored. However, events that cause arousal or oxygen desaturations should be considered significant even if they are not 20 seconds or longer.

4. HYPOPNEA AND RERA RULES [P.49]

There is only one rule for hypopnea in children.

A. Score a hypopnea when:
   1) The nasal pressure signal drops by at least 50%
      AND
   2) The event lasts at least 2 missed breaths
      AND
   3) The nasal pressure drop lasts at least 90% of the event
      AND
   4) The event is associated with an arousal, awakening or at least 3% oxygen desaturation

This makes the pediatric hypopnea rule similar to rule 4.B. in adults [p. 46] with the exception of the minimum duration of the event.

A. Score a RERA in children when:
   1) The nasal pressure signal:
      a) Drops some, but not as much as 50%
         AND
      b) The nasal pressure waveform is flattened
         AND
      c) There is:
         1. Snoring or noisy breathing
            OR
         2. Increased $PaCO_2$ (end tidal or transcutaneous)
            OR
         3. Some evidence that the child is working hard to breathe
      AND

d) The event lasts at least 2 missed breaths

OR

2) The esophageal pressure signal:
   a) Shows increasing effort during the event

      AND

   b) There is
      1. Snoring or noisy breathing

         OR

      2. Increased PCO_2 (end tidal or transcutaneous)

         OR

      3. Some evidence that the child is working hard to breathe

      AND

   c) The event lasts at least 2 missed breaths

After the publication of the *AASM Manual*, it was noted that the scoring rules for RERAs in children failed to include an arousal rule. The FAQs include:

Is arousal required for scoring RERAs in children?

Yes. Scoring of RERAs in both adults and children requires that the RERA be associated with an arousal that conforms to the recommended AASM arousal rule.

Notes:

1) You can score hypopneas using a thermal sensor if the nasal pressure transducer is not working.
2) You can only score RERAs with a nasal pressure transducer or esophageal manometer.

5. HYPOVENTILATION RULE [P.49]

A. Score hypoventilation in children when more than 25% of sleep time has a $PaCO_2$ (end tidal or transcutaneous) that is higher than 50 mm Hg.

Notes:

1) It is important to be sure that the end tidal CO_2 monitor is functioning properly. Patients who breathe through their mouth or have trouble breathing through their nose may not have accurate readings. Patients on oxygen or CPAP may also have inaccurate readings.
2) The transcutaneous CO_2 readings are delayed compared to the end tidal CO_2 monitors.

In adults, hypoventilation is scored when the $PaCO_2$ rises from the waking baseline. This is a relative number. The criterion for hypoventilation in children is an absolute number (50 mm Hg). This means that you must be sure that the monitor is working properly. The end tidal monitor records only from the nose, so you have to be sure that the patients are actually breathing through their nose. Moisture in the tubing and other problems may also lead to an inaccurate reading.

6. PERIODIC BREATHING RULE [P.49]

A. Score periodic breathing in children when there are more than 3 episodes of central apnea lasting more than 3 seconds separated by no more than 20 seconds of normal breathing.

Periodic breathing is common in premature infants and may be present in some full term infants. It usually occurs during R or active sleep. The rule says you must have 4 central apneas lasting at least 3 seconds, but central apneas in children must last at least 20 seconds [p. 48]. These are actually "pauses" in breathing rather than apneas. The pattern may look like Cheyne Stokes breathing, but usually the cycle time is much shorter and children may not have the increase and decrease of breathing amplitude.

Report parameters come at the beginning of the *AASM Manual*, but in order to make the calculations and fill in the report you have to score the entire record first. That is why it comes at the end of this *Handbook*. Your center will have a standard report template for you to fill in the numbers. Many of the current sleep study software manufacturers include a standard template and many fill in the numbers for you automatically. In this section we will describe what the numbers mean and, should you have a system that doesn't do the calculations for you, a way to generate the numbers with a calculator.

The polysomnographic report has a number of required elements. These are listed as "recommended" in the *AASM Manual*. Other elements of the report are "optional" and may be included if required by the center director. Not included in this section but essential for every report is patient identification information. This should include the patient's name and an identification number such as medical record number or social security number (to avoid confusion with another patient with the same name). This should be on every page of the report in case the pages become separated. The age of the patient is critical for interpretation of the report. For infants, this should be provided both in terms of chronological age (time since birth) and age at birth (gestational age). Other information usually includes height and weight (or body mass index – BMI), a list of all medications and the reason for the test. Finally, the report should contain information on who should get copies of the report. In most cases this will be the referring physician and the sleep center physician.

A. PARAMETERS

The parameters section includes information on how the sleep study was run. Unless there are special conditions (for example, additional electrodes for a patient suspected of seizures or arm electrodes for a patient suspected of REM sleep behavior disorder), the parameters should be the same for every study.

1) Standard EEG derivations are $F_4 - M_1$, $C_4 - M_1$ and $O_2 - M_1$. The alternative derivations are $F_z - C_z$, $C_z - O_z$ and $C_4 - M_1$. If your center uses equipment that can store and display extra channels, the EEG parameters may include recording of back up electrodes as well.
2) Standard EOG derivations are $E_1 - M_2$ and $E_2 - M_2$. The left electrode (E_1) is 1 cm below the eye and the right electrode (E_2) is 1 cm above the eye. The alternative derivations have both electrodes below the eye and substitute Fpz for the M2 electrode.
3) The *AASM Manual* recommends placement of 3 chin EMG electrodes. One is placed in the middle of the chin just above the jaw line, and 2 are placed below the jaw and 1 cm to either side of the middle. The standard derivation is between the electrode above the jaw and one or the other below the jaw. The third electrode is used as a backup.
4) Leg EMG electrodes are to be placed on the left and right anterior tibialis muscle with one 1/3 of the way down the muscle and the other 2 – 3 cm below. The *AASM Manual* allows a single channel with one electrode from each leg, but separate recordings are strongly preferred.
5) Airflow parameters should indicate that the standard sensors are used: an oronasal thermal sensor for scoring apneas and a nasal pressure transducer for scoring hypopneas. Non-standard recordings should provide details of the methods used. For example, recording from a patient with a tracheostomy may require placing the thermal sensor at the tracheostomy site. If sensors fail during the night and alternatives are used, this should be clearly indicated in the report.
6) The standard sensors for respiratory effort are respiratory inductance plethysmography (RIP) belts. You should indicate whether they are used in the calibrated or uncalibrated mode. Esophageal manometry is also standard but is not used by most centers. The back up recording is intercostal EMG.
7) Oxygen saturation is measured with a pulse oximeter. The maximum averaging time is 3 seconds at a heart rate of 80 beats per minute.
8) No method for determining body position is specified in the *AASM Manual*. Centers may use a position sensor (often a mercury switch) or require that the technician write down the body position at regular intervals. These technician notes should be no less than once every 15 minutes.

Here is a sample of how the parameter section of the report should look:

Patient:	James T. Kirk		MR#:	1234567
Age: 34	Sex: M	Height: 70"	Weight: 175 lb	
Reason for test: Snoring, EDS		Referring Phys:	Dr. McCoy	
Medications:	Trazodone, Prilosec			
Sleep Phys:	Dr. Kleitman		Date of Study:	1/7/2054

This sleep study was obtained in compliance with standards from the *AASM Manual* including: 3 EEG channels ($F_4 - M_1$, $C_4 - M_1$ and $O_2 - M_1$), 2 EOG channels ($E_1 - M_2$ and $E_2 - M_2$), chin EMG, left and right leg EMG, a snore microphone taped to the neck, an oronasal thermal sensor and a nasal pressure transducer, respiratory inductance plethysmography, an Enterprise pulse oximeter with 3 second averaging time and a Kling-on body position sensor.

B. Sleep Scoring Data

Once the report has been scored for sleep stages, the sleep scoring data can be calculated. Many of the parameters are calculated automatically by simple programs built in to the scoring software. If these are not provided, you can easily make the calculations with a calculator or by hand.

1) The first measure is the time when the study starts – when the lights are turned out and the patient is told to try to fall asleep. This is used to compare with the patient's usual bedtime.
2) The time when the study ends is when the lights are turned on. This may be when the patient indicates that they will not fall back to sleep or when the patient is awakened at the end of the standard recording period.
3) Total sleep time (TST) is the time spent in N1 + N2 + N3 + R. All of the measures of sleep time are calculated in minutes (number of 30 second epochs divided by 2).
4) The total recording time (TRT) is the length of the study in minutes from lights out to lights on.
5) Sleep latency (SL) is the time in minutes from lights out to the time of the first epoch of any stage other than W. This is the time it takes for the patient to fall asleep. All of the minutes of SL are W. SL is high in patients with sleep onset insomnia and in patients who are anxious about the sleep study.
6) Stage R latency is the time in minutes from sleep onset to the first epoch of R. A stage R latency of 0 means that the first epoch of sleep is R. If there is no R in a record, this should be indicated as "None" rather than 0.
7) Wake after sleep onset (WASO) is the amount of W after sleep onset. This is the total amount of W scored in minutes minus the sleep latency in minutes. This includes time spent in the bathroom or with the patient disconnected from the recording for any other reason. WASO is high in patients with broken sleep, sleep maintenance insomnia or early morning awakening insomnia.
8) Sleep efficiency (SE) is the part of the recording time actually spent asleep. It is reported as a percentage. It is calculated by dividing TST by TRT and multiplying by 100. A SE of 100% means no W during the entire recording time. A SE of 0% means no sleep during the entire recording time.
9) The number of minutes in each stage is a basic measure used in calculating many of the parameters above.
10) The percentage of time in each stage (minutes in each stage divided by TST and multiplied by 100) is useful to compare patients to standard data. Older adults have a smaller percentage of N3 than adolescents. Patients with high percentages of N1 sleep are likely to have some factor disrupting their sleep.

Sleep scoring data may look like this:

Lights out: 10:27 PM		Lights on: 7:31 AM		TRT: 544 min	
SL: 33 min		R latency: 97 min		WASO: 62 min	
TST: 449 min	W: 95 min	N1: 32 min	N2: 354 min	N3: 16 min	R: 47 min
Efficiency: 82.6%	% TST:	N1: 7.1%	N2: 78.8%	N3: 3.6%	R: 10.5%

C. Arousal Events

1) First, count up the number of arousals in the entire recording.
2) Second, determine the number of arousals per hour of sleep. This is the arousal index (ArI). What is the value added by including this index? It provides a better indicator of the patient's sleep. Suppose a patient has 30 arousals. If the 30 arousals occurs in 8 hours of sleep, that would be 3.75 arousals per hour of sleep, which is a pretty normal number. But if the patient slept only 1 hour, that would be 30 arousals per hour or one every other minute and that would be very high. Because the amount of sleep recorded in a study is very different from one study to another, the index is calculated to better compare numbers from patient to patient.

You can calculate the arousal index in one of 2 ways: find the numbers of hours of sleep by dividing the number of minutes of sleep by 60, then divide the number of arousals by the number of hours of sleep; or, you can multiply the number of arousals by 60 and then divide by the number of minutes of sleep. For those who like to see this as a formula, it is:

Where number of arousals = A and number of minutes of sleep = TST

ArI = A / TST / 60 **OR** ArI = A * 60 / TST

If our sample sleep study has 75 arousals, this is:

TST in hours (449 min/60 min/hr) = 7.5 hours (the minutes cancel out); 75 arousals / 7.5 hours = 10 arousals per hour of sleep

OR

A * 60 minutes/hr (75 * 60) = 4500 arousals/min/hr /449 min = 10 arousals per hour of sleep (the minutes cancel out leaving arousals/hr)

The report for this section has 2 entries:

Number of arousals: 75 Arousal Index: 10/hour of sleep

D. Respiratory Events

Measurement of respiratory events in a sleep study is the basis for making a diagnosis of sleep apnea. In contrast to other measures, a sleep study that meets an index for obstructive and mixed apneas can be all that is needed to make a diagnosis of obstructive sleep apnea syndrome – clinical judgment may not be necessary. The purpose of these measures is to provide a marker of the severity of a patient's apnea. All of the aspects of breathing during sleep that are measured may be included in the assessment of apnea severity.

1) Count the number of obstructive apneas.
2) Count the number of mixed apneas.
3) Count the number of central apneas.
4) Count the number of hypopneas. State the criteria used (hypopnea rules 4.A. or 4.B. [p.46]). According to the Frequently Asked Questions page, *"Each AHI reported should be based on consistent application of either rule 4.A. or 4.B. Scoring using 4.A. and 4.B. cannot be combined to compute a single AHI. Laboratories that choose to use both rules must report AHI for each rule separately."* If you choose to use both rules, count "Hypopneas 4.A. and Hypopneas 4.B." separately.
5) Report the total number of respiratory events (obstructive apneas + mixed apneas + central apneas + hypopneas). If you are using 4.A. and 4.B. you will calculate 2 totals.
6) Calculate the apnea index (AI). First, add up the total number of apneas (obstructive + mixed + central). Then use one of the formulas for the index (either total apneas/hours of sleep or total apneas * 60 / minutes of sleep).
7) Calculate the hypopnea index (HI). First, add up the total number of hypopneas. Then use one of the formulas for the index (either total hypopneas / hours of sleep or total hypopneas * 60 / minutes of sleep). If you are using both 4.A. and 4.B. you will have to calculate separately a 4.A. HI and a 4.B. HI.

8) Calculate the apnea + hypopnea index (AHI). Don't use the formula in the *AASM Manual* – just add the AI and the HI. Again, if you are using both 4.A. and 4.B. you will have to calculate separately a 4.A. AHI and a 4.B. AHI.
9) Scoring of RERAs is optional; if you score them, you should report them in the same way that other respiratory events are reported. First report the total number of events.
10) Calculate the RERA index as the number of events per hour of sleep. The definition of a respiratory disturbance index (RDI) is inconsistent. Some centers use RDI as the same as AHI. Other centers include RERAs in the RDI but not the AHI. The *International Classification of Sleep Disorders, Second Edition* includes RERAs in the definition of obstructive sleep apnea syndrome, but not all insurers (Medicare, for example) accept RERAs.
11) Oxygen desaturation plays a role in the scoring of hypopneas, but desaturations may occur without a change in airflow needed to meet the criteria for scoring a hypopnea. Centers may choose to count the number of oxygen desaturations of 3% or more or 4% or more, independent of the scoring of apnea, hypopnea and RERA. The method used should be described in the report.
12) As with the other breathing measures, an oxygen desaturation index provides a way to compare patients with different sleep times. These oxygen desaturation measures are optional.
13) Two required measures provide a crude indication of oxygen desaturation. The first is the average value of oxygen saturation during the night. This adds up all of the values measured and divides by the number of data points. Calculating this by hand would be extraordinarily time consuming. If your software does not provide this, you can take samples throughout the night and calculate the average.
14) A single measure of oxygen desaturation is the lowest value of the night. If this is not available from your software you can measure it from a graph of the oxygen saturation across the night. Be sure that you are not recording artifact by checking the low value and insuring that it does not come from a epoch of major body movement.
15) If you are measuring $PaCO_2$ (end tidal or transcutaneous) you can choose to report the presence or absence of hypoventilation. For children you will need to report the percentage of TST with $PaCO_2$ above 50 mm Hg.
16) Report the presence or absence of Cheyne Stokes breathing pattern. You must have at least 3 breathing cycles and either 5 or more central apneas or at least 10 minutes of the breathing pattern.

A respiratory event report may look like this:

OA: 127	MA: 12	CA: 27	Apnea Total: 166	AI: 22.2
Hypopnea (4.A): 26		HI: 3.5	Apnea + Hypopnea: 192	AHI: 25.7
RERAs: 32		RI: 4.3	RDI (AI + HI + RI): 30.0	
Desats ≥ 3%: 227		Desats ≥ 3% Index: 30.33	Avg. O_2: 89%	Low O_2: 77%
Hypoventilation: Not measured			Cheyne Stokes Breathing: Not present	

Most software will not only calculate these measures, but will also provide a separate AHI for each stage and body position. Some patients may have apneas only in R or only when supine. This information may be useful in determining treatment options.

E. Cardiac Events

The use of a single ECG channel limits the number of parameters that can be calculated for cardiac events. The easiest measure is interval between heart beats, usually measured as the time between R waves in the QRS complex, and usually reported as beats per minute (60 seconds/minute divided by the interval in seconds).

1) Report the average heart rate for the sleep portion of the recording. If your system does not calculate this you can sample several episodes of sleep and count the heart rate by hand. The number of beats in 2 epochs is the number of beats per minute.
2) Report the highest heart rate during sleep.
3) Report the highest heart rate in the recording. In normal recordings this will be during wake time before

sleep onset.

4) Report bradycardia if it occurs. Bradycardia in patients 6 years and older is slower than 40 beats per minute. Give the lowest heart rate.
5) Report episodes of asystole if they occur. Asystole in patients 6 years and older is longer than 3 seconds. Give the duration of the longest asystole.
6) Report episodes of sustained sinus tachycardia of 90 beats per minute or faster. Sustained tachycardia lasts 30 seconds or more. Give the fastest heart rate during sustained tachycardia.
7) Report episodes of narrow complex tachycardia, lasting more than 3 consecutive beats with a rate of at least 100 beats per minute. Give the fastest heart rate seen.
8) Report episodes of wide complex tachycardia, lasting more than 3 consecutive beats with a rate of at least 100 beats per minute. Give the fastest heart rate seen.
9) Report episodes of atrial fibrillation with an irregularly irregular heart rate.
10) Report any other arrhythmias that can be determined.

A sample cardiac event report is:

Avg. Sleep Rate: 58 bpm	Highest Sleep Rate: 92 bpm	Highest Rate: 98 bpm
Bradycardia: None	Sust. Tachycardia: None	A. Fibrillation: None
Narrow Complex Tachycardia: None	Wide Complex Tachycardia: None	
Other Arrhythmias: Infrequent premature beats (~5/hour)		

F. Movement Events

1) Count the total number of PLMS.
2) Count the total number of PLMS with arousals (PLMSAr). Remember that arousals must occur within 0.5 seconds before or after the limb movement.
3) Calculate the PLMS per hour of sleep index (PLMSI).
4) Calculate the PLMS with arousal per hour of sleep index (PLMS ArI).

A movement event summary will look like this:

PLMS: 56	PLMSI: 7.48
PLMSAr: 22	PLMSArI: 2.94

G. Summary Statements

The summary statements include all of the abnormalities found. The summary statement should state if there are no abnormalities. A sleep hypnogram is a useful summary of the stage scoring for the entire night, but is optional as part of the final report. Many systems provide other graphic results such as heart rate, oxygen saturation and incidence of apneas across the night.

A sample final report might look like this:

Patient:	James T. Kirk		MR#:	1234567
Age: 34	Sex: M	Height: 70"	Weight: 175 lb	
Reason for test: Snoring, EDS		Referring Phys:	Dr. McCoy	
Medications:	Trazodone, Prilosec			
Sleep Phys:	Dr. Kleitman		Date of Study:	1/7/2054

Description

This sleep study was obtained in compliance with standards from the *AASM Manual* including: 3 EEG channels ($F_4 - M_1$, $C_4 - M_1$ and $O_2 - M_1$), 2 EOG channels ($E_1 - M_2$ and $E_2 - M_2$), chin EMG, left and right leg EMG, an oronasal thermal sensor and a nasal pressure transducer, chest and abdominal uncalibrated respiratory inductance plethysmography, an Enterprise pulse oximeter with 3 second averaging time and a Kling-on body position sensor.

Lights out: 10:27 PM		Lights on: 7:31 AM		TRT: 544 min	
SL: 33 min		R latency: 97 min		WASO: 62 min	
TST: 449 min	W: 95 min	N1: 32 min	N2: 354 min	N3: 16 min	R: 47 min
Efficiency: 82.6%	% TST:	N1: 7.1%	N2: 78.8%	N3: 3.6%	R: 10.5%

Arousals

Number of arousals: 75

Arousal Index: 10/hour of sleep

Respiratory Events

OA: 127	MA: 12	CA: 27	Apnea Total: 166		AI: 22.2
Hypopnea (4.A): 26		HI: 3.5	Apnea + Hypopnea: 192		AHI: 25.7
RERAs: 32		RI: 4.3	RDI (AI + HI + RI): 30.0		
Desats ≥ 3%: 227		Desats ≥ 3% Index: 30.33		Avg. O_2: 89%	Low O_2: 77%
Hypoventilation: Not measured			Cheyne Stokes Breathing: Not present		

Cardiac Events

Avg. Sleep Rate: 58 bpm	Highest Sleep Rate: 82 bpm	Highest Rate: 98 bpm
Bradycardia: None	Sust. Tachycardia: None	A. Fibrillation: None
Narrow Complex Tachycardia: None		Wide Complex Tachycardia: None
Other Arrhythmias: Infrequent premature beats (5/hour)		

Movement Events

PLMS: 56

PLMSAr: 22

PLMSI: 7.48

PLMS ArI: 2.94

Summary Statements

This study shows moderate mostly obstructive sleep apnea with an AHI of 25.7 events per hour of sleep. The lowest oxygen saturation was 77% during an apnea in R sleep. No EEG abnormalities were noted with the limited montage used. Respiratory events were accompanied by a pattern of mild ECG rate increases and decreases but no bradycardia or tachycardia was seen. Only infrequent premature beats were detected with the single channel ECG recording. Mild snoring was noted by the technologist, with some episodes of gasping for air at the conclusion of apneas. The patient had 4 episodes of waking to urinate during the night.