INTERPRETATION OF POLYSOMNOGRAPHY

DR ANKAN BANDYOPADHYAY

SR PULMONARY MEDICINE

Polysomnography is a comprehensive recording of biophysiological changes that occur during sleep.

PSG includes -

1.identification of sleep stage

2.Analysis of patterns of respiration

3.Analysis of movement patterns

What are various types of sleep studies?

- Type 1: Fully attended polysomnography (≥ 7 channels) in a laboratory setting
- Type 2: Unattended polysomnography (≥ 7 channels)
- Type 3: Limited channel study (using 4–7 channels)
- Type 4: One or two channels usually using oximetry as one of the parameters

	level1	level2	level3	level4
	attended	unattended	Cardiorespiratory monitoring	Continuous single or dual bio parameter recording
channels	Minimum of 7 channels including EEG, EOG, chin EMG, ECG, airflow, respiratory effort, oxygen saturation	Minimum of 7 channels including EEG, EOG, chin EMG, ECG, airflow, respiratory effort, oxygen saturation	Minimum of 4, including ventilation (at least 2 channels of respiratory movement or respiratory movement and airflow), heart rate or ECG, and oxygen saturation	Minimum of one including oxygen saturation, flow or chest movement
Body position	Objectively measured	Possible	Possible	No
Leg movement	EMG or motion sensor desirable but optional	optional	optional	No

- Level 1 study or in-hospital, in-laboratory, technician-attended, overnight polysomnography (PSG) is the “Gold standard” for evaluation of sleep-disordered breathing **(Evidence Quality A, Strong Recommendation)**.

- Level 1 polysomnography remains the cornerstone for the diagnosis in patients of comorbid sleep disorders, unstable medical conditions or complex sleep-disordered breathing.

INOSA GUIDELINE 2014

- Laboratory attended PSG (level 1) is not necessary in all patients suspected to have OSA.

- Portable monitoring with devices (which should at least include airflow, oxygen saturation and respiratory effort) is adequate for diagnosis if
  - Used in conjunction with comprehensive sleep evaluation
  - In patients with high pre-test probability of moderate to severe OSA
  - Without co-morbid sleep disorders or medical disorders like pulmonary disease, neuromuscular disease, or congestive heart failure **(Evidence Quality A, Strong Recommendation)**.

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Other indications for unattended portable sleep study:

a. Severe clinical symptoms indicate OSA and initiation of treatment is urgent and PSG is not readily available

b. Patients are unable to be studied in the sleep laboratory (safety or immobility)

c. As a follow-up study when the diagnosis of OSA was previously established by PSG and the intent of testing is to evaluate the response to therapy (weight loss, surgery, oral appliance)

INTERPRETATION AND MONITORING OF RESPIRATORY EVENTS

RESPIRATORY SENSORS

- The sensor to detect absence of airflow in apnea is oronasal thermal sensor.
- The sensor for detection of air flow for identification of hypopnea is a nasal air pressure transducer.
- The sensor for detection of respiratory effort is either esophageal manometry or calibrated or uncalibrated inductance plethismography.
- The sensor for detection of blood oxygen is pulse oxymetry .

- ***AASM MANUAL OF SCORING SLEEP 2012***

COMPARING 2007 AND 2012 AASM RULES

	2007 rule	2012 rule
APNOEA	Drop in peak thermal sensor excursion by > 90% of baseline Duration of event lasts > 10 seconds At least 90% of event's duration meets amplitude reduction criteria for apnea	Drop in peak thermal sensor excursion by > 90% of pre-event baseline Duration of event lasts > 10 seconds **NOTE: Removed**: 90% of event duration must meet amplitude reduction criteria. **Added**: If a portion of a respiratory event that would otherwise meet criteria for a hypopnea meets criteria for apnea, the entire event should be scored as an apnea

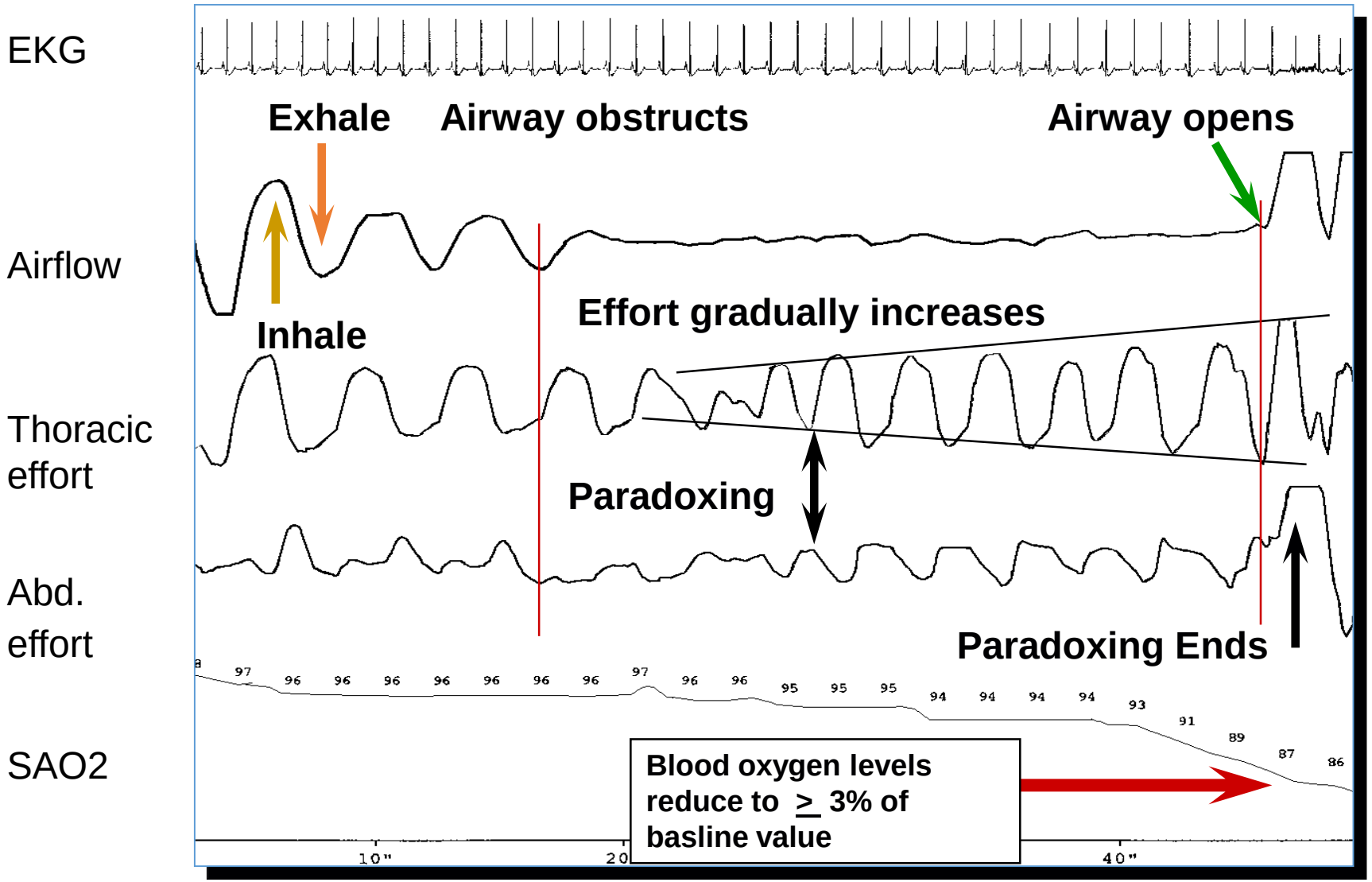
Types of apneas

- **Obstructive apnea:** If the event meets apnea criteria and associated with continued or increased inspiratory effort throughout the entire period of absent airflow.

- **Central apnea:** If the event meets the apnea criteria and associated with absent inspiratory effort through the entire period of absent airflow.

- **Mixed apnea:** If the event meets apnea criteria and is associated with absent inspiratory effort in the initial portion of event followed by resumption of inspiratory effort in second portion of event.

- ***AASM GUIDELINE OF SCORING SLEEP 2012***


EKG
Airflow
Thoracic effort
Abd. effort
SAO2
Exhale
Airway obstructs
Airway opens
Inhale
Effort gradually increases
Paradoxing
Paradoxing Ends
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Blood oxygen levels reduce to > 3% of basline value
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20
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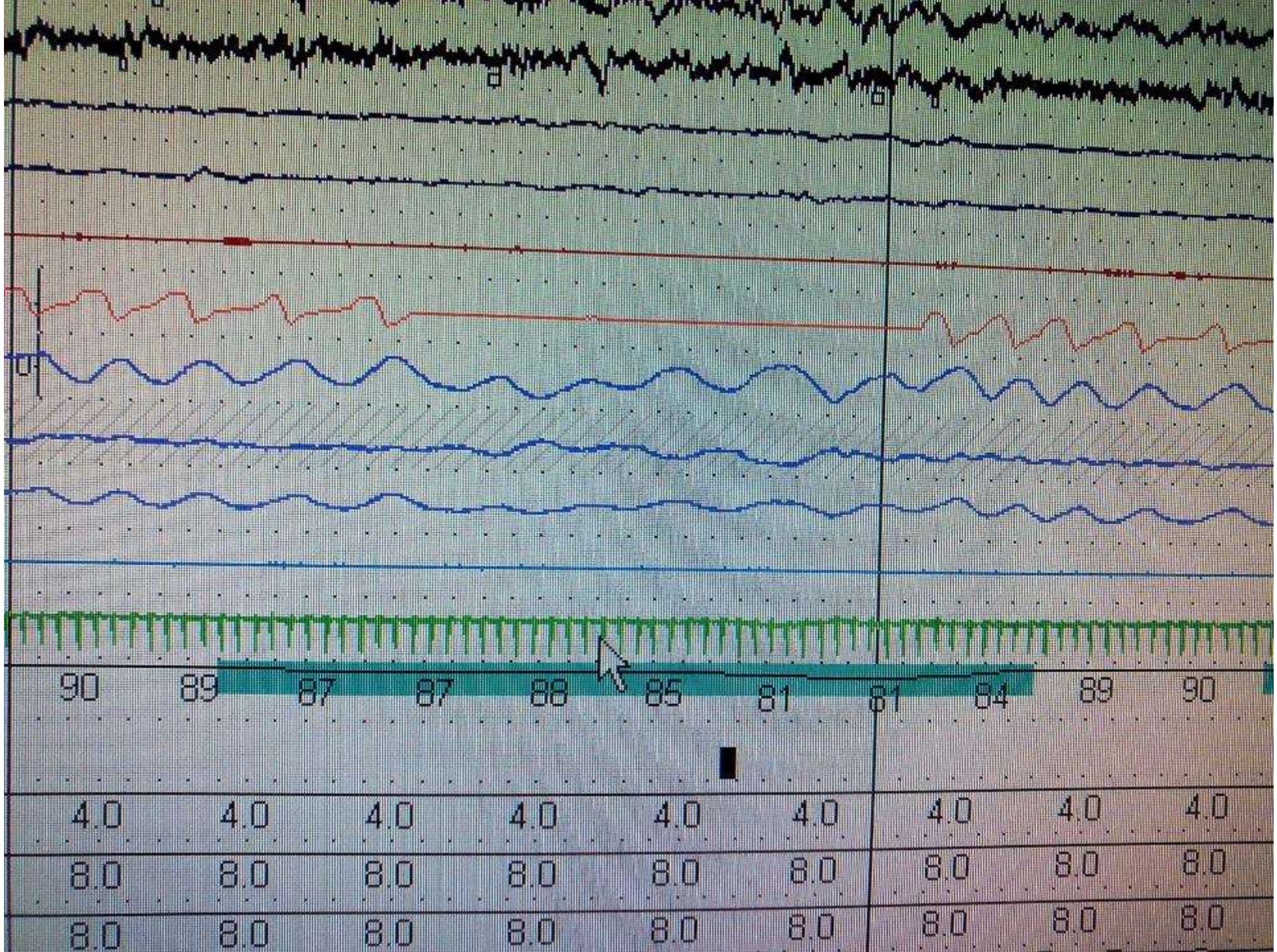
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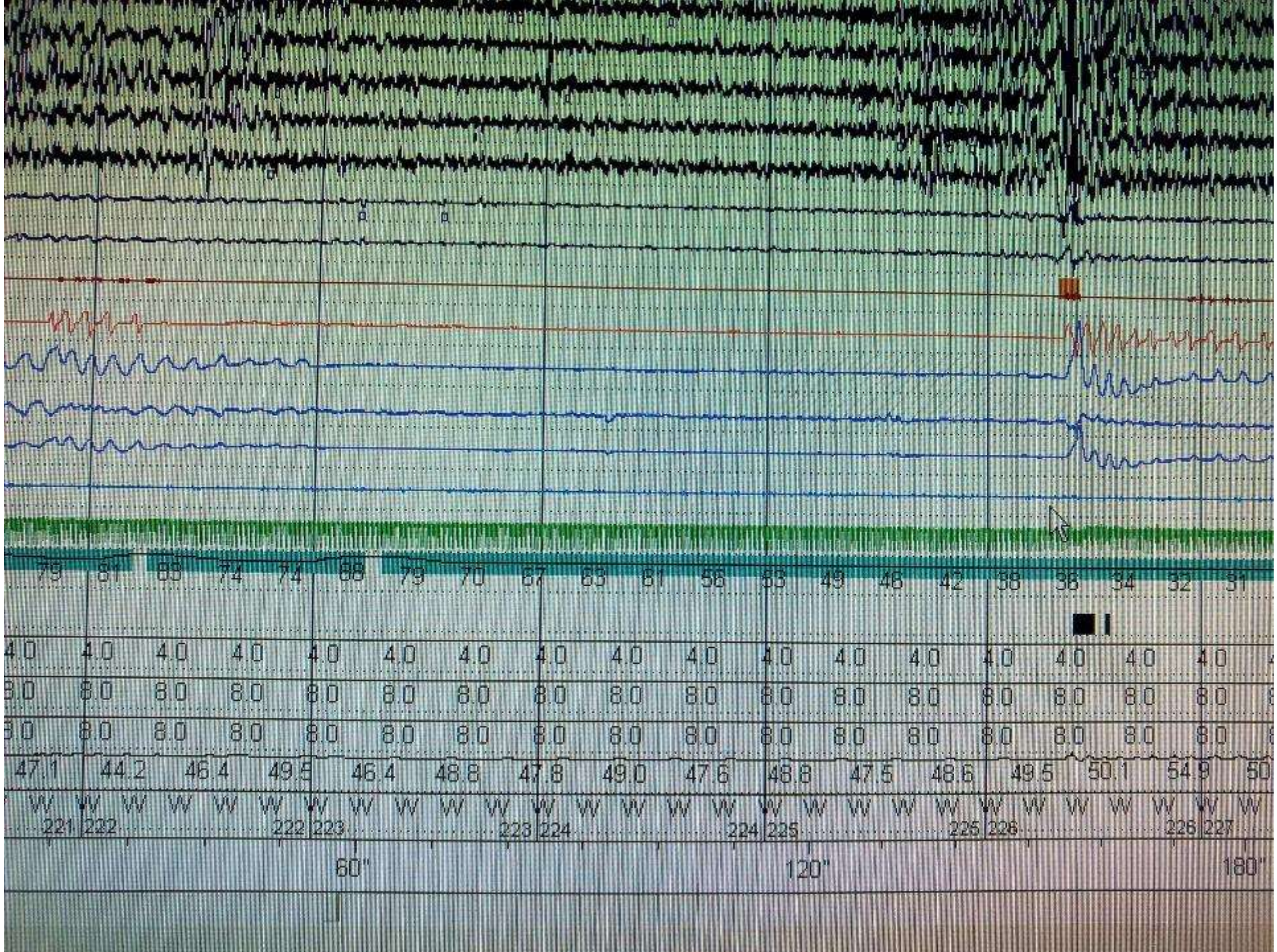
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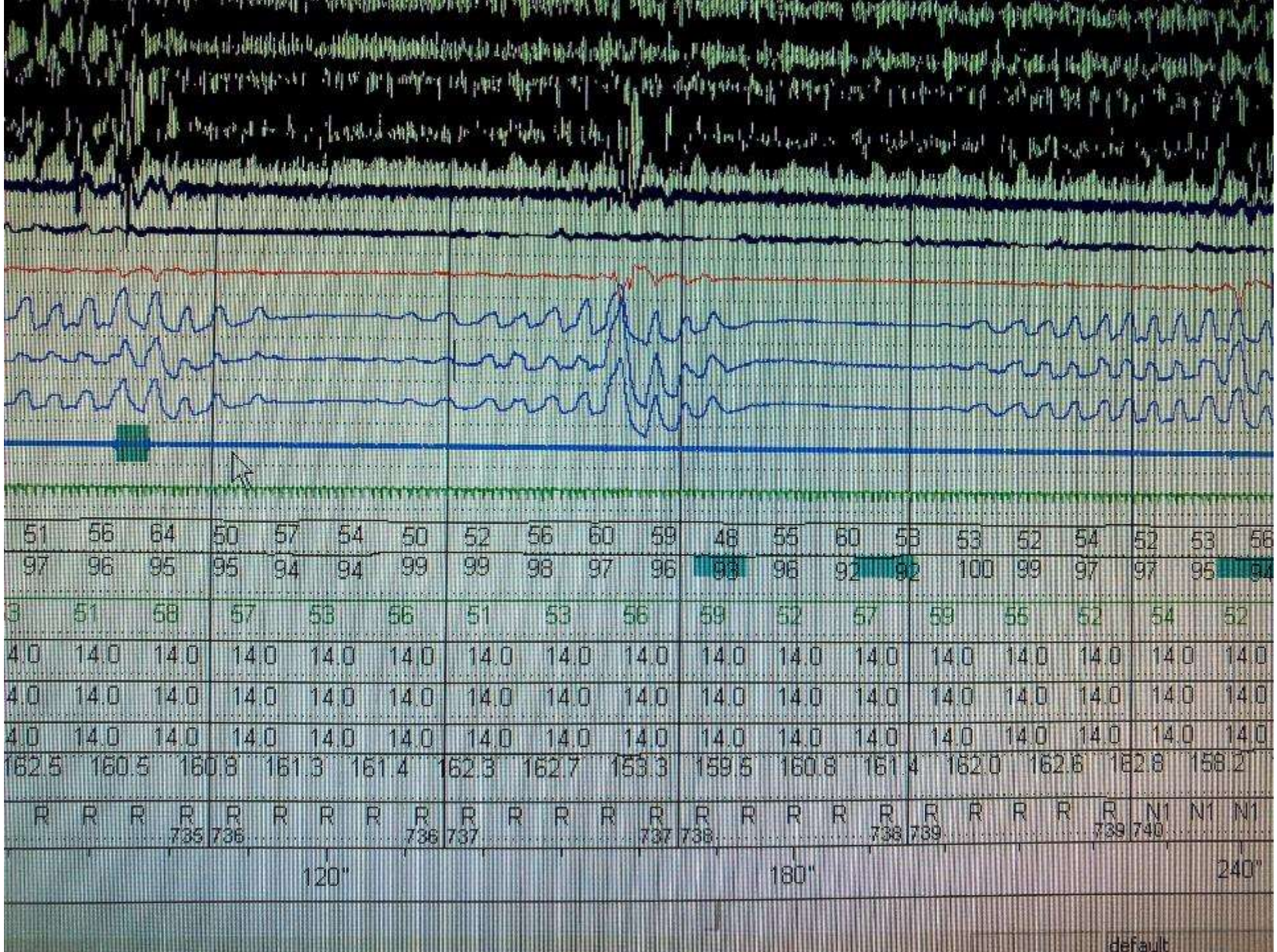
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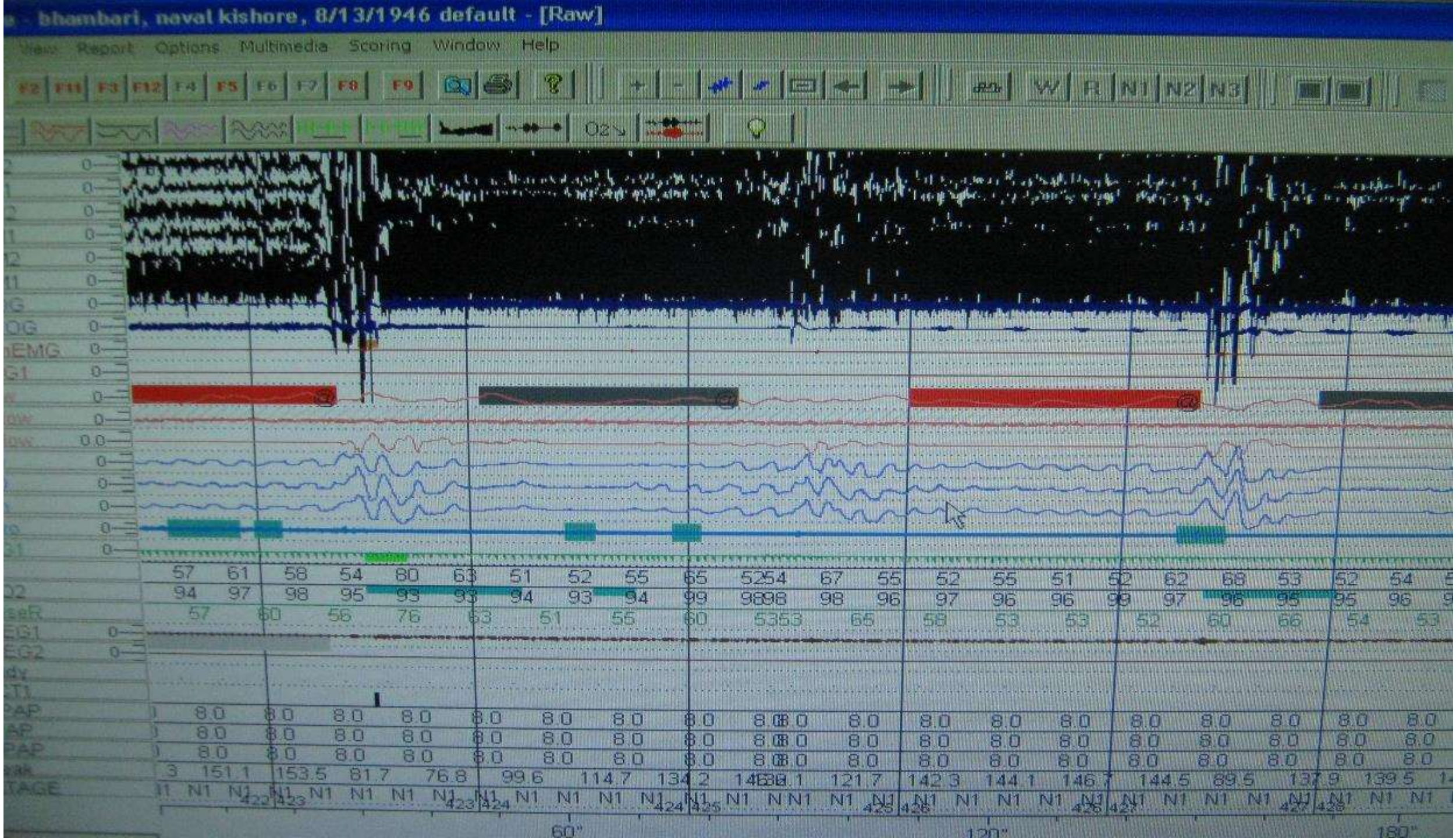
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View Report Options Multimedia Scoring Window Help
F2 F11 F3 F12 F4 F5 F6 F7 F8 F9
W R N1 N2 N3
O2
EMG
60"
120"
180"

HYPOPNOEA RULES- 2007

Criteria 1: When all of the following criteria are made-

- Nasal pressure signal excursions drop by ≥30% of baseline.
- Duration of drop occur for a period lasting at least 10 seconds.
- ≥ 4% desaturation from pre event baseline
- At least 90% of event duration must meet amplitude reduction criteria for hypopnea.

Criteria 2: When all of the following criteria are met

- Nasal pressure signal excursion drop by ≥ 50% from baseline.
- Duration of drop for a period lasting at least 10 seconds
- ≥ 3% desaturation from pre event baseline or event is associated with arousal
- At least 90% of event duration must meet the amplitude reduction criteria for hypopnea.

AASM MANUAL OF SCORING SLEEP 2007

HYPOPNEA RULE -2012

1.Nasal pressure signal excursions drop by > 30% in airflow from pre event baseline

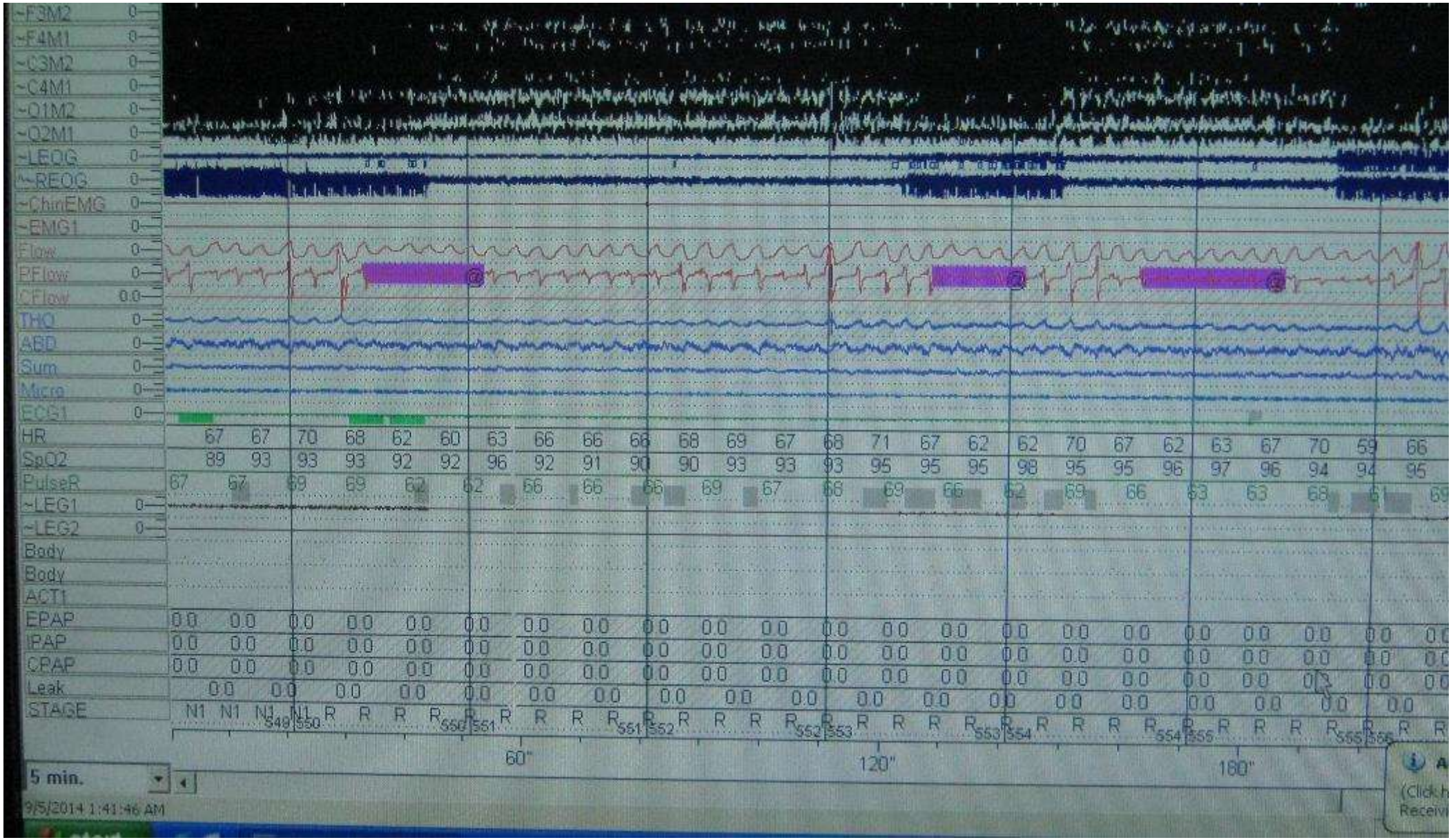
2.Duration of this drop occurs for > 10 seconds

3.> 3% oxygen desaturation or event is associated with an arousal

Removed: 90% of event duration must meet amplitude reduction criteria.

No Alternative Rule

Added: Definitions for scoring obstructive and central hypopnea. Scoring hypopneas as obstructive or central is optional


~F3M2
~F4M1
~C3M2
~C4M1
~O1M2
~O2M1
~LEOG
~REOG
~ChinEMG
~EMG1
Flow
PFlow
CFlow
THO
ABD
Sum
Micro
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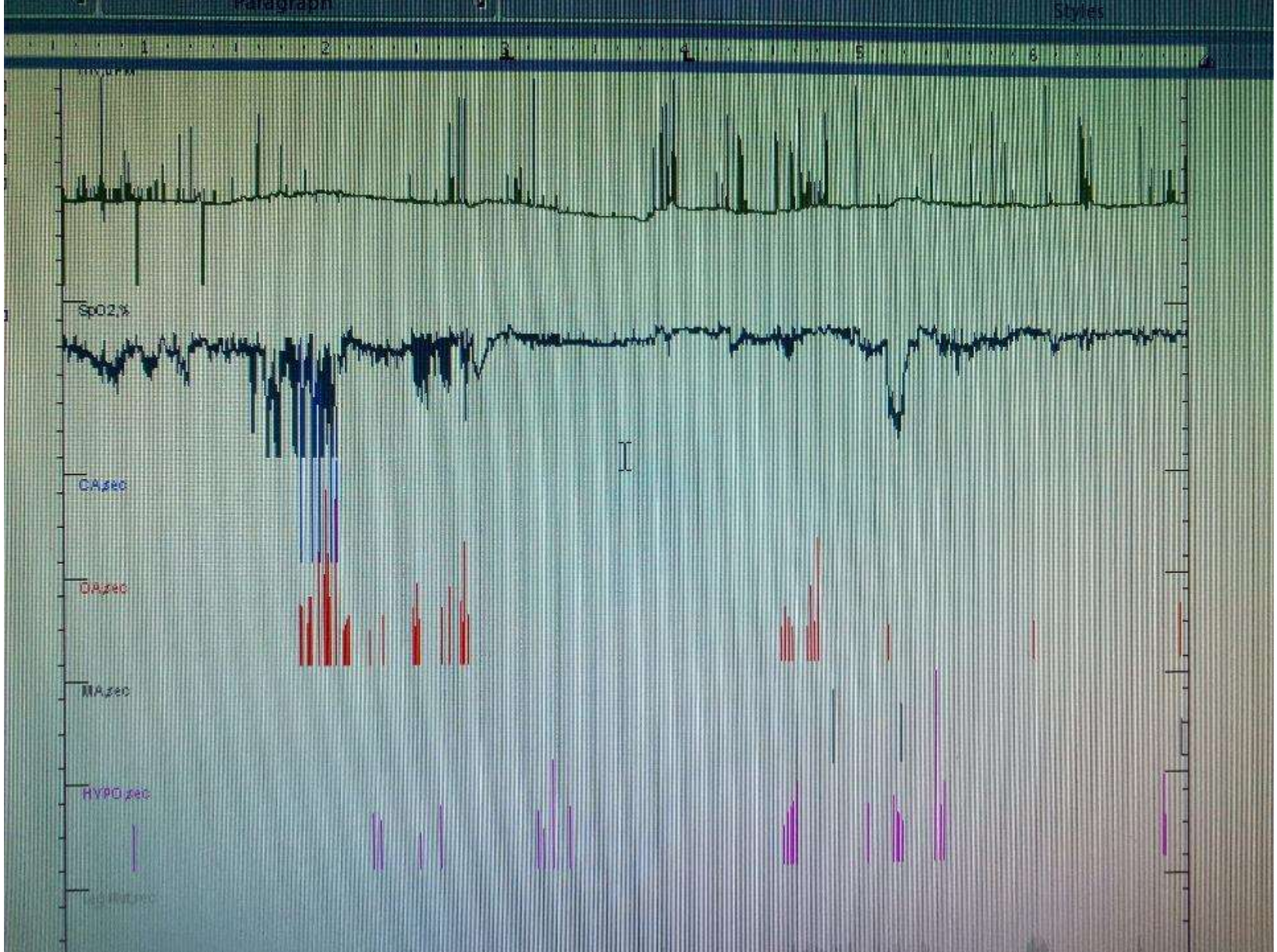
Paragraph
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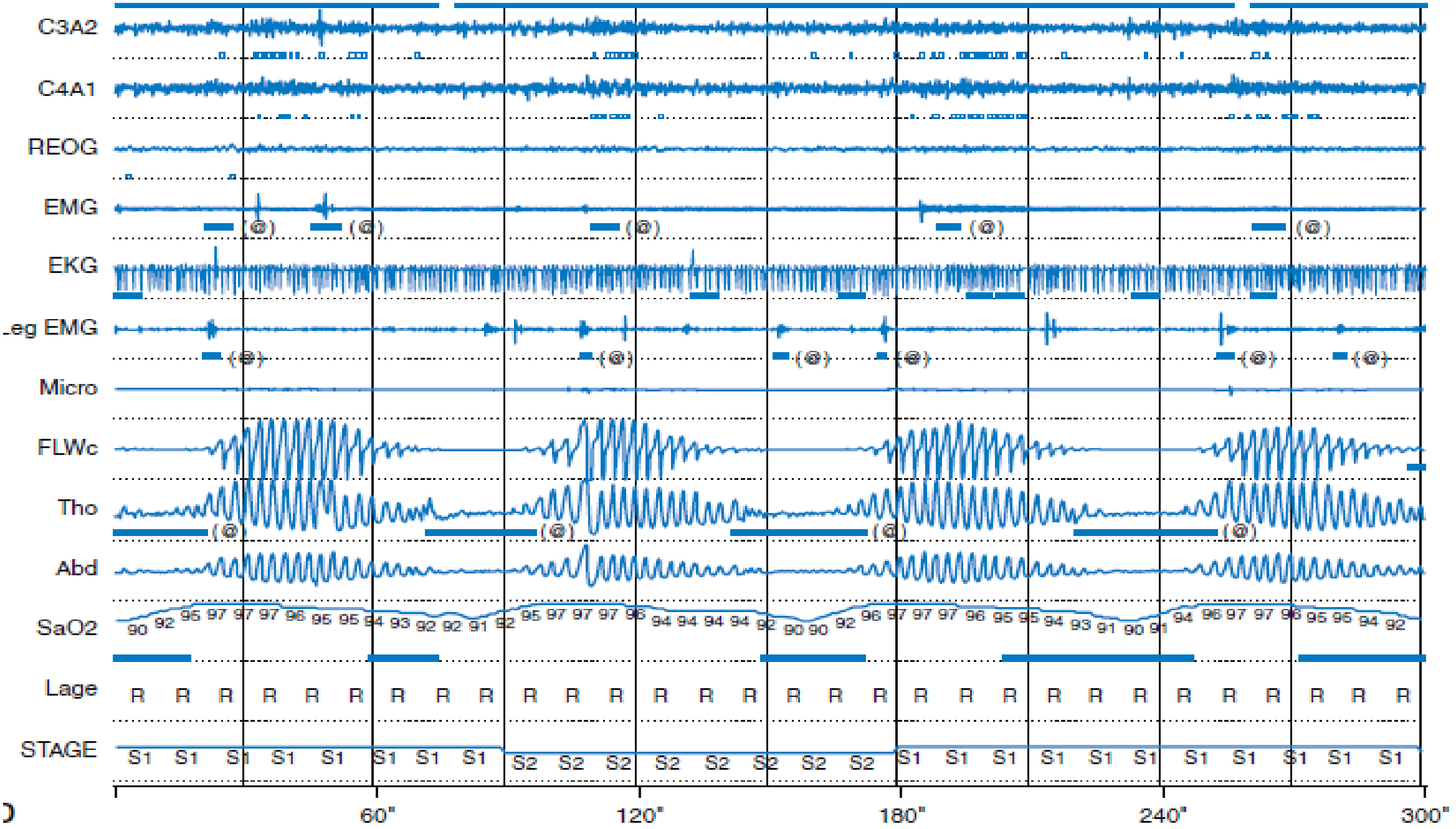
SpO2,%
CA/sec
OA/sec
MA/sec
HYPO/sec

CHEYNE STROKES RESPIRATION

CHEYNE- STROKES RESPIRATION	2007 rule	2012 rules
	Score CSR if there is: a. > 3 consecutive cycles of cyclical crescendo-decrescendo change in breathing amplitude AND at least one of the following: 1) >5 central apneas and/or hypopneas per hour of sleep 2) The cyclical crescendo and decrescendo change in breathing amplitude has duration of > 10 consecutive minutes	Score as CSR if BOTH the following are met: a. episodes of > 3 consecutive central apneas and/or central hypopneas separated by crescendo-decrescendo change in breathing amplitude with a cycle length of > 40 seconds AND b.There are >5 central apneas and/or central hypopneas per hour of sleep associated with crescendo/decrescendo breathing pattern recorded over > 2 hours of monitoring **NOTE**: Central apneas occurring within a run of CSR should be scored as individual apneas as well


C3A2
C4A1
REOG
EMG
EKG
Leg EMG
Micro
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Tho
Abd
SaO2
Lage
STAGE
60"
120"
180"
240"
300"

Respiratory effort related arousal

- Sequence of breaths lasting at least 10 seconds characterized by increasing respiratory effort or flattening of the nasal pressure waveform leading to an arousal from sleep when sequence of breath does not meet criteria for apnea or hypopnea.

- Use of esophageal pressure is preferred method of assessing change of respiratory effort .

- ***AASM MANUAL OF SCORING SLEEP 2007***

HYPOVENTILATION RULE

hypoventilation	2007 rules	20 12 rules
	During sleep, > 10 mmHg increase in $PaCO_2$ during sleep compared to wake supine value	Score a respiratory event as hypoventilation during sleep if EITHER of the below occur: a. There is an increase in the arterial PCO_2 (or surrogate) to a value >55 mmHg for ≥10 minutes. b. There is ≥10 mmHg increase in arterial PCO_2 (or surrogate) during sleep (in comparison to an awake supine value) to a value exceeding 50 mmHg for ≥10 minutes.

	OLD 2007 RULES	NEW 2012 RULES
CARDIAC EVENT PARAMETER		**Added**: Average heart rate during sleep, highest heart rate during sleep, highest heart rate during recording Occurrence of arrhythmia: Bradycardia (yes/no) [list lowest rate] Asystole (yes/no) [list longest pause] Sinus tachycardia (yes/no) [list highest rate] Narrow complex tachycardia (yes/no) [list highest rate] Wide complex tachycardia (yes/no) [list highest rate] Atrial fibrillation (yes/no) Other arrhythmias if present (yes/no)

	2012 rule
General reporting, Sleep scoring and data parameter	Added ECG as recommended parameter
Optional respiratory event report parameter	**Added the following optional reporting parameters**: Obstructive apnea hypopnea index(OAHI) Central apnea hypopnea index (CAHI) Respiratory disturbance index (RDI) index Arterial oxygen saturation, mean value Occurrence of hypoventilation Occurrence of hypoventilation during PAP titration **Removed or changed the following optional reporting parameters:** Oxygen desaturations ≥3% total number Oxygen desaturation index ≥3% (ODI)

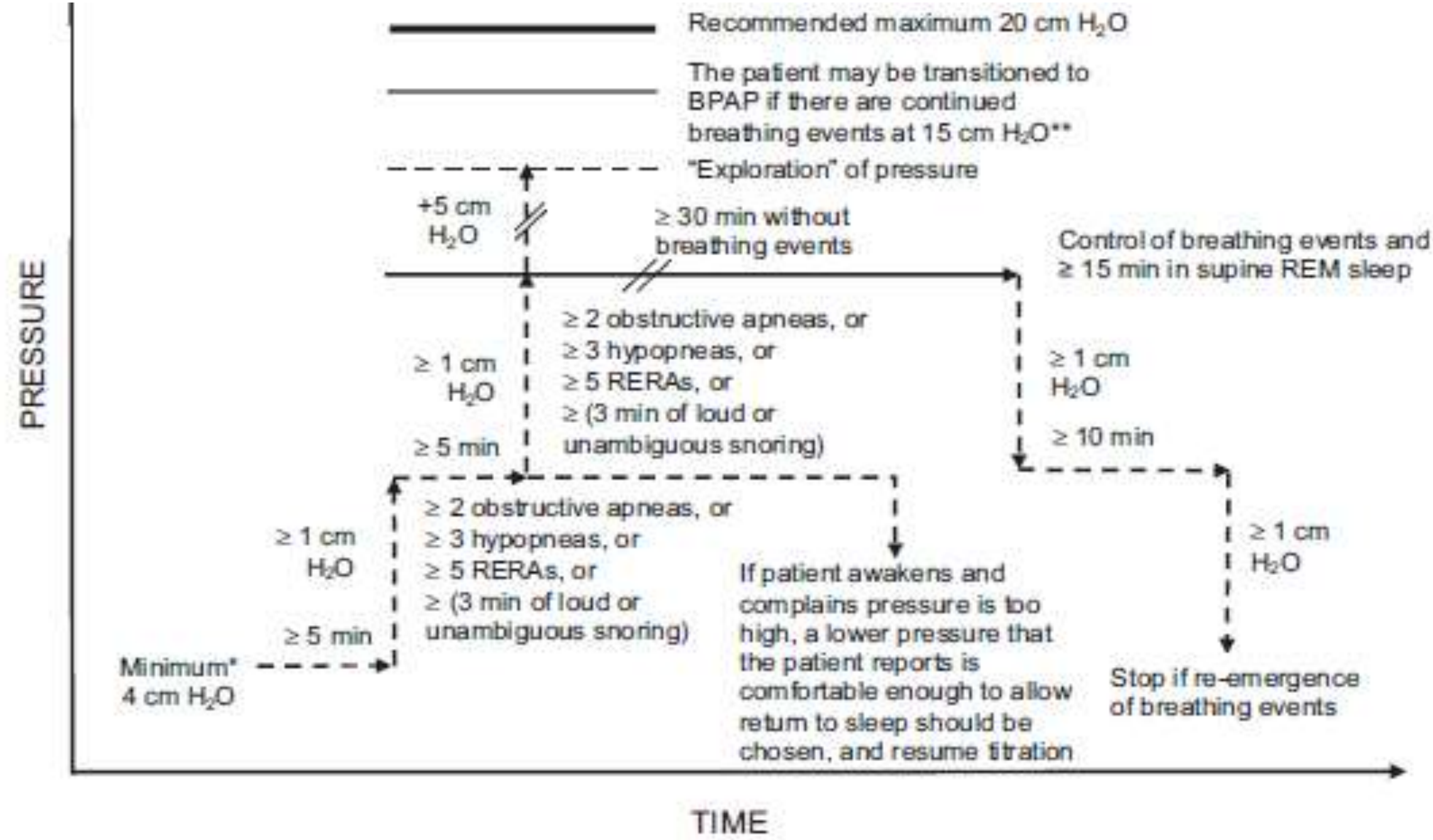
DESCRIPTION AND METHODOLOGY OF MANUAL PAP TITRATION

(AASM clinical guideline for manual titration of PAP in OSA patients –update 2012)*Journal of Clinical Sleep Medicine, Vol. 4, No. 2, 2008*

CPAP TITRATION	
PATIENTS<12 YEARS	PATIENTS>12 YEARS
CPAP MINIMUM OF 4CM OF WATER AND MAXIMUM OF15 CM OF WATER	CPAP MINIMUM OF 4CM OF WATER AND MAXIMUM OF 20 CM OF WATER

Increase pressure by one cm of water at an interval of no less than five minutes in following cases-

Patient<12 yr	Patient>12 yr
1 obstructive apnoea	2 obstructive apnoeas
1 hypopnoea	3 hypopnoeas
3 RERAS	5 RERAS
1 min of loud unambigious snoring	3 min of loud unambiguous snoring


Recommended maximum 20 cm H_2O
The patient may be transitioned to BPAP if there are continued breathing events at 15 cm H_2O**
"Exploration" of pressure
+5 cm H_2O
≥ 30 min without breathing events
Control of breathing events and ≥ 15 min in supine REM sleep
≥ 1 cm H_2O
≥ 5 min
≥ 2 obstructive apneas, or
≥ 3 hypopneas, or
≥ 5 RERAs, or
≥ (3 min of loud or unambiguous snoring)
≥ 1 cm H_2O
≥ 10 min
≥ 1 cm H_2O
≥ 5 min
≥ 2 obstructive apneas, or
≥ 3 hypopneas, or
≥ 5 RERAs, or
≥ (3 min of loud or unambiguous snoring)
If patient awakens and complains pressure is too high, a lower pressure that the patient reports is comfortable enough to allow return to sleep should be chosen, and resume titration
≥ 1 cm H_2O
Stop if re-emergence of breathing events
Minimum* 4 cm H_2O
PRESSURE
TIME

DOWN TITRATION

A “down” titration is recommended due to the “hysteresis” phenomenon. During upward titration the PAP level at which flow limitation disappears is 2-5 cm H2O higher than the level at which it reappears during downward titration. If a “down” titration is implemented, at least one “up-down” CPAP titration (1 cycle) should be conducted during the night.

It should be conducted when at least 30 min has elapsed without obstructive respiratory events.

CPAP should be decreased by more than 1 cm H2O with an interval no shorter than 10 min, until there is reemergence of obstructive respiratory events.

Titration guideline for when and how to switch to BIPAP

1. When the patient complains that he/she is uncomfortable or is intolerant of high CPAP pressures. (Document this on the record.)

2. When CPAP level is 15 cm H2O and respiratory disturbances continue. (Document this on the record.)

Begin BPAP at EPAP 4 cm H2O or the CPAP level at which obstructive apnea was eliminated; set IPAP 4 cm H2O higher.

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012

PATIENT<12 YRS	Patients >12 yrs
Minimum IPAP 8cm of water, EPAP 4cm of water	Minimum IPAP 8 cm of water , EPAP 4cm of water
Maximum IPAP 20 cm of water	Maximum IPAP 30 cm of water
Minimum I/E difference 4 cm of water	Minimum I/E difference 4 cm of water
Maximum I/E difference 10 cm of water	Maximum I/E difference of 10 cm of water

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012

- Increase both IPAP and EPAP pressures by a minimum of 1 cm H2O with an interval of no less than 5 minutes when the following occur:

Patient age<12 yrs	Patient age >12 yrs
One obstructive apnoea	Two obstructive apnoeas

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012

- Increase IPAP pressure by a minimum of 1 cm H2O with an interval of no less than 5 minutes when the following occurs :

<12 years	>12 years
One hypopnoea	Three hypopnoeas
Three RERAS	Five RERAS
One min of loud or unambiguous snoring	Three min of loud or unambigious snoring

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012

- **Determining the Optimum Pressure**
- The patient must be able to sleep in order for PAP titration to be successful. If the patient awakens and complains the pressure is too high, the pressure should be reduced to a level at which the patient is able to return to sleep.
- Mask and mouth leaks should be promptly addressed.

- Pressure relief technologies may be implemented to improve patient comfort.
-
- BPAP may be utilized for patients who are intolerant of high CPAP pressures.

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012

- **Supplemental Oxygen**
- when awake supine SpO2 on room air is less than 88% for 5 minutes or longer. Supplemental O2 may also be added during the PAP titration when SpO2 is ≤88% for ≥5 minutes in the absence of obstructive respiratory events

Supplemental oxygen should be introduced into the PAP device at the device tubing connection using a T connector, not at the PAP mask.

The recommended minimum starting rate for adult and pediatric patients is 1 L/min.

Titrate O2 in 1 L/min increments with an interval of no less than 15 minutes until SpO2 is between 88% and 94.

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012 *Journal of Clinical Sleep Medicine, Vol. 4, No. 2, 2008*

Types of Titration achieved

1. Optimal
2. Good
3. Acceptable
4. Unacceptable

Optimal titration is achieved when-

1. The Respiratory Disturbance Index (RDI) is < 5 per hour for a period of at least 15 minutes at the selected pressure and within the manufacturer's acceptable leak limit.

2. The SpO2 is above 90% at the selected pressure.

3. Supine REM sleep at the selected pressure is not continually interrupted by spontaneous arousals or awakenings.

AASM clinical guideline for manual titration of PAP in OSA patients –update 20122012 *Journal of Clinical Sleep Medicine, Vol. 4, No. 2, 2008*

Good titration is achieved when

1. The Respiratory Disturbance Index (RDI) is < 10 per hour (or is reduced by 50% if the baseline RDI was <15) for a period of at least 15 minutes.

2. The SpO2 is above 90% at the selected pressure.

3. Supine REM sleep at the selected pressure is not continually interrupted by spontaneous arousals or awakenings.

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012 *Journal of Clinical Sleep Medicine, Vol. 4, No. 2, 2008*

Adequate Titration-

Which does not reduces overnight RDI<10 per hour but reduces RDI>75% of baseline in severe OSA patients or in which titration grading criteria of optimal or good titration are achieved with exception that supine REM does not occur at selected pressure.

- *Journal of Clinical Sleep Medicine, Vol. 4, No. 2, 2008*

Split-Night Studies

- Split-night studies must be performed using algorithms identical to those used for full-night PAP titration and should include greater than 3 hours of titration time.
- Split-night studies should not be performed in children less than 12 years old.
- Due to the reduced titration time available during split-night studies, increase PAP pressures by a minimum of 2 cm H2O with an interval of no less than 5 minutes.

Journal of Clinical Sleep Medicine, Vol. 4, No. 2, 2008

AASM clinical guideline for manual titration of PAP in OSA patients –update 2012

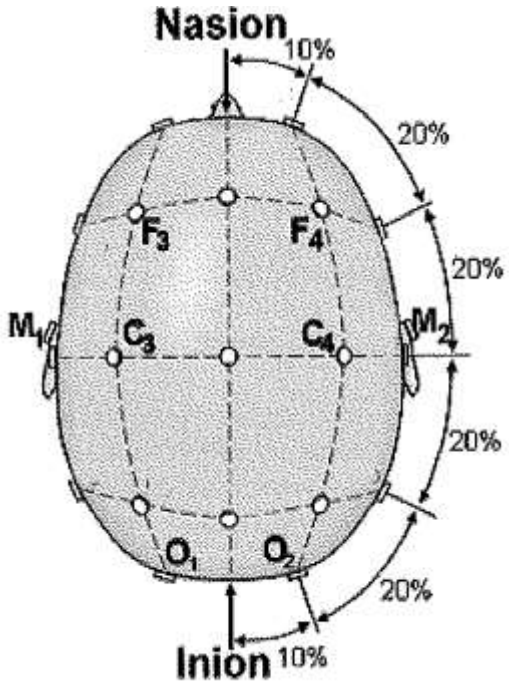
INTERPRETATION OF EEG

EEG electrode position determined by international 10-20 system.

A minimum of 3 EEG derivations are required in order to sample activity from frontal, central and occipital regions.

This system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex.

"10" and "20" refer to the actual distances between adjacent electrodes are either 10% or 20% of the total front–back or right–left distance of the skull.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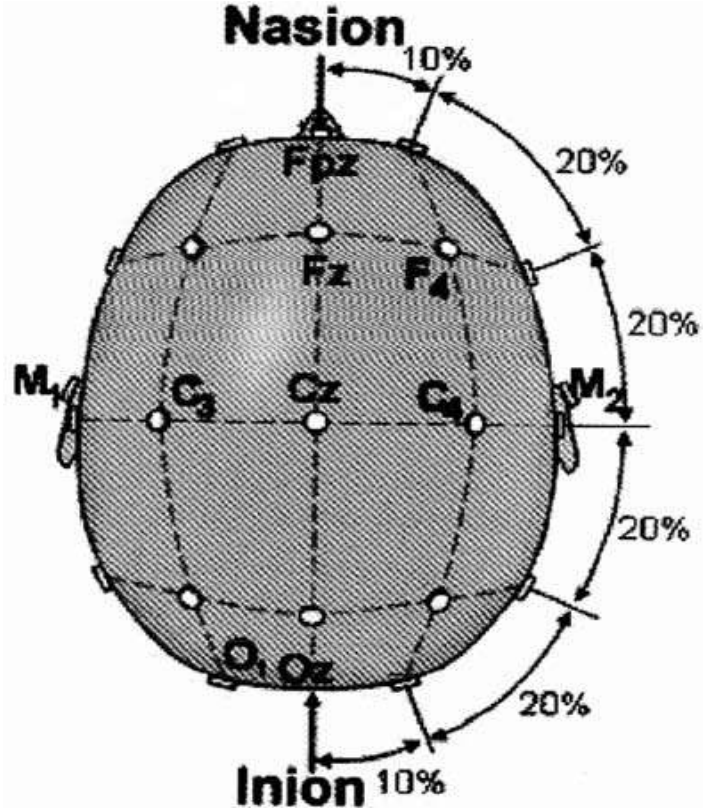
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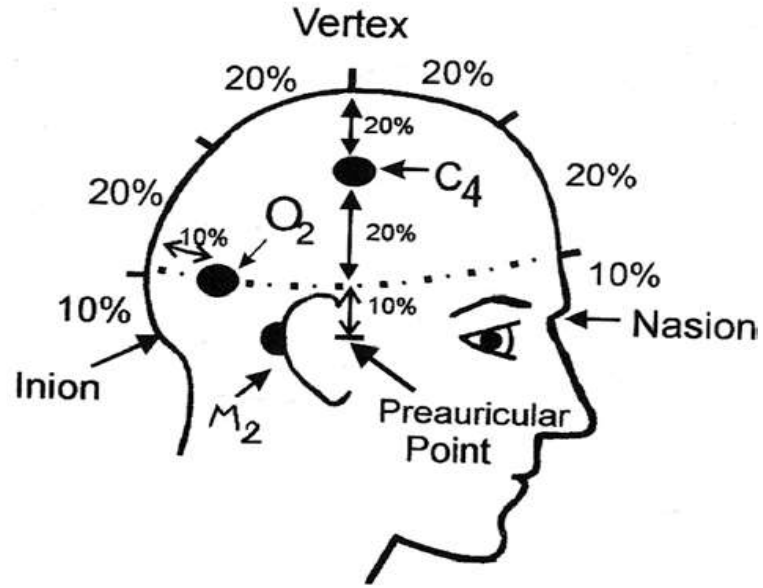
Vertex
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C4
O2
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20%
10%
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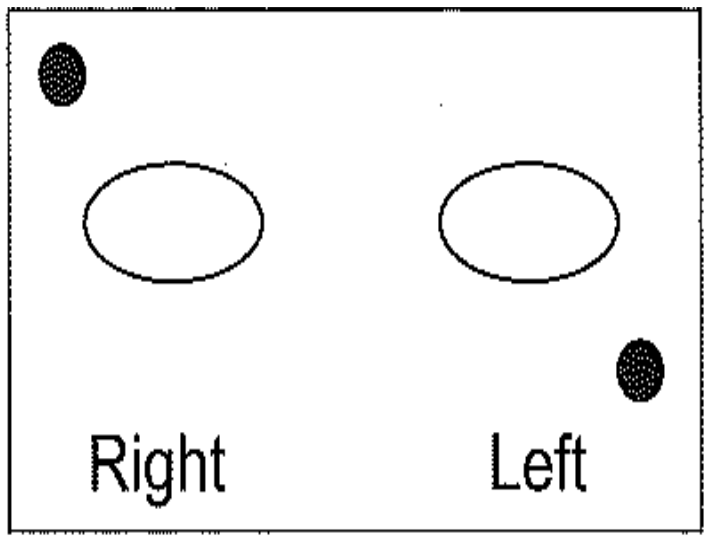
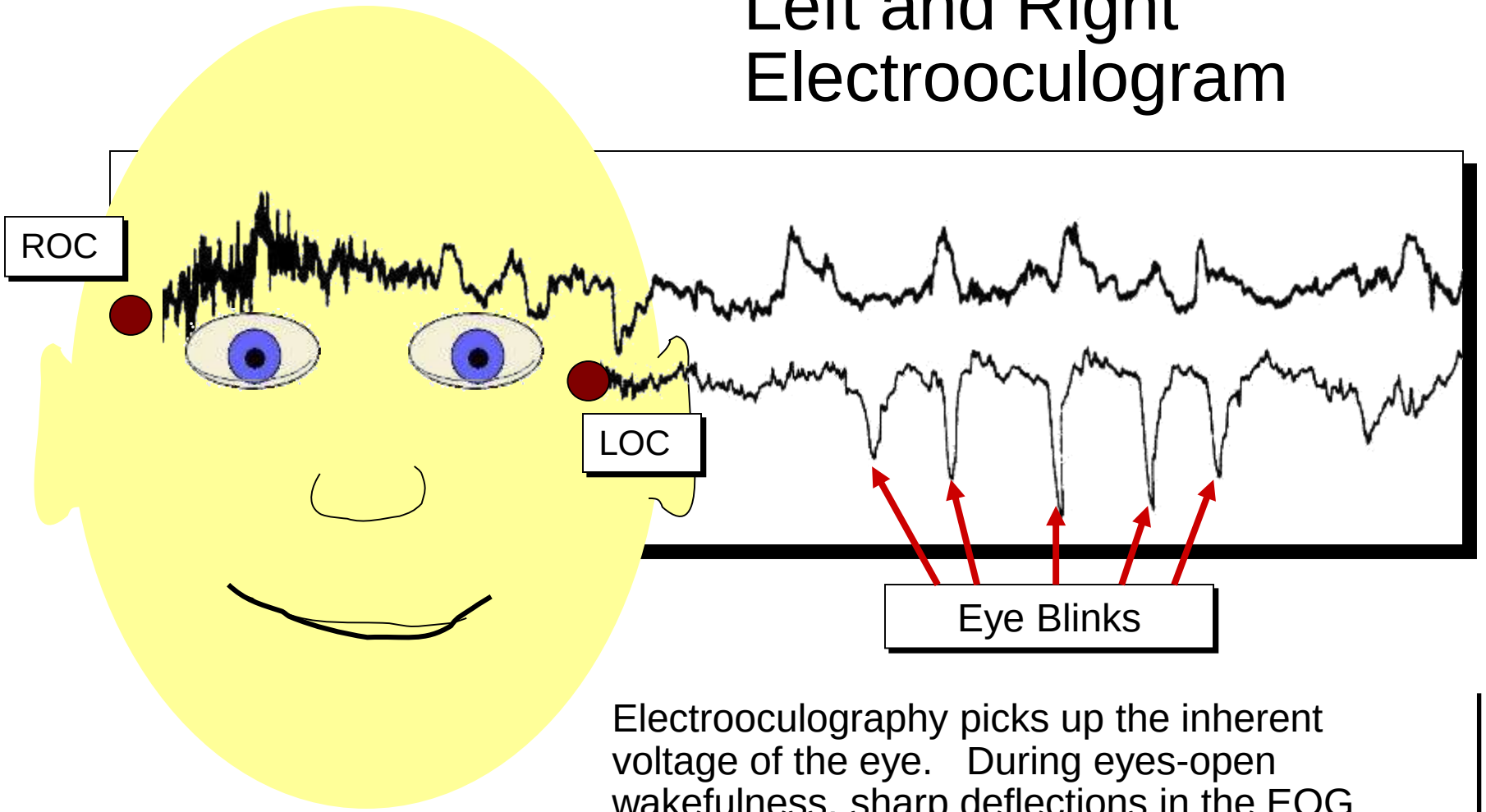
10%
Nasion
Inion
M2
Preauricular
Point

- Recommended derivations are F4-M1,C4-M1,O2-M1.
- M1 and M2 refer to right and left mastoid process

EOG

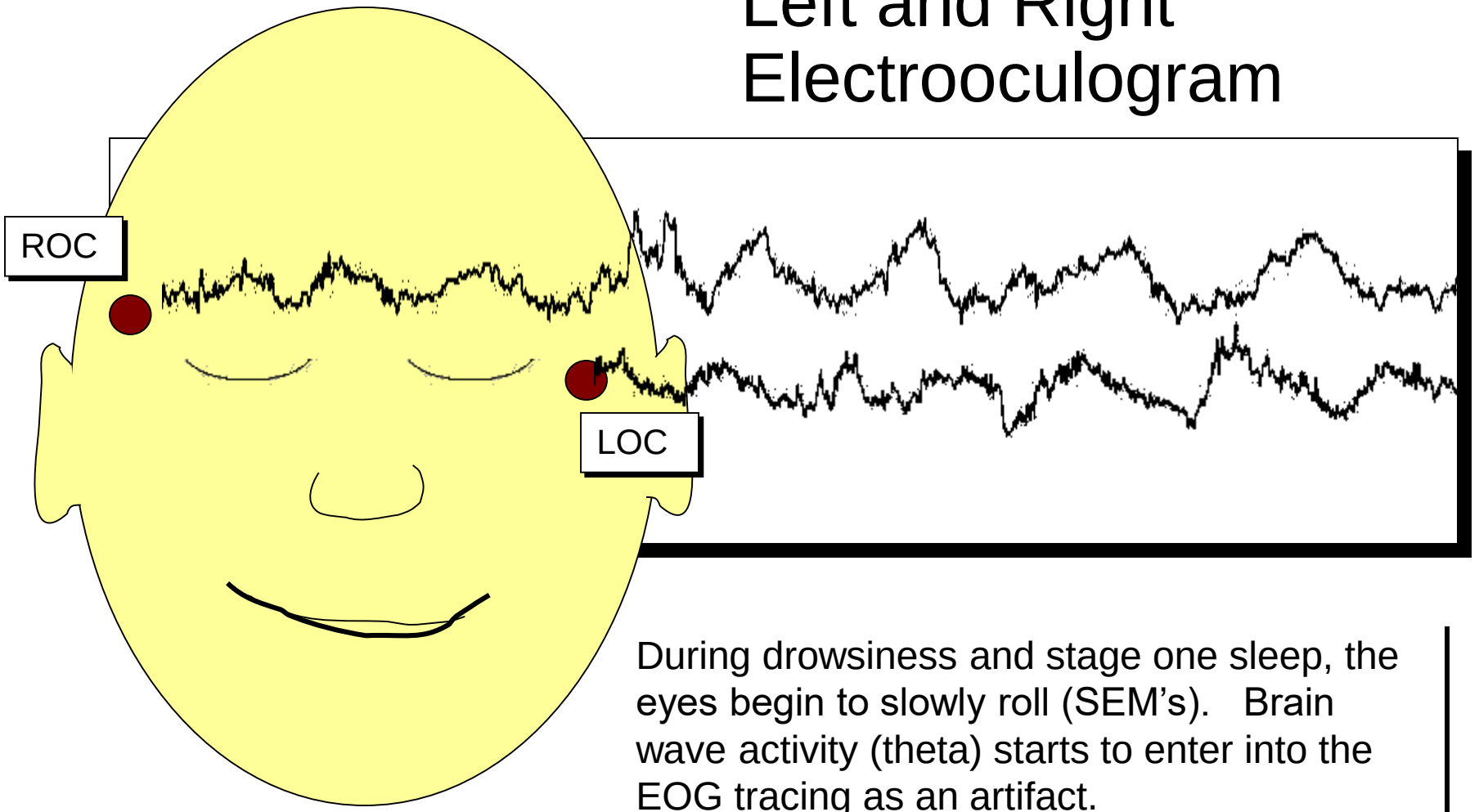


Left and Right Electrooculogram



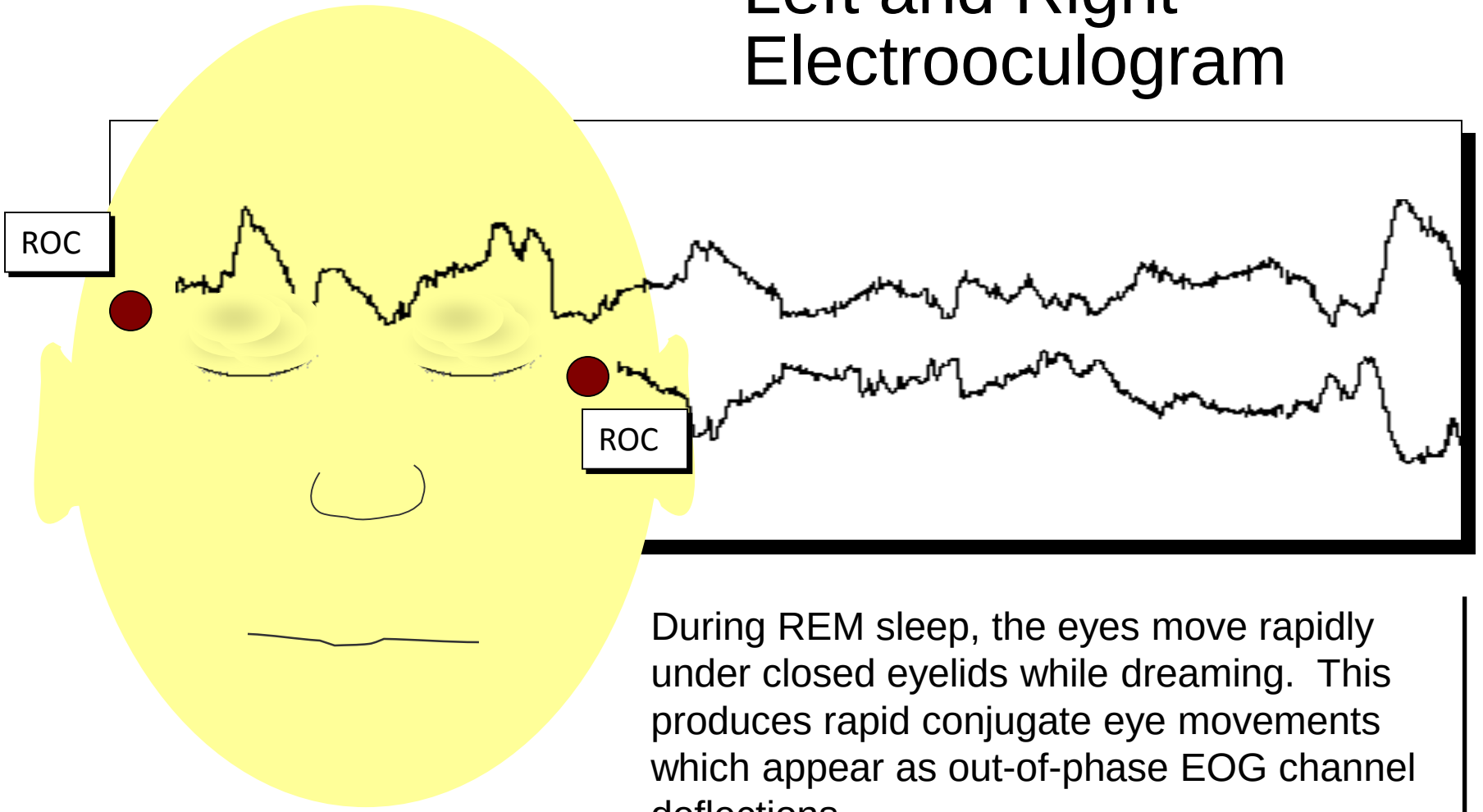
Electrooculography picks up the inherent voltage of the eye. During eyes-open wakefulness, sharp deflections in the EOG tracing may indicate the presence of eye blinks.

Left and Right Electrooculogram



During drowsiness and stage one sleep, the eyes begin to slowly roll (SEM's). Brain wave activity (theta) starts to enter into the EOG tracing as an artifact.

Left and Right Electrooculogram



During REM sleep, the eyes move rapidly under closed eyelids while dreaming. This produces rapid conjugate eye movements which appear as out-of-phase EOG channel deflections.

CHIN EMG-

Three electrodes should be placed to record chin EMG-

- One in the midline one cm above the inferior edge of mandible .
- One two cm below the inferior edge of mandible and 2cm to right of midline.
- One two cm below the inferior edge of mandible and two cm to the left of mandible

SCORING OF SLEEP STAGES-

Stages of sleep:

Stage N1

Stage N2

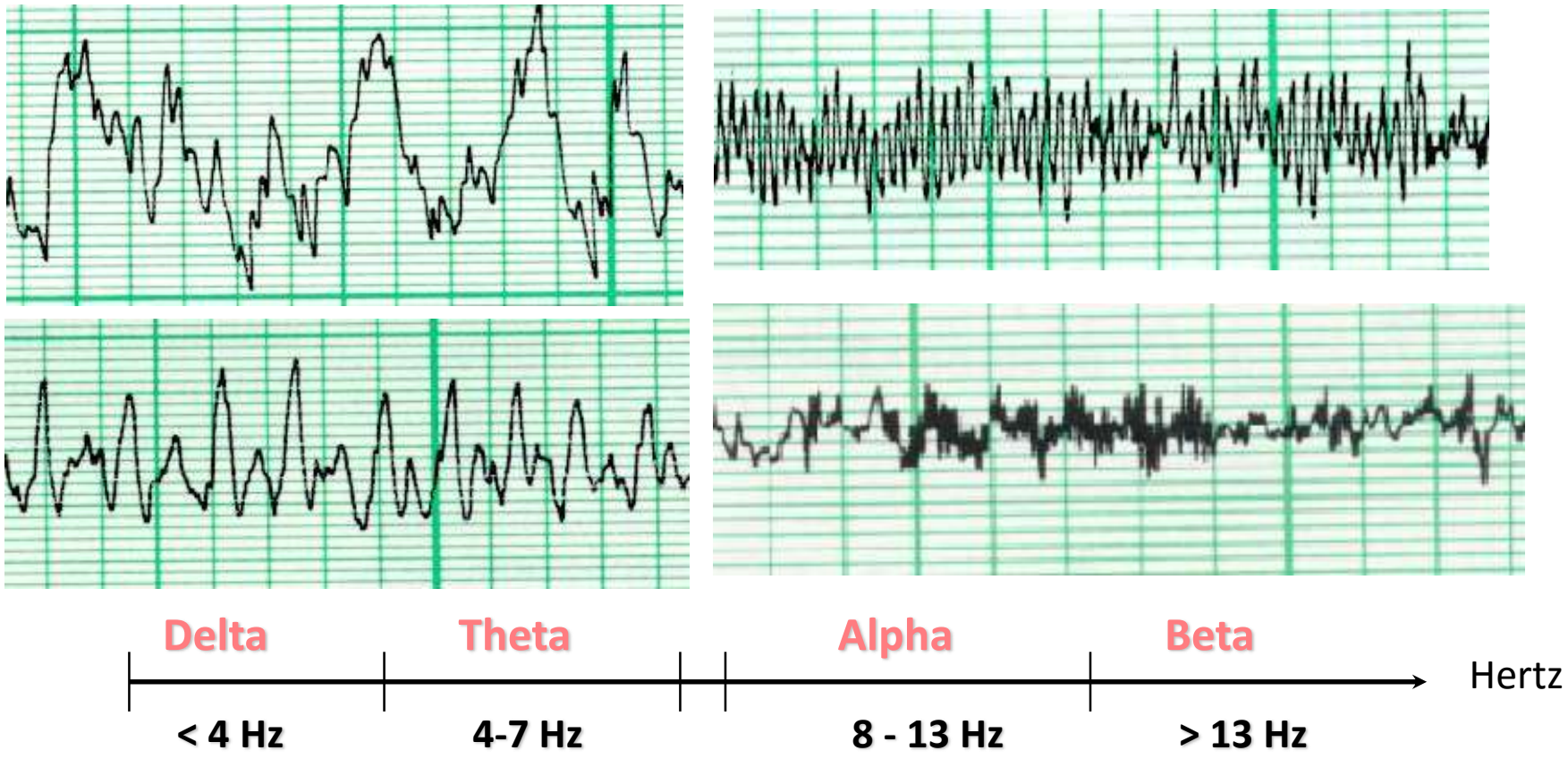
Stage N3

Stage R

- Scoring by Epoch-Scored in 30 second sequential epoch
- Assign a stage to each epoch.
- If two or more stage coexist during single epoch, assign the stage comprising the greatest portion of epoch

Frequency band width

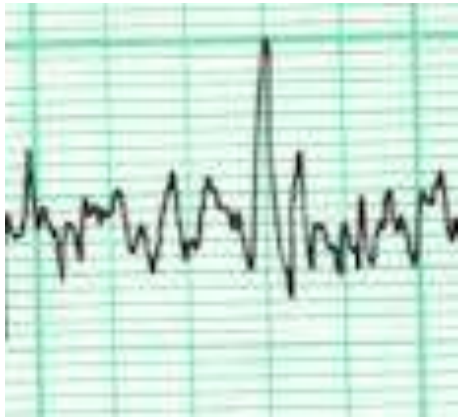
Frequencies in polysomnography limited to 4 distinct patterns:



EEG scoring

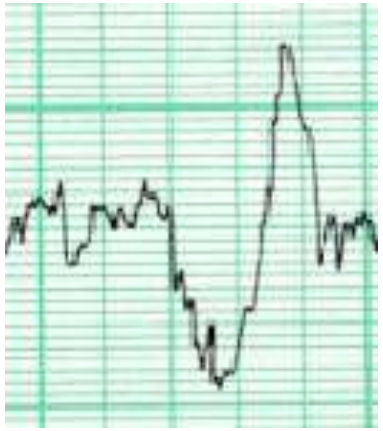
EEG waves can be described in terms of their **SHAPE**:

Vertex waves



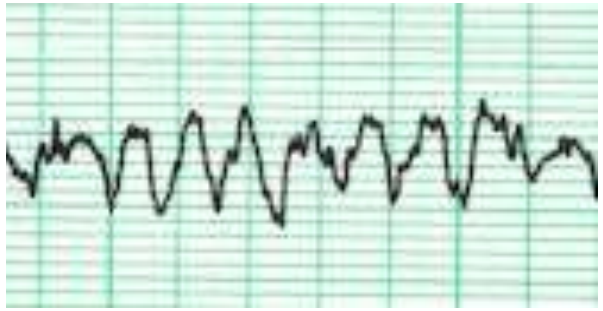
sharp positive waves, theta frequency range, occuring *latter part* of **Stage1**

K Complex



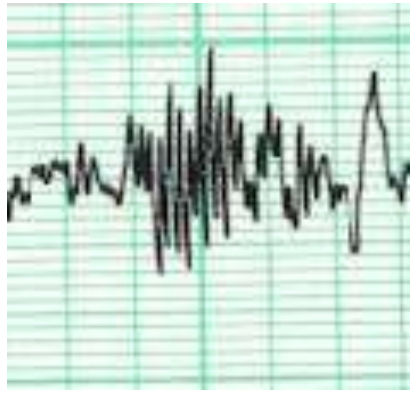
sharp positive wave, followed by slower negative component, seen in **Stage 2**

Sawtooth waves



low amplitude sawtooth appearance seen in **REM**

Spindle



short rhythmic waveform clusters of 12-14 Hz seen in **stage2**

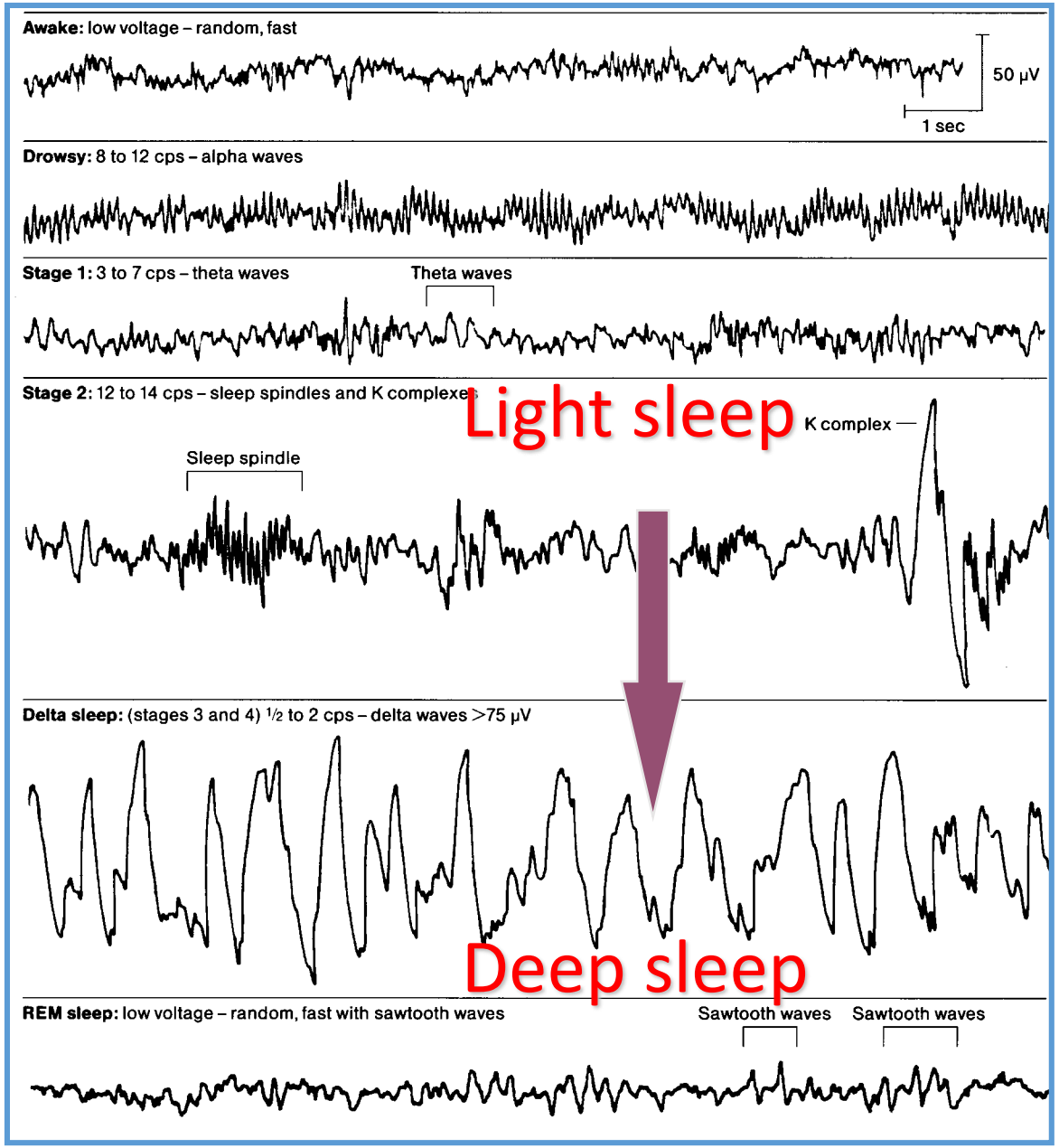
Non
Rapid
Eye
Mov

Stage 1

Stage 2

Stage 3(4)

REM



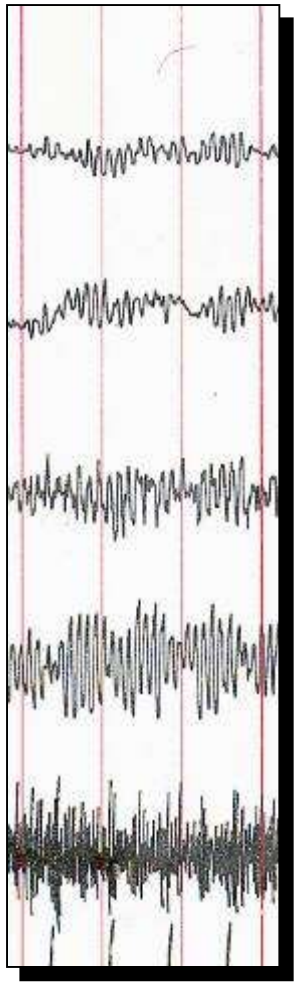
STAGE W

More than 50% of epoch has alpha rhythm over occipital region or any of the following are present-

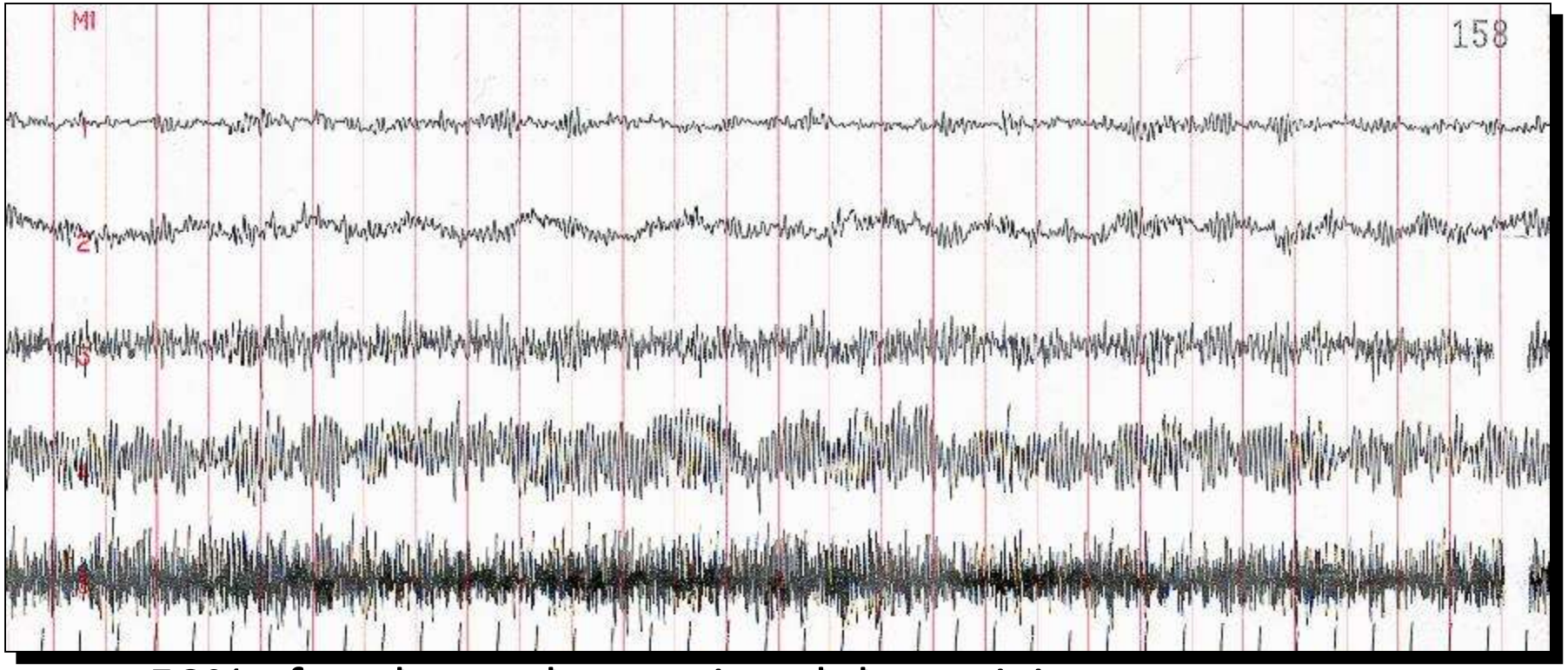
- Eye blink at a frequency of 0.5 -2 Hz
- Reading eye movement
- Irregular conjugate rapid eye movements associated with normal or high chin muscle tone

Alpha Activity

- Alpha EEG: 8-13 cps.
- Alpha: occipital region
- Alpha: crescendo-decrescendo appearance
- Decrease in frequency occurs with aging



Stage Wake



- >50% of each epoch contains alpha activity.
- Slow rolling eye movements or eye blinks will be seen in the EOG channels
- Relatively high submental EMG muscle tone

STAGE N1

- Alpha rhythm is attenuated and replaced by low amplitude mixed frequency activity more than 50% of epoch

In subjects who do not generate alpha rhythm score stage N1 with any of the following phenomenon-

- Activity in range of 4-7Hz with slowing of background frequency by >_ 1Hz from those of stage W

- Vertex sharp wave

- Slow eye movements

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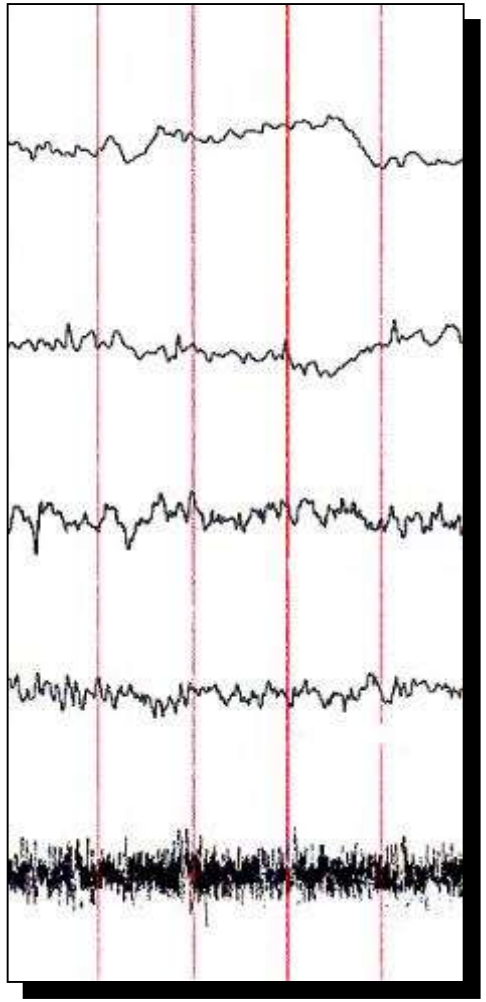
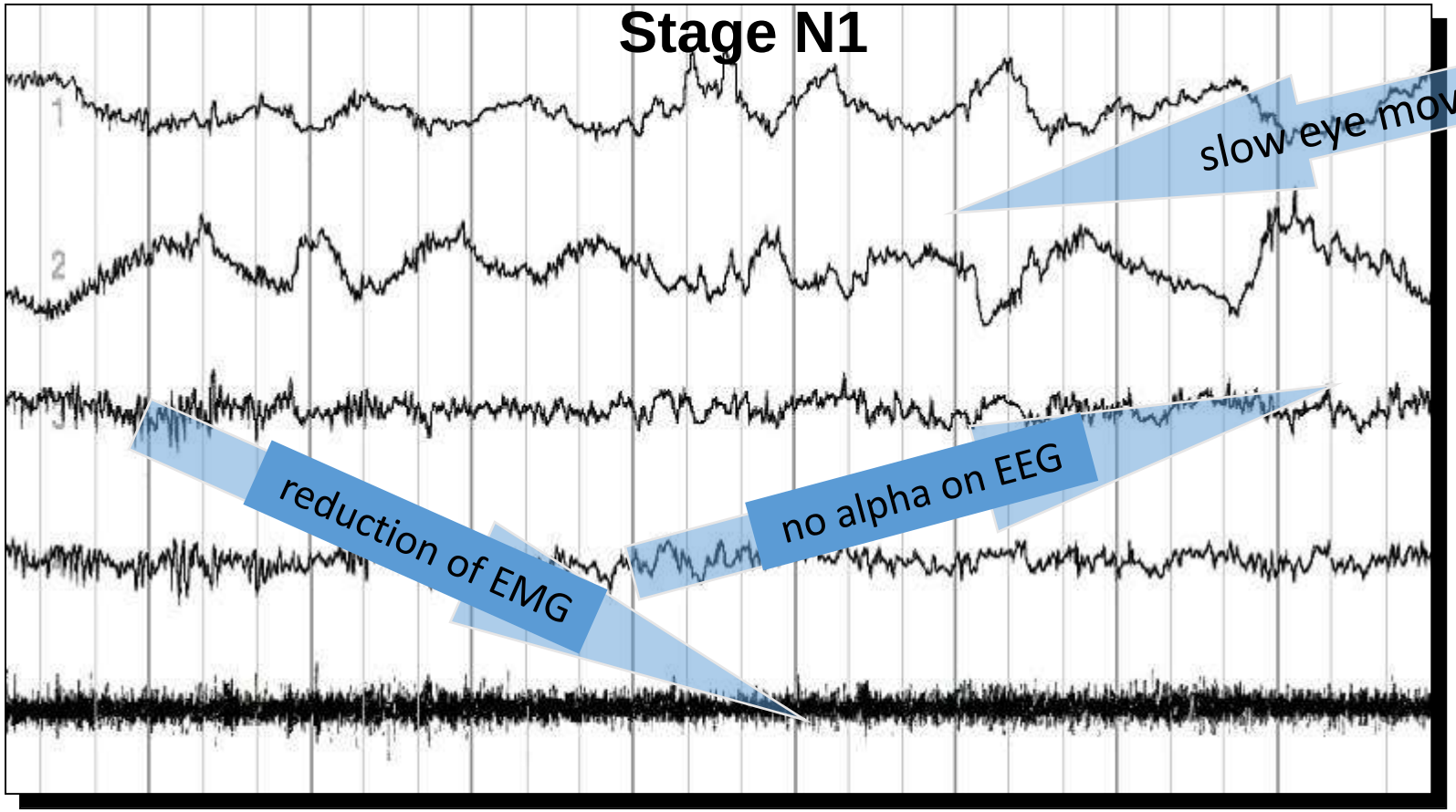
Theta Activity

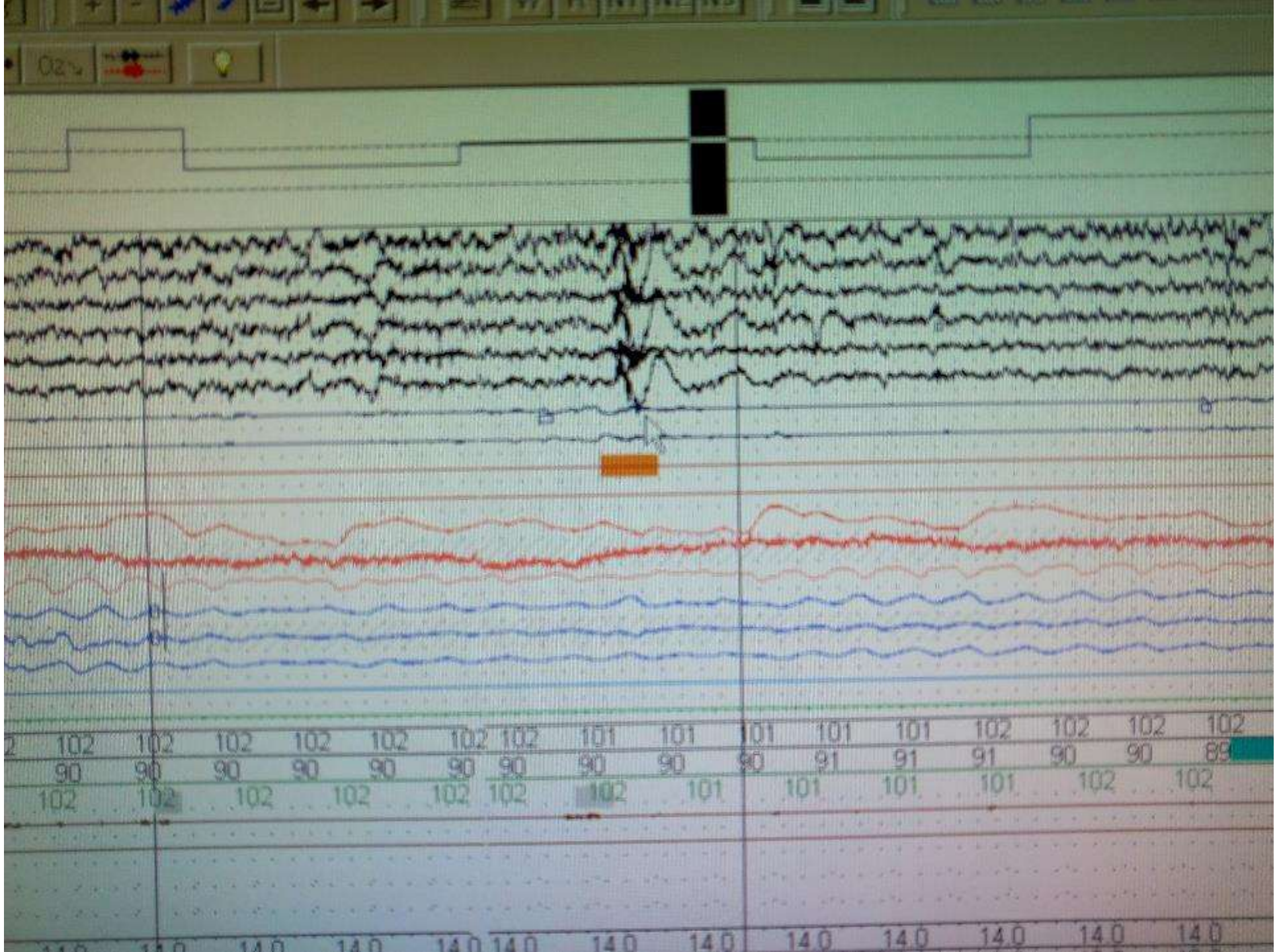
- A frequency of 4-7 Hz
- Produced in the central vertex region
- No amplitude criteria for Theta
- The most common sleep frequency

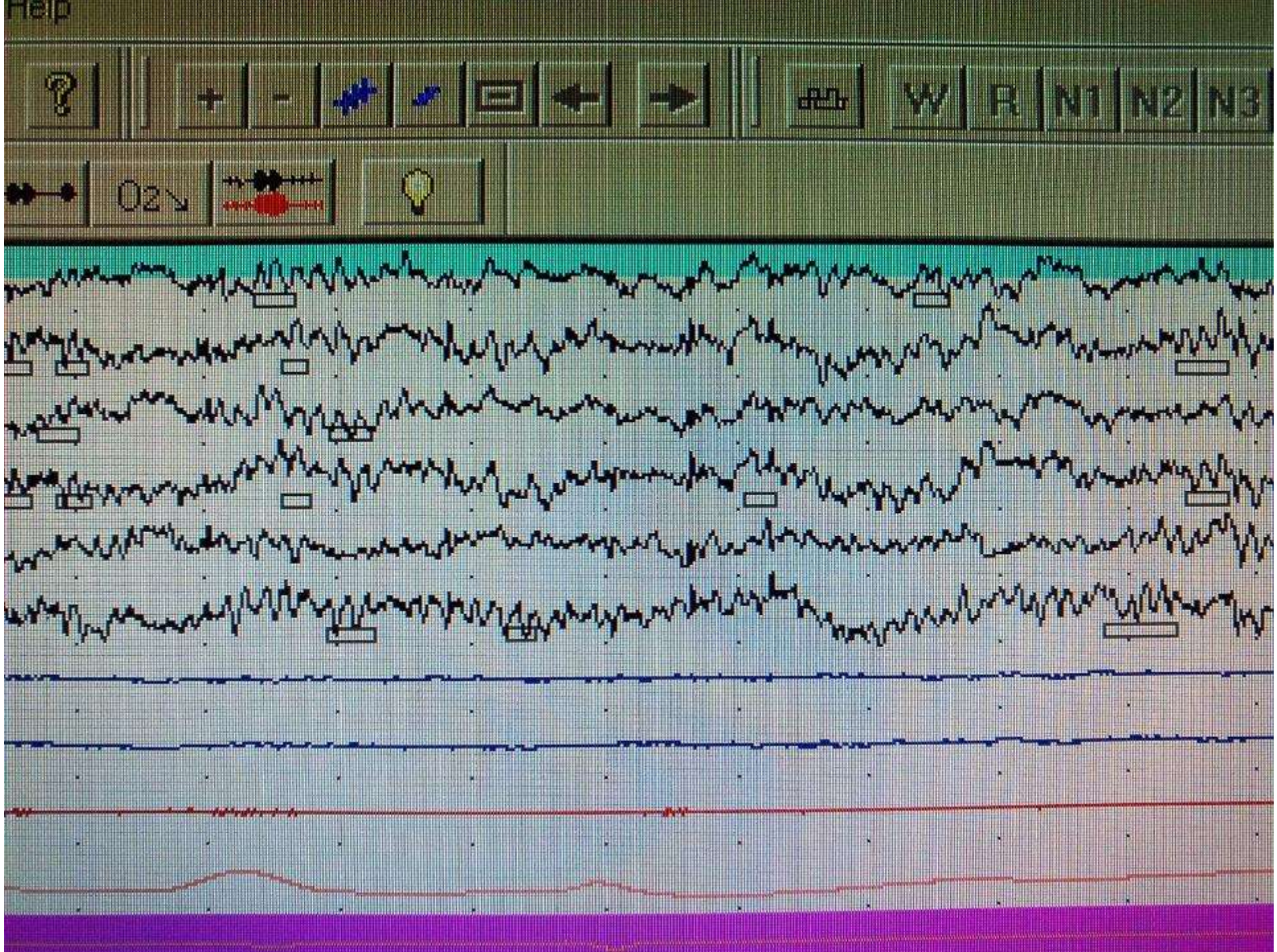


Stage N1



- ≥ 50% of the epoch contains Theta activity (3-7 cps.) There may be alpha activity within <50% of the epoch.
- Slow rolling eye movements in the EOG channels
- Relatively high submental EMG tone




Help
W
R
N1
N2
N3
O2↘

STAGE N2

- Score N2 (in absence of criteria for N3) if one or both occur in first half of epoch or last half of the previous epoch-
- One or more k complexes unassociated with arousal
- One or more trains of sleep spindles

Continue to score epochs with low amplitude mixed frequency EEG activity without K complexes or sleep spindles as N2 if they are preceded by K complex unassociated with arousal or sleep spindle

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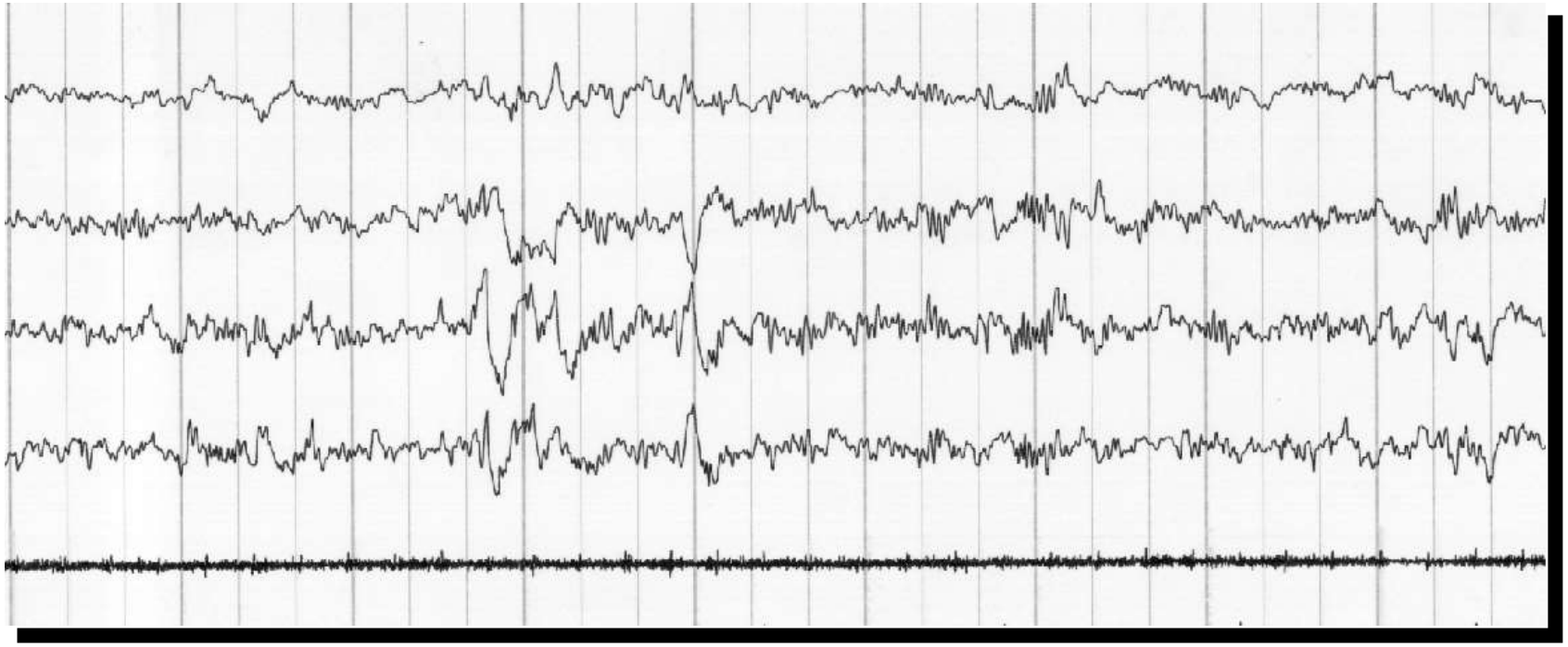
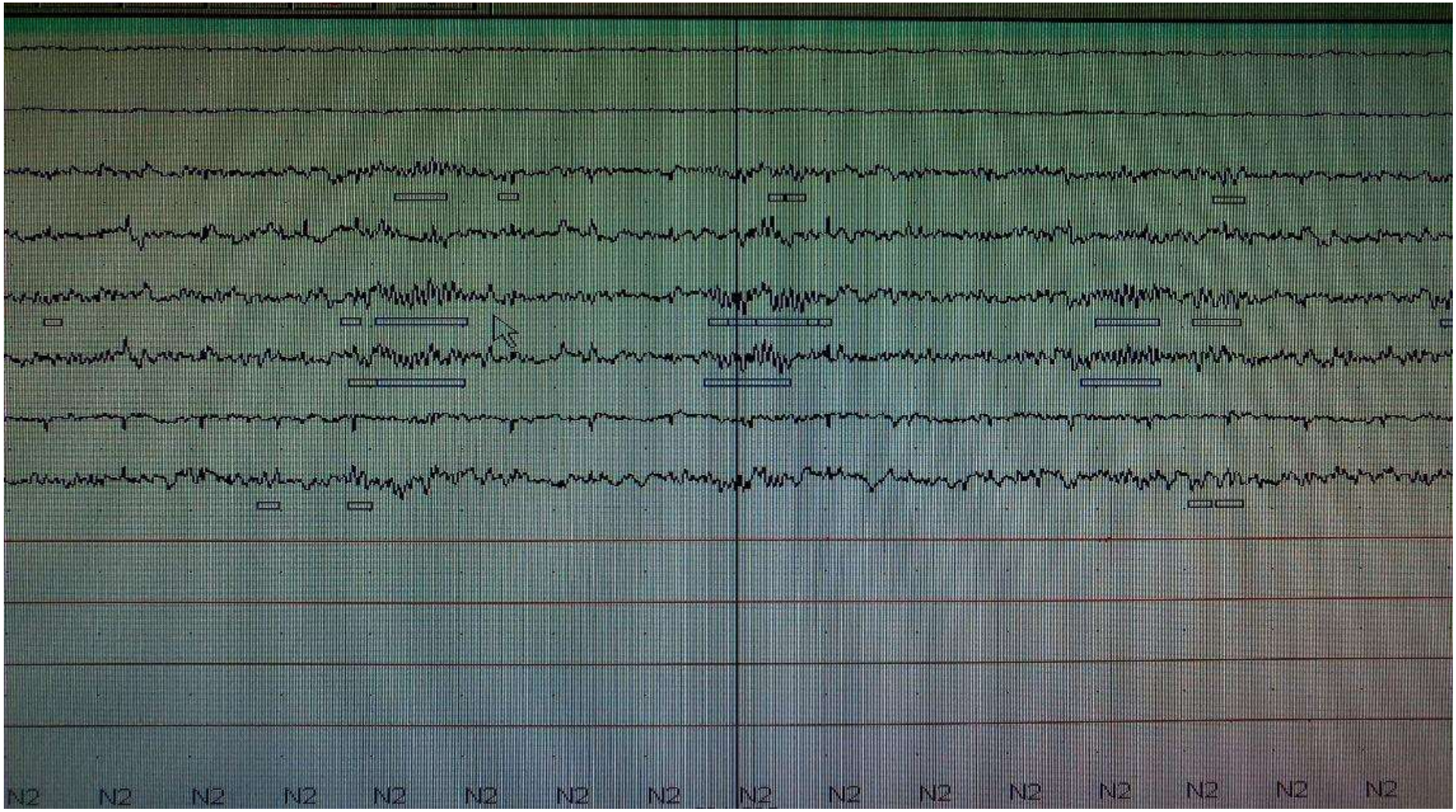
Stage Two Sleep



- Background EEG is Theta (3-7 cps.)
- K-Complexes and Spindles occur episodically
- Mirrored EEG in the EOG leads
- Low tonic submental EMG

K Complex: A well delineated negative sharp wave immediately followed by a positive component standing out from the background EEG, with total duration > or equal to 5 seconds, usually maximal in amplitude when recorded using frontal derivations

Sleep Spindle: A train of distinct waves with frequency 11-16 Hz with a duration of > and equal to 0.5 seconds usually maximal in amplitude using central derivations


N2 N2 N2 N2 N2 N2 N2 N2 N2 N2 N2 N2 N2 N2 N2 N2

End of N2 sleep when one of the following events occur-

- Transition to stage W or N3 or stage R

- Major body movement followed by slow eye movements and low amplitude mixed frequency EEG without nonarousal associated K complexes or sleep spindles

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- STAGE N3- When 20% or more of an epochs consists of slow wave activity irrespective of age.
- Sleep spindles may persist in stage N3 sleep.
- Eye movements are not typically seen in N3 sleep.
- In N3 stage the chin EMG is of variable amplitude often lower than in stage N2 sleep and sometimes as low as in stage R sleep.

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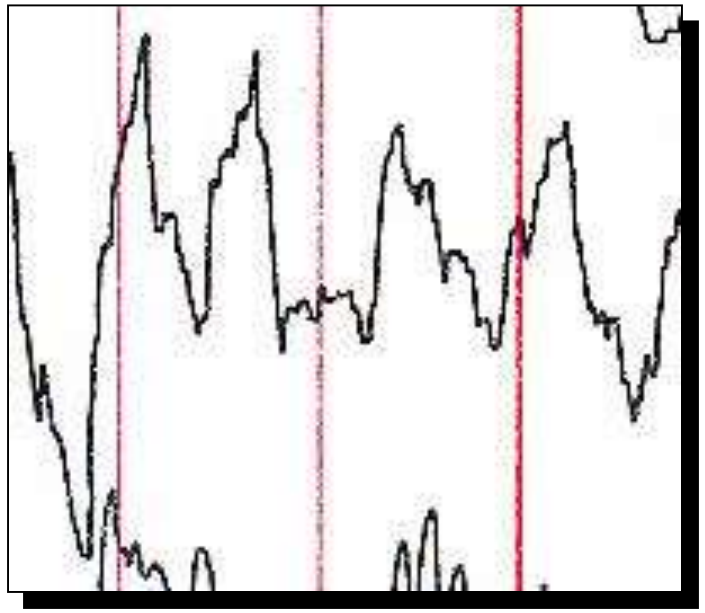
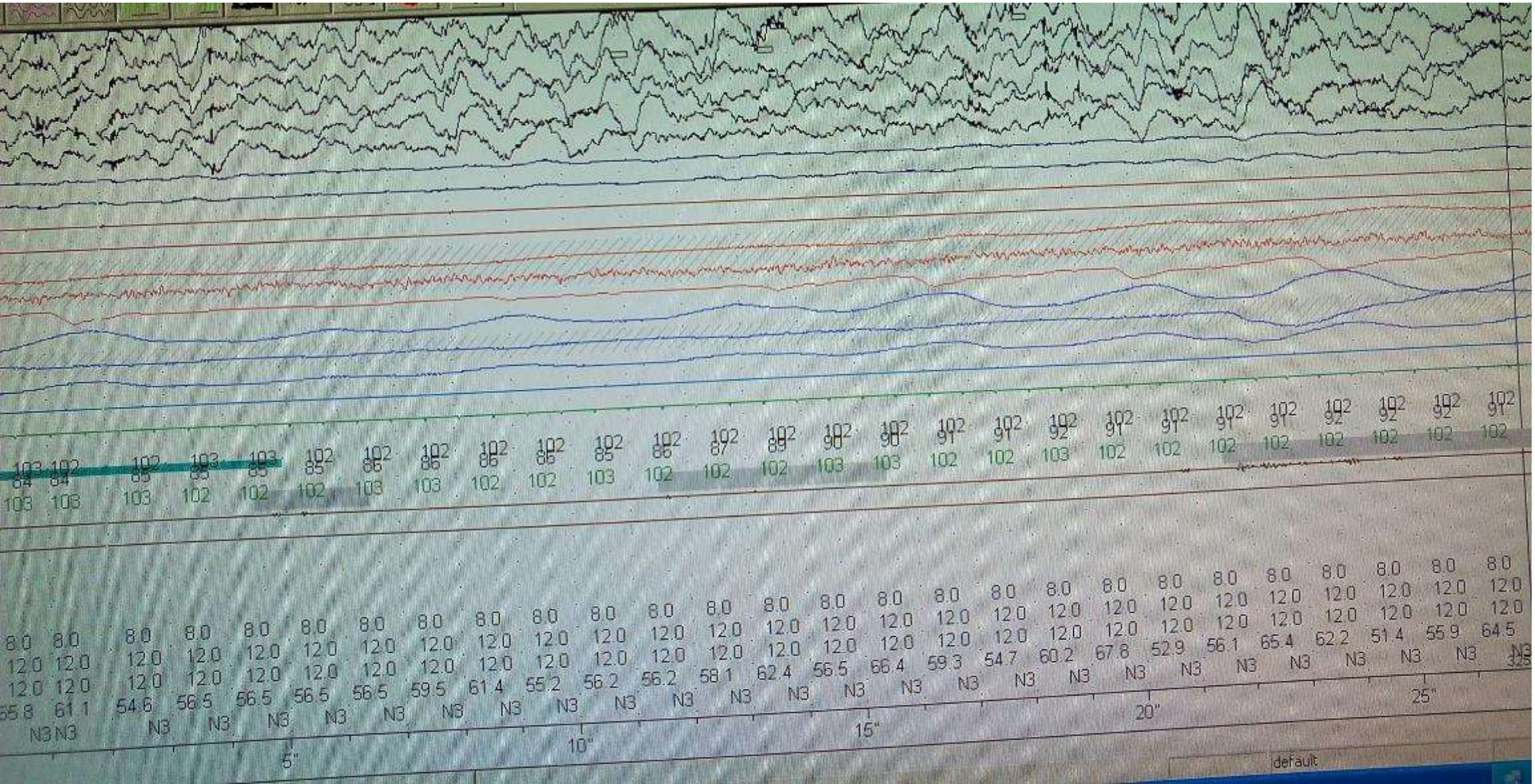
Delta Activity

- Sleep Delta Activity - frequency of .5-2 cps.
- Seen predominantly in the frontal region
- Delta Activity - amplitude of ≥ 75mn



Stage Three Sleep

- 20% to 50% Delta Activity is seen
- EOG leads will only pick up the EEG activity
- EMG may be slightly lower than that of Stage two


5"
10"
15"
20"
25"
default

STAGE R

- Low amplitude mixed frequency EEG
- Low chin EMG tone
- Rapid eye movements
- Saw tooth waves

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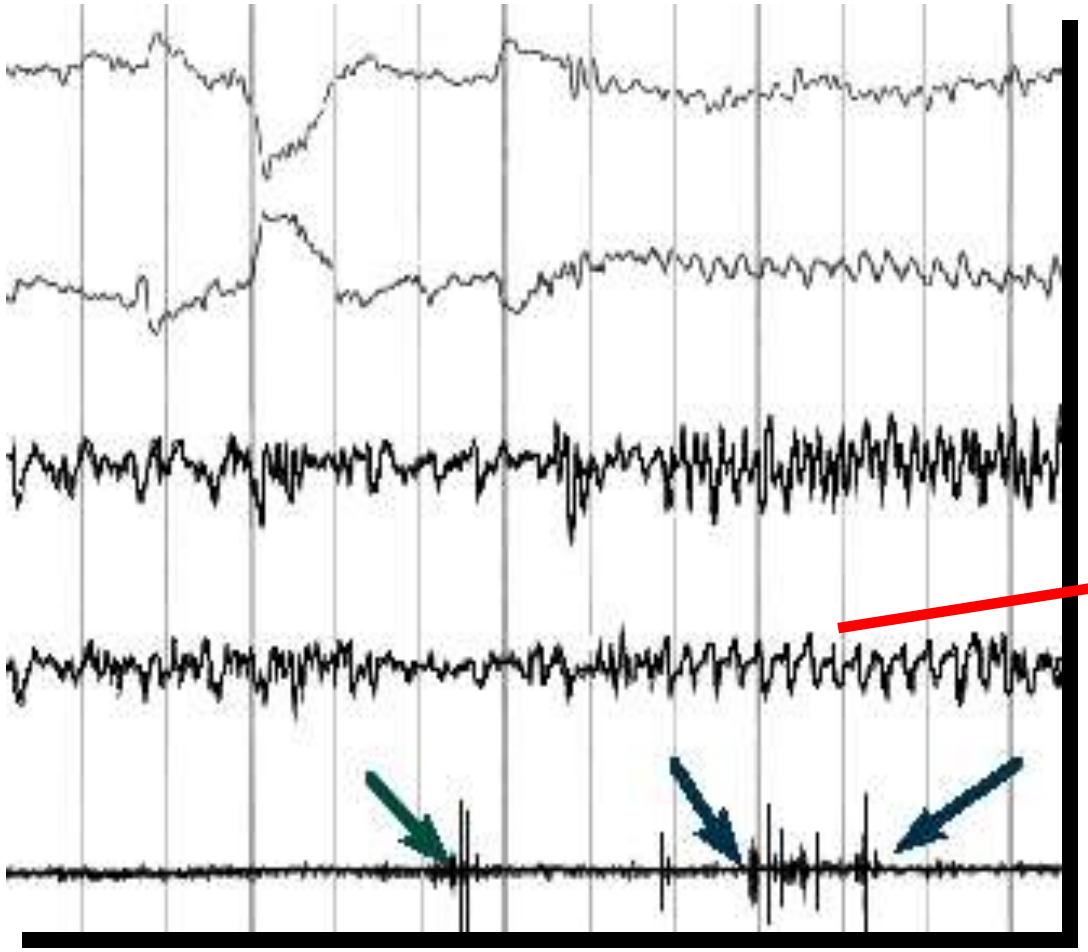
Stage R: phasic twitching



- Very short **muscle twiches** that normally occur in REM sleep
- **"Saw tooth" waves**: jagged & evenly formed EEG pattern seen usually in the vertex region

These arrows are pointing to phasic twitching

MAJOR BODY MOVEMENTS-

- Movement and muscle artifact obscuring EEG for>half of epoch to the extent that sleep stage can not be determined

Score an epoch with major body movement as follows-

- If alpha rhythm is present for part of epoch score as stage W.
- Otherwise score the epoch as the same stage as the epoch follows it.

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PULSE TRANSIT TIME

- Pulse transit time (PTT) is the time taken for the arterial pulse pressure wave to travel from the aortic valve to a peripheral site. For convenience, it is usually measured from the R wave on the electrocardiogram to the pulse wave arrival at the finger.
- Pulse transit time is inversely proportional to blood pressure, and the falls in blood pressure which occur with inspiration (pulsus paradoxus) correspond to rises (lengthening) in pulse transit time.

- Pulse transit time may, therefore, provide a clinically useful noninvasive and quantitative measure of inspiratory effort in patients with sleep-related breathing disorders.

Eur Respir J., 1995, 8, 1669–1674