

# Data Acquisition systems

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Robertson Chapter 7



# Digitization and Manipulation of Data

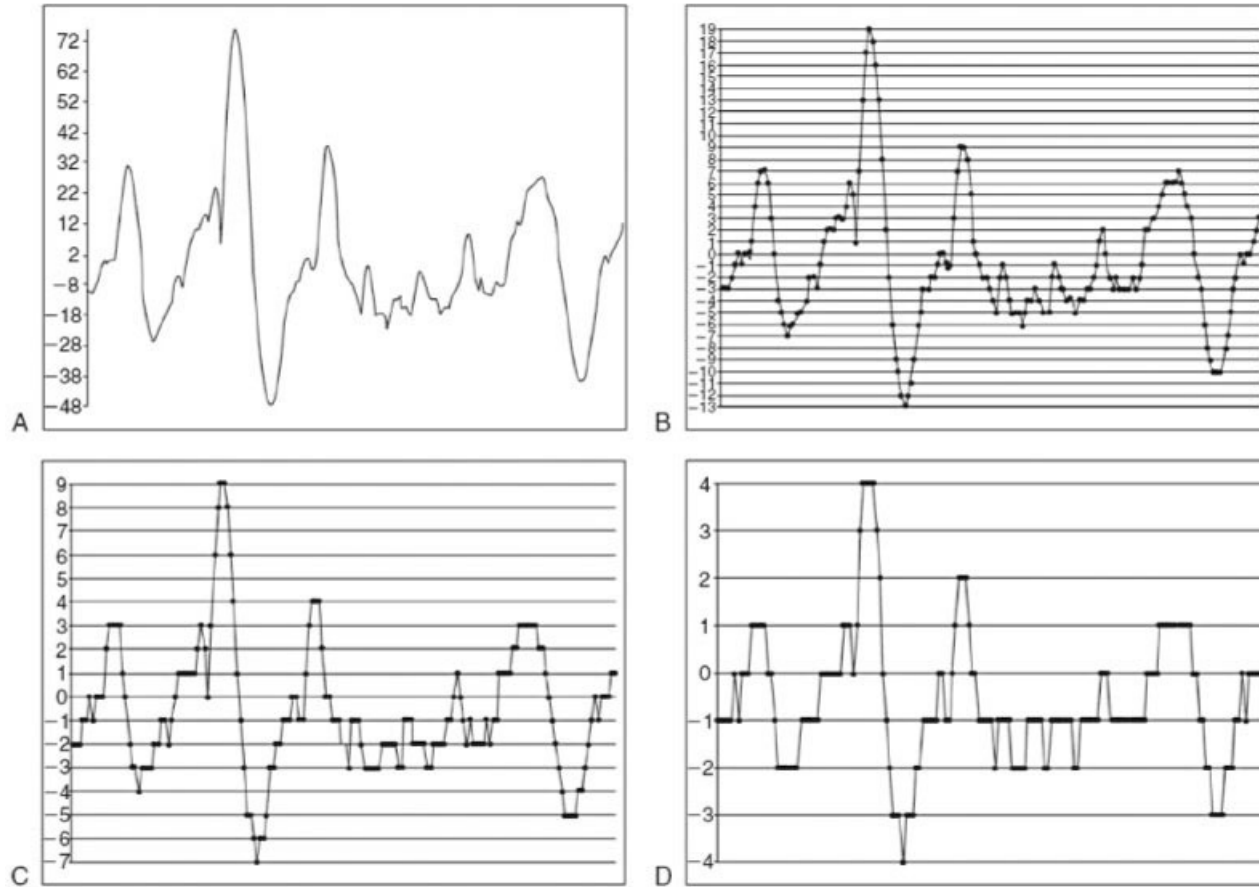
- Physiologic signals travel through electrodes and other devices to a common connection point (jack box)
- A-to-D converter converts analog signals to digital
- Montage lists type, order, and recorder settings for each channel of data
- Signal travels from body to amplifier through electrodes
- Data enters PC through a port (USB or proprietary board in PC)
  - Initially cached into RAM (random access memory)
- Annotations merged with signal data
- Caching stores small segments of data to the hard drive

# Data Storage

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- Storage compression controlled in montage
  - Expressed as Hz or samples per second
- Nyquist principle = Any single waveform must be stored with a minimum of 2 points
  - Sampling rate must be 2x the frequency of fastest signal of interest to minimize distortion
- AASM minimum storage rate recommendation = 3:1 ratio
- Aliasing = Distortion of original signal

# Signal Aliasing

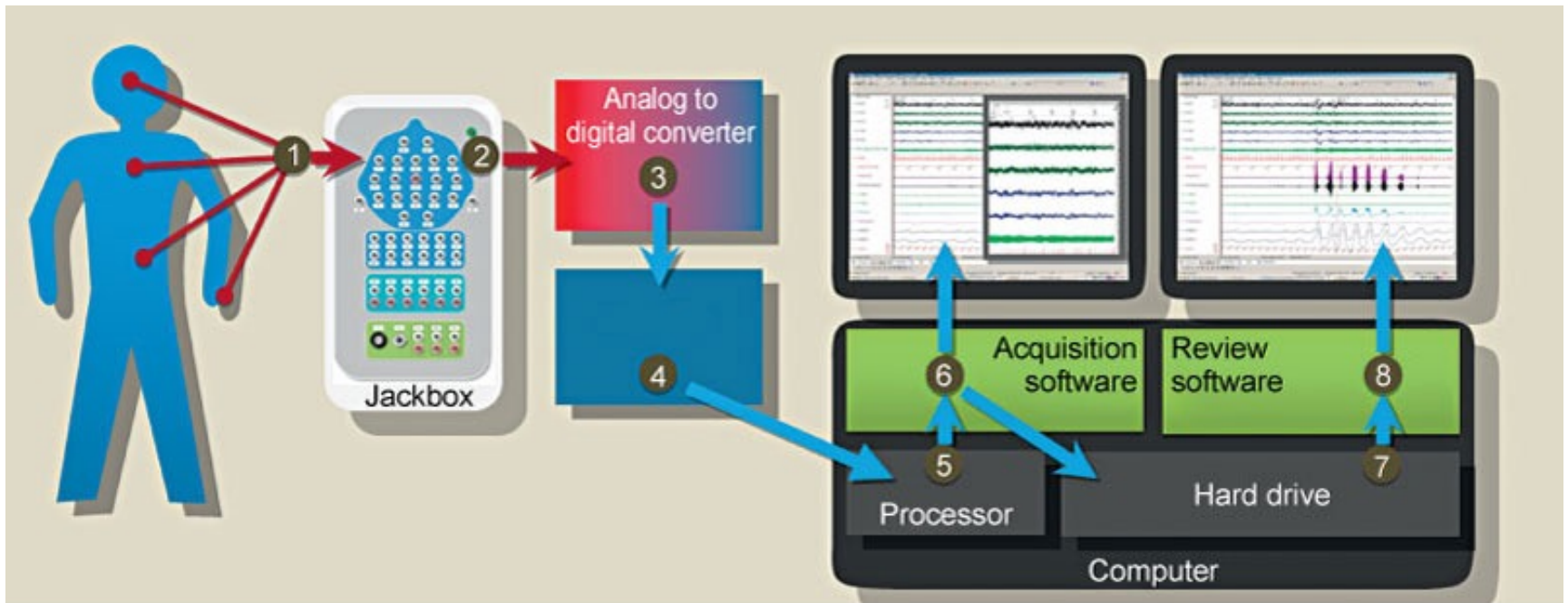


From Fisch BJ: Fisch and Spehlmann's EEG Primer, 3rd Edition Basic Principles of Digital and Analog EEG. Philadelphia, 2000, Elsevier.

# System Components

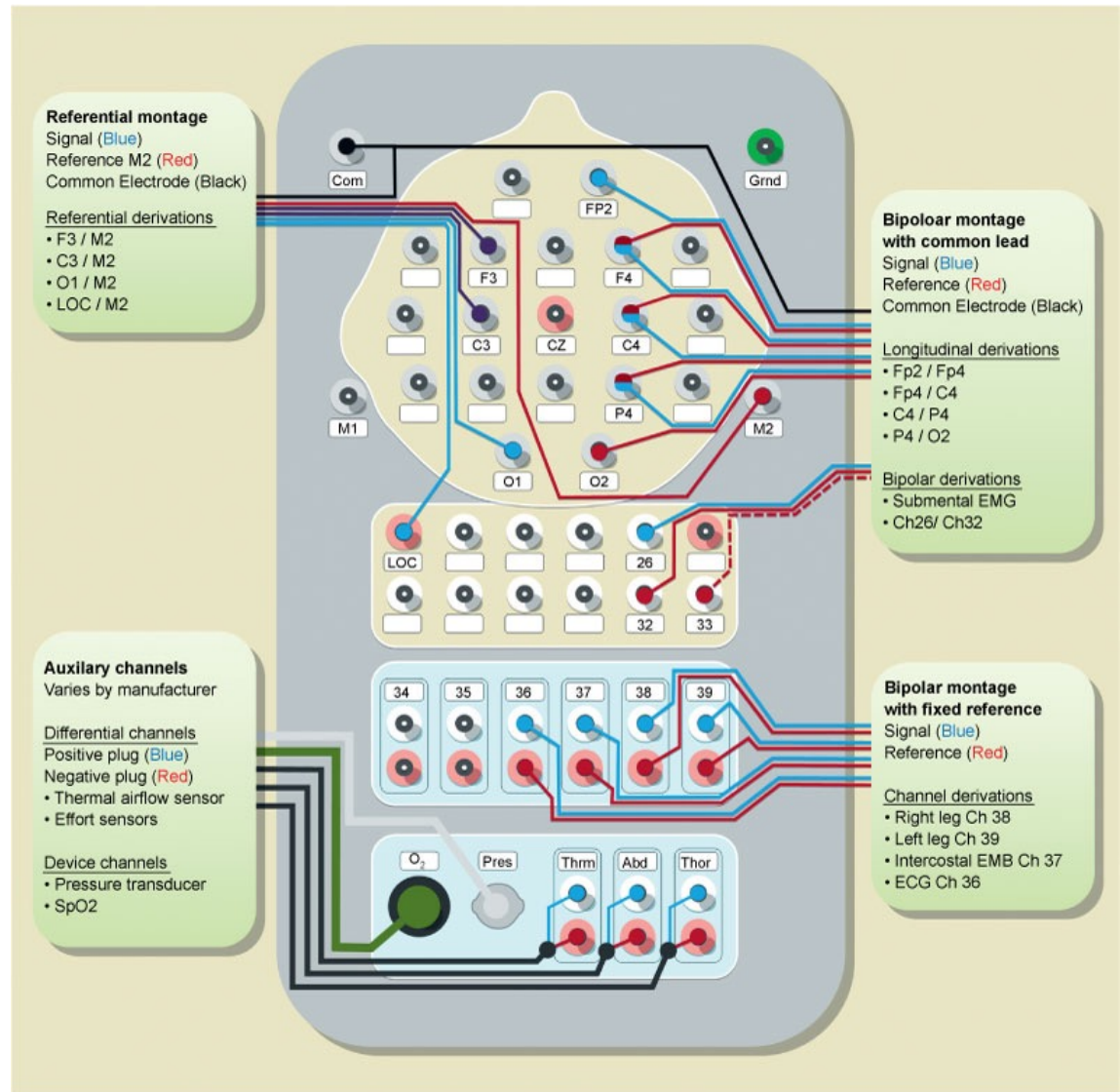
- 3 primary functions of software:
  - Data acquisition
  - Data storage
  - Data review
- Hardware components
  - Jack box (head box) shows how the system hardware is configured and provides glimpse into montage controls for referential bipolar and differential derivations
    - Inputs designed for repeated use

# Data Pathway for Digital PSG



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# Jack Box (Head Box)





# Montages

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- Montage = Use of several different processes of combining signals into derivations
- Multiplexing = Any process of combining 2 or more signals into single channel
- Can have multiple montage templates:
  - Diagnostic PSG
  - Split-night PSG
  - Treatment PSG / PAP titration
  - MSLT
  - Double study / seizure



A close-up, circular inset image on the left side of the slide. It shows a portion of a film reel with a white plastic hub and a black film strip. The film strip is partially unspooled, showing its characteristic sprocket holes and a dark, textured surface. The lighting is soft, highlighting the textures of the plastic and film.

# Static and Dynamic Recording Methods

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- Static Recording = Channel modifications made during acquisition are permanently written to the disk
- Dynamic Recording = Data are stored with settings that allow for broad array of modifications during review
  - Most labs prefer this but still like to see what the recording tech actually saw

# Filtering and Derivations

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- Filtering: Typical amplifier for EEG and EMG has HFF cut-off of approx. 150 Hz and LFF cut-off of 0.1 Hz
- Derivations = Description of signal inputs that are combined to create a physiologic signal on a PSG
  - Example: C4 = C4-M1
  - Input 1 = Exploring electrode
  - Input 2 = Reference electrode
- System referencing = When derivations are created electronically within jack box or amplifier

# Derivations

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- 2 primary classifications:
  - Referential
    - Input 1 over an electrically active recording area
    - Input 2 over a relatively inactive site
    - Uses G1-G2 convention
  - Bipolar
    - Both G1 and G2 over an electrically active recording area
    - G1-G2 convention is basis of common mode rejection
    - Can't re-reference once written to hard drive
      - Can only re-reference during live data collection
    - Usually used for EMG and ECG or during seizure studies

# Referential and Differential Recording

- Referential recording = Method of data collection in which several signals share a common reference
  - Electrodes on left side of head referenced to M2
  - Electrodes on right side of head referenced to M1
- Differential recording = Process of collecting data from devices such as effort belts and thermal airflow sensors that attach to jack box with separate positive and negative connectors

# Montage Collection and Review

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- Generally controlled from within the montage:
  - Channel assignment = Order of inputs
  - Channel label = Abbreviations for channel name
  - Signal input and reference
    - Bipolar
    - Referential
  - Sensitivity
  - Gain
  - Polarity
  - 50/60-Hz notch filter
  - Storage rate

# Visual Display

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- Display position
  - Group families of channels together (EEG, EOG, respiratory)
  - Can order the channel groups to user liking
  - Hotkeys can help users determine which channels are seen
- Display color
  - Individual preference
- Visual filters allows recording tech to impose a filter setting on channel during acquisition without affecting data recorded on hard drive
- Automated sleep staging and event scoring is common but controversial

# Visual Display

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- Window configuration
  - Look-back window allows tech to review data recorded earlier in session
    - Allows tech to score and stage during data acquisition
  - Histogram = Summary of signals and data displayed in a compressed fashion along a common time axis
  - Tabular data = Numeric data saved for each epoch
    - Common tabular entries = Epoch number, sleep stage, SpO2, tech notes
  - Respiratory window allows tech to view respiratory events with a compressed time base
  - Full display allows user to display each PSG data in its own window



# AASM Recommendations for Recognition of Sleep-Wake Stages and Events

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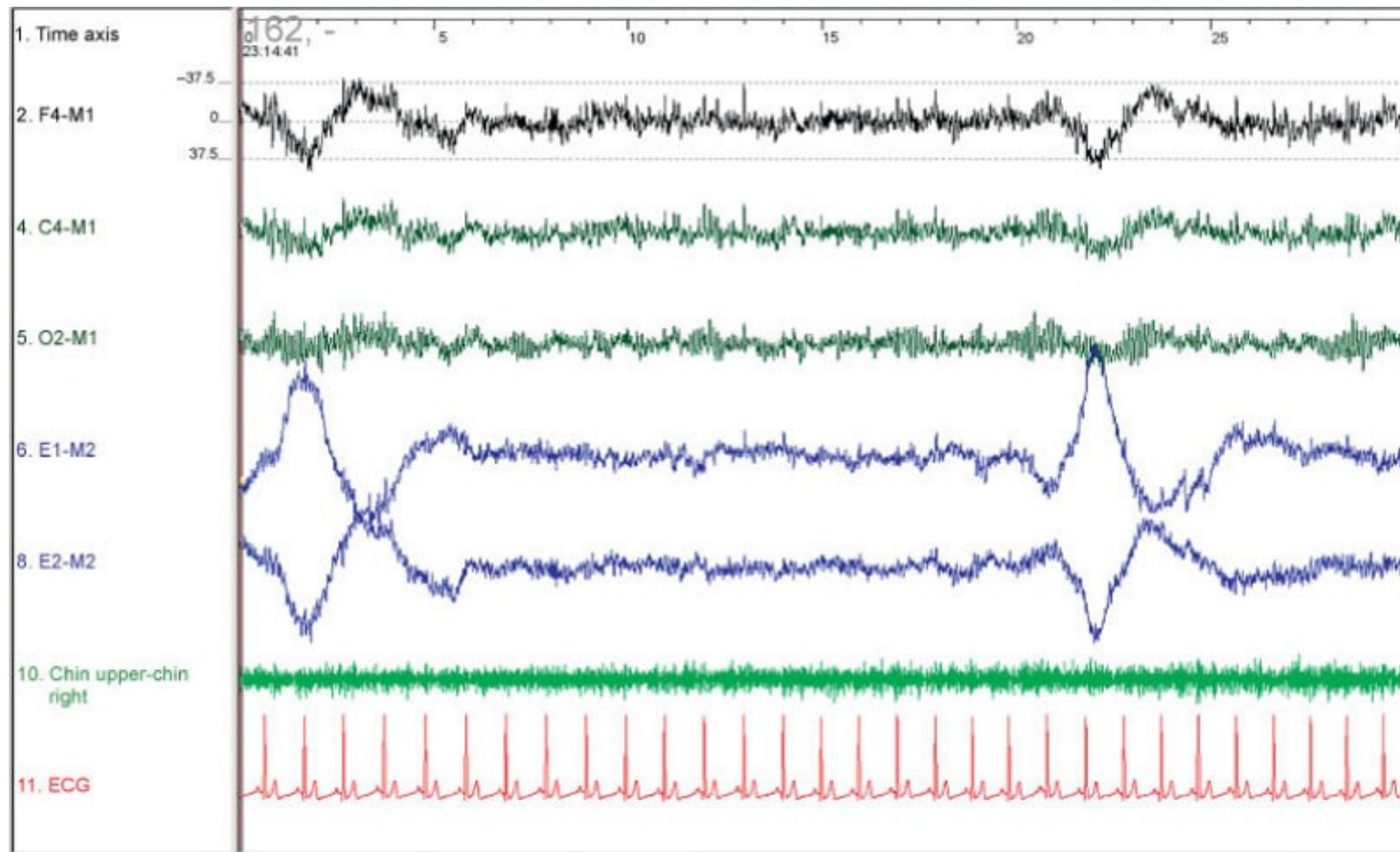
- 2012: AASM updated scoring standards for sleep staging, arousals, movements, and respiratory events
  - AASM Manual for the Scoring of Sleep and Associated Events
- Respiratory Events
  - Measurement Technologies:
    - Oronasal thermal sensor: Detects apneas
    - Nasal pressure transducer: Detects hypopneas and RERAs
    - Esophageal manometry or RIP belts: Detect respiratory effort

# Staging Examples

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- Stage W (Wake)
  - Alpha rhythm = 8-13 Hz
  - Eye blinks = Conjugate, 0.5-2 Hz
  - Reading eye movements
  - REMs = Conjugate, irregular, sharply peaked; initial deflection < 500 msec
  - SEMs = Conjugate, reasonably regular, sinusoidal; initial deflection > 500 msec
  - Score when > 50% of epoch has alpha over occipitals
  - Without alpha: Score if any of following present:
    - Eye blinks at frequency of 0.5-2 Hz
    - Reading eye movements
    - Irregular, conjugate REMs associated with normal or high chin tone

# Stage W

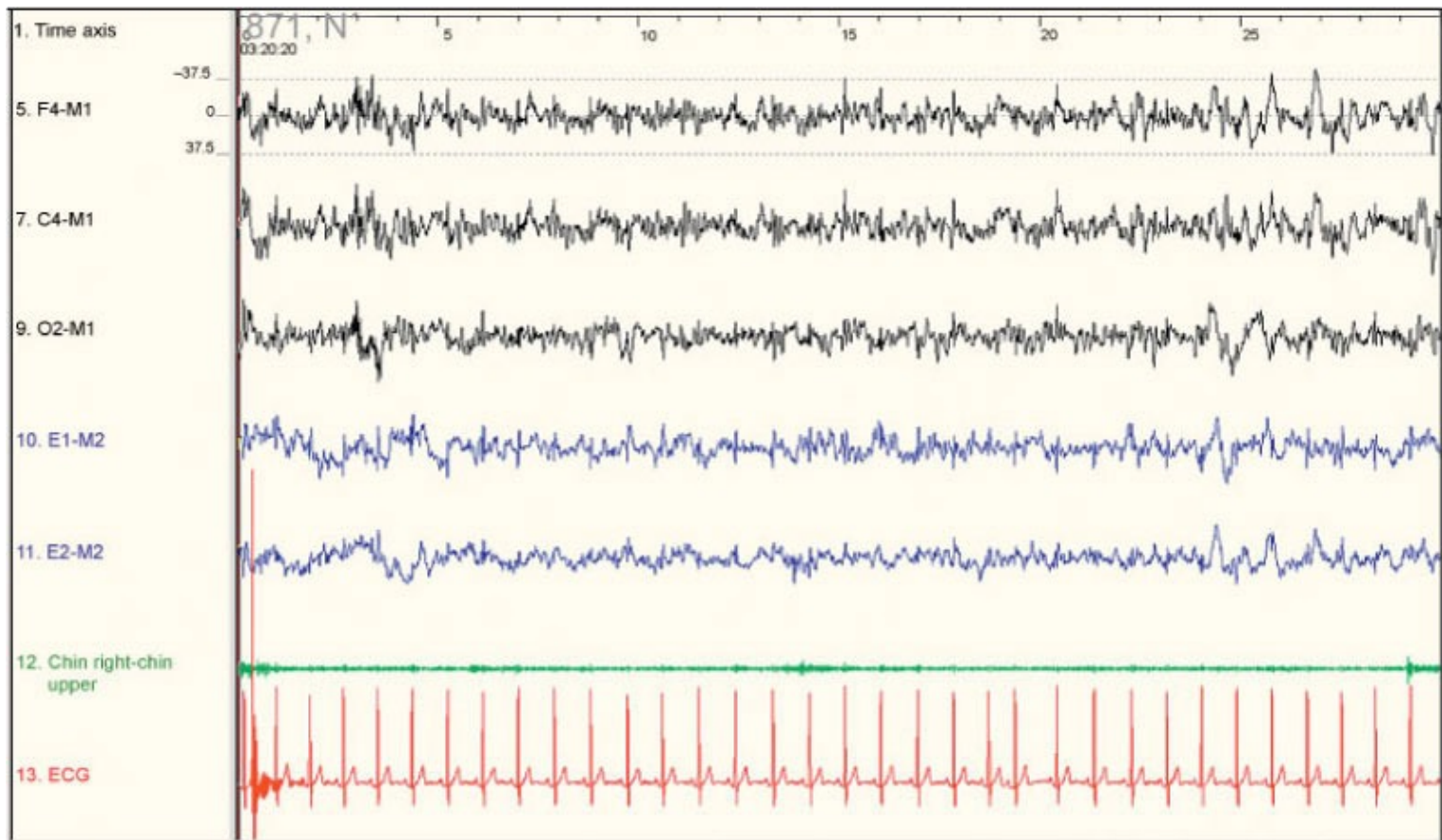


# Staging Examples

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- Stage N1
  - SEMs = Conjugate, reasonably regular, sinusoidal; initial deflection > 500 msec
  - LAMF = 4-7 Hz
  - Vertex sharp waves (V waves) = Sharply contoured with <0.5 second duration maximal over central region
  - Sleep onset = 1<sup>st</sup> epoch scored as any stage other than W
  - If LAMF = > 50% of epoch, score as N1
  - Without alpha, score if any of the following present:
    - EEG in 4-7 Hz range with slowing of background frequencies by  $\geq 1$  Hz from Wake
    - V waves
    - SEMs

# Stage N1

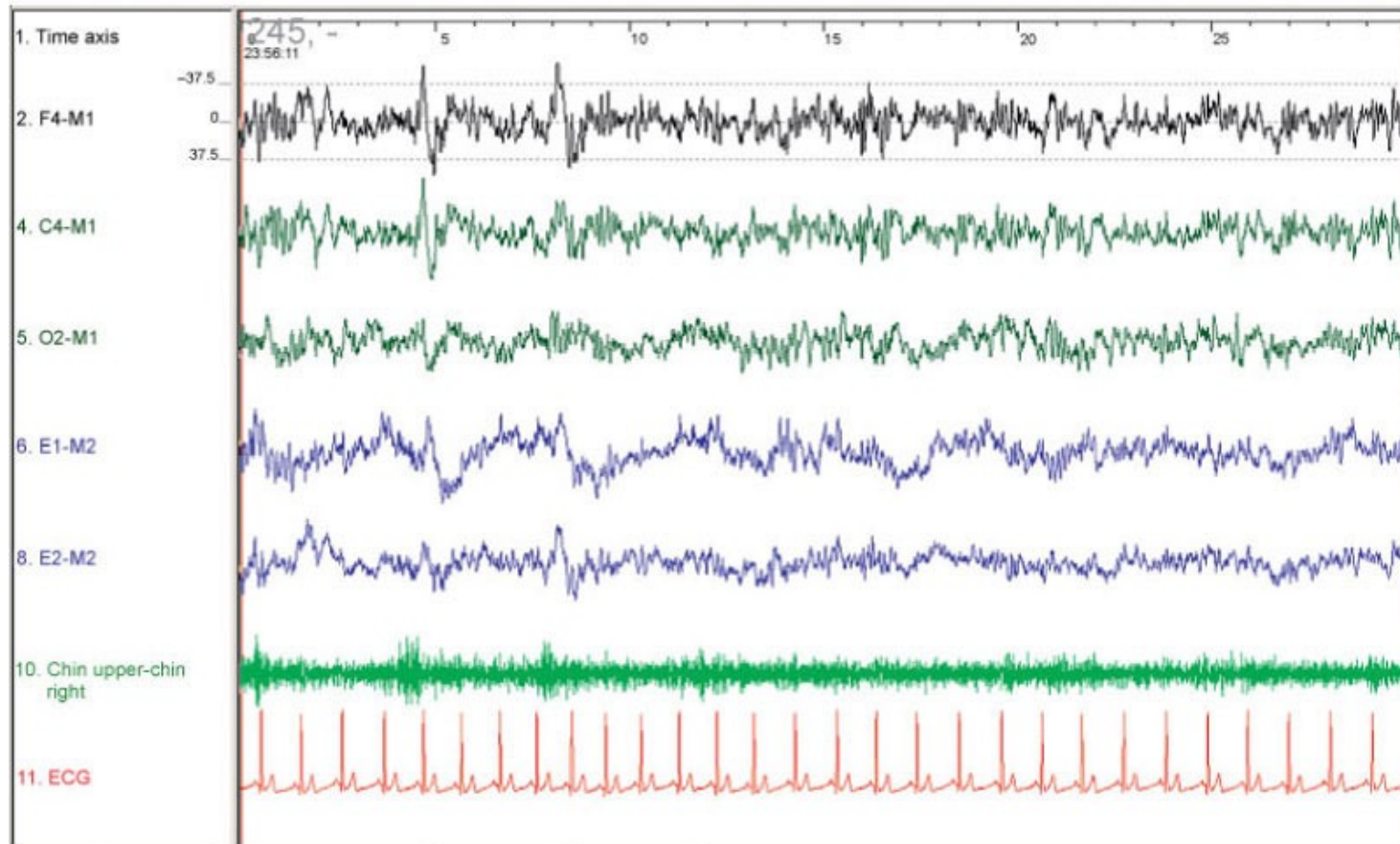


# Staging Examples

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- Stage N2
  - K complex = Negative, sharp wave followed by positive component; duration = 0.5 second; maximal in frontal region
  - Sleep spindle = 11-16 Hz; duration =  $\geq 0.5$  second; maximal in central region
  - Score if either or both occur in 1<sup>st</sup> half of epoch or last half of previous epoch:
    - 1 or more K complexes unassociated with arousals
    - 1 or more trains of spindles
  - End N2 when 1 of the following occurs:
    - Transition to Wake, N3, or REM
    - Arousal
    - Major body movement followed by SEMs and LAMF

# Stage N2

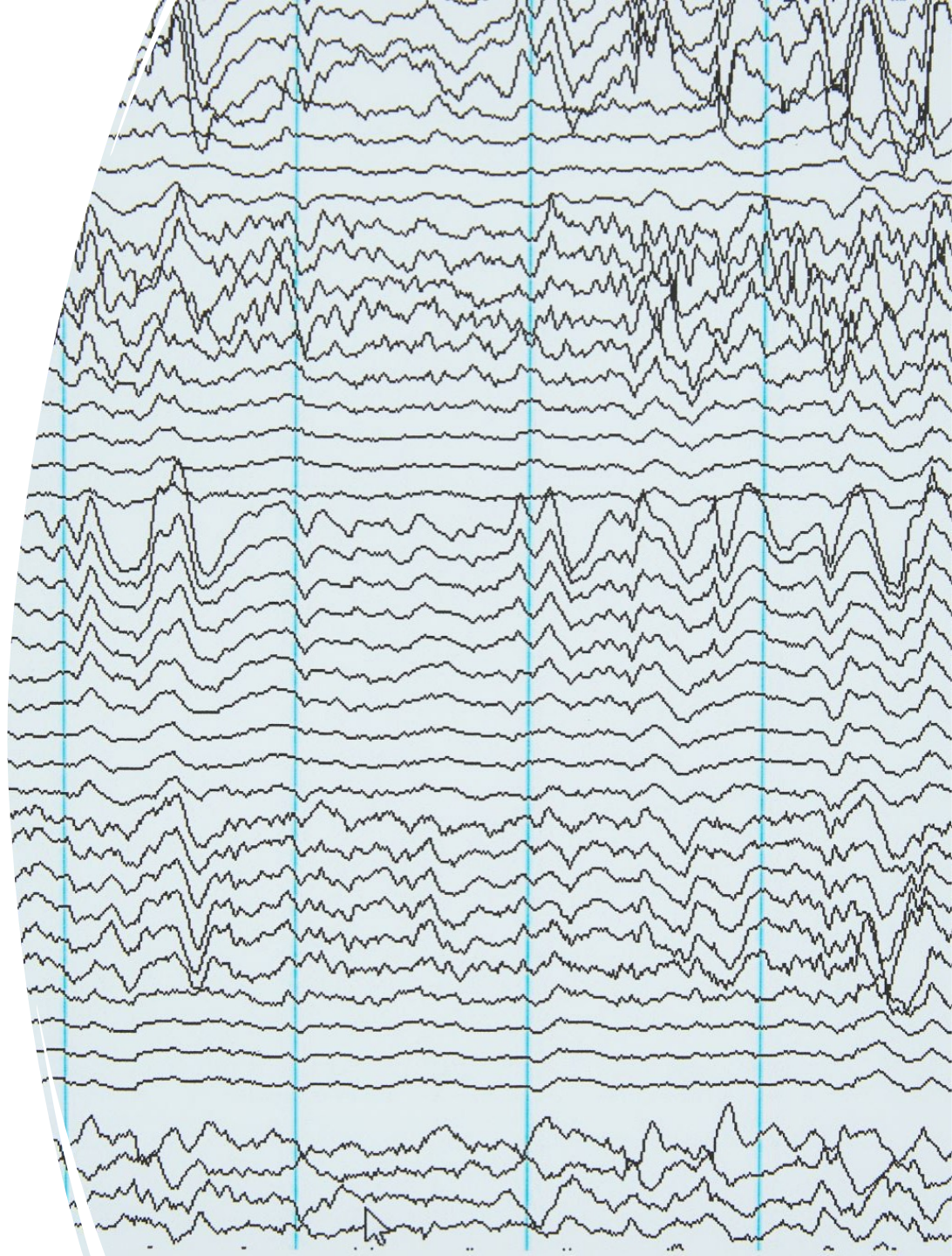




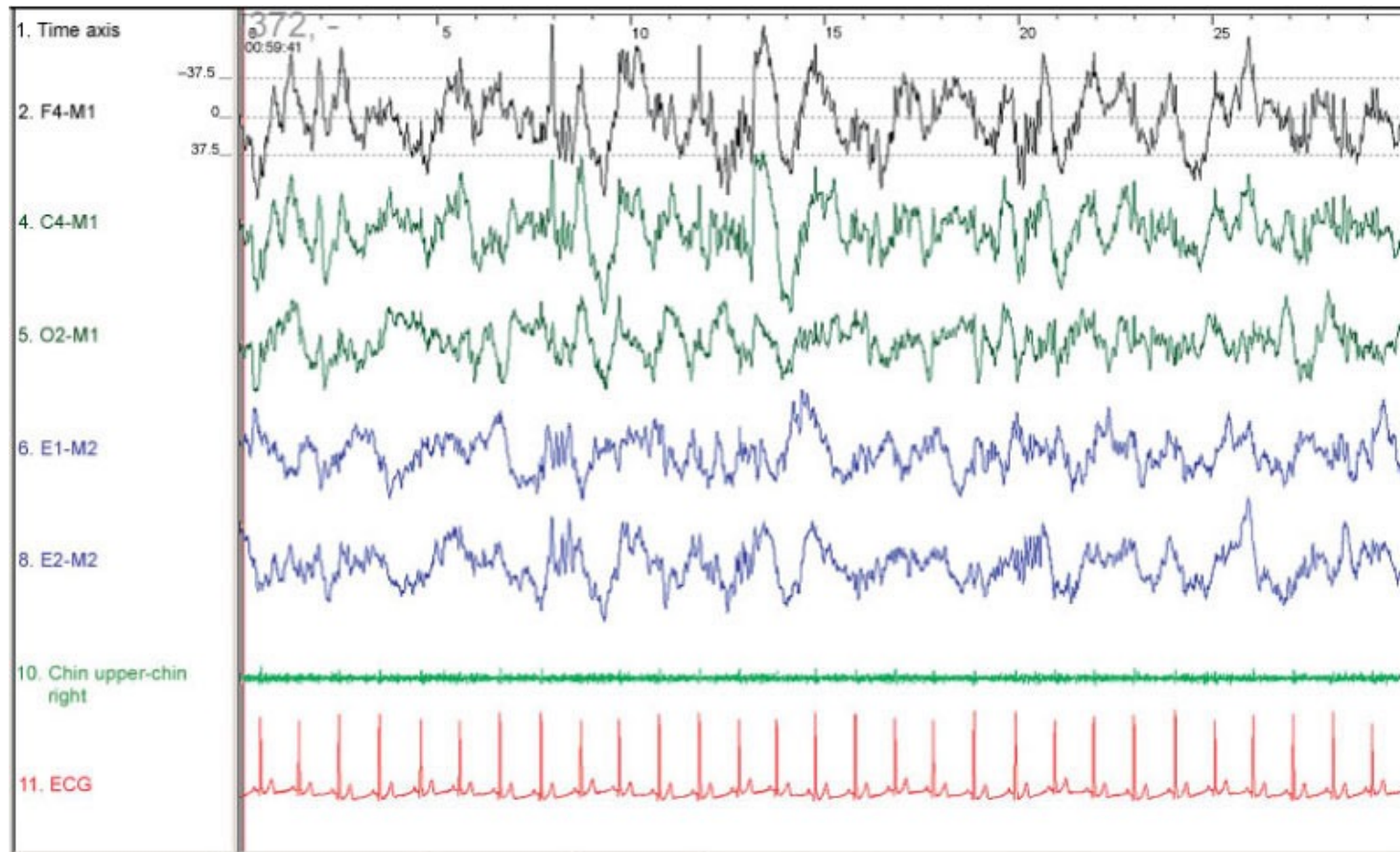
# Staging Examples

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- Stage N3
  - Slow waves (Delta waves) = 0.5-2 Hz; peak-to-peak amplitude > 75  $\mu$ V; maximal over frontal region
  - Score when  $\geq 20\%$  of epoch consists of slow waves



# Stage N3



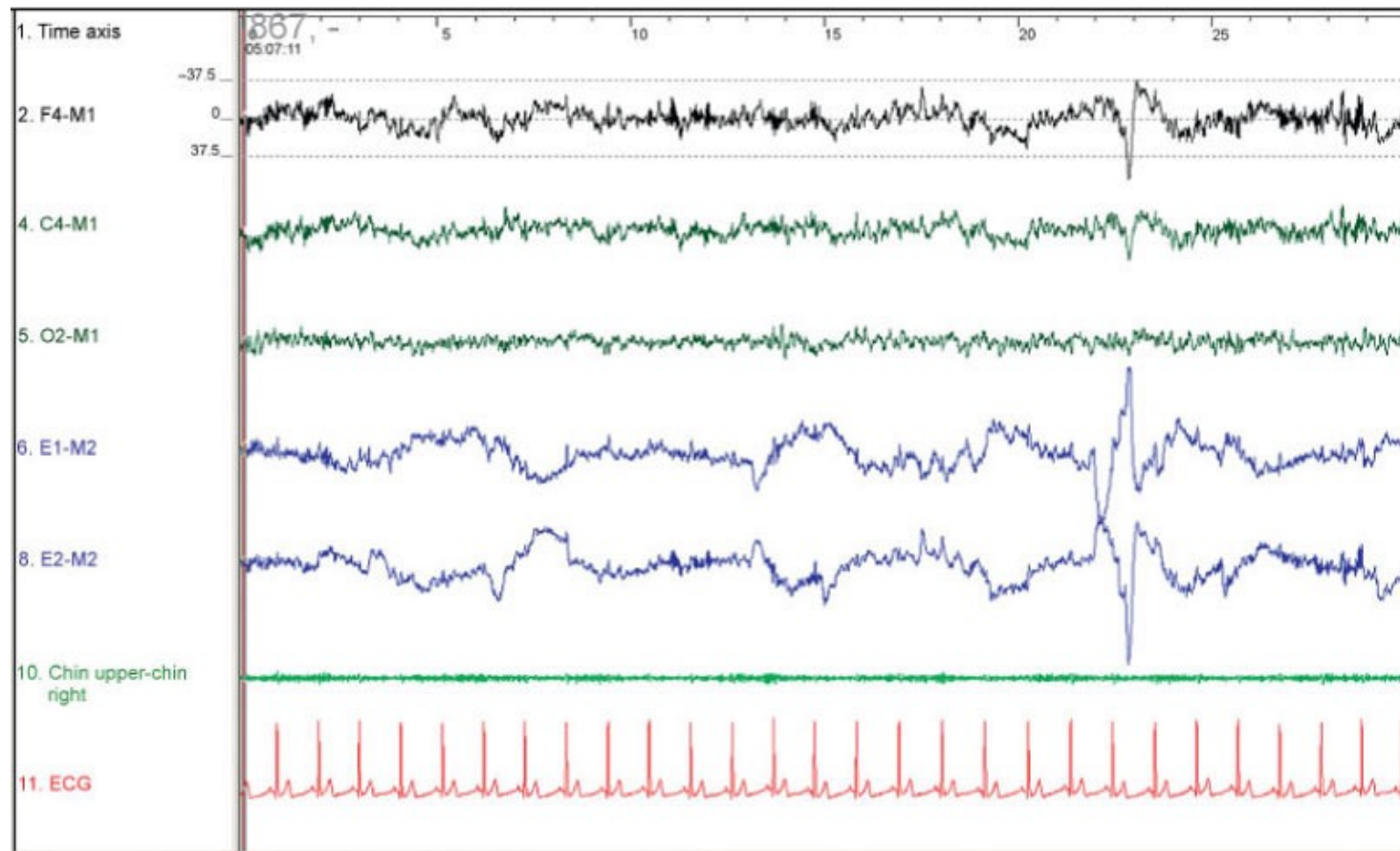
# Staging Examples

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- Stage R (REM)
  - REMs = Conjugate, irregular, sharply peaked; initial deflection < 500 msec
  - Low chin EMG tone
  - Sawtooth waves = Sharply contoured or triangular, often serrated, 2-6 Hz waves; maximal in central region
  - Transient muscle activity = Short irregular bursts of EMG activity usually with duration < 0.25 second superimposed on low EMG tone
  - Score if all are present:
    - LAMF EEG
    - Low chin EMG tone
    - REMs
  - Continue to score without REMs if LAMF EEG without K complexes or spindles and chin EMG remains low



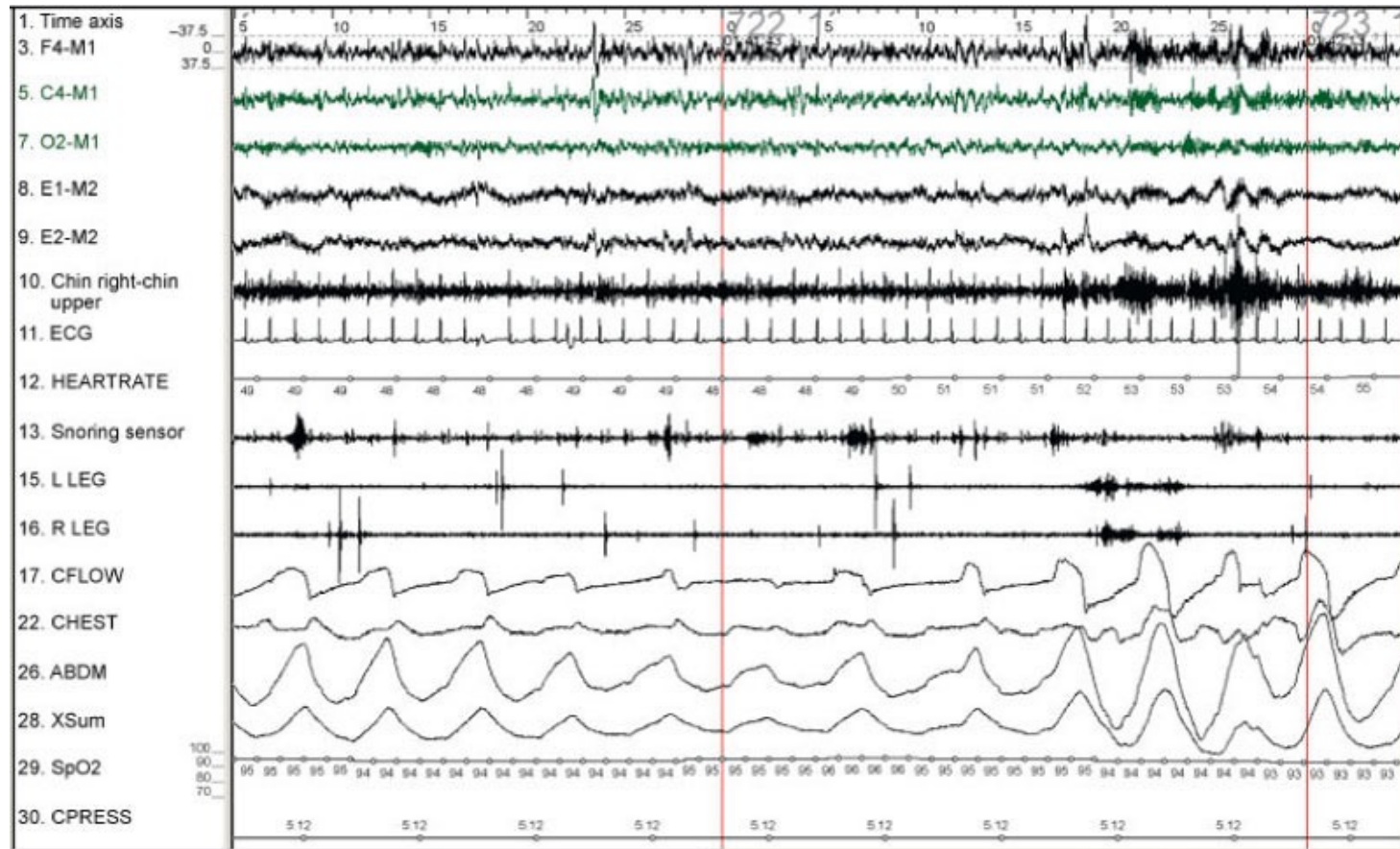
# Stage R (REM)



# Respiratory Examples

- RERA = Arousal from sleep caused by increased work of breathing from a partial obstruction of upper airway
  - Score if there is sequence of breaths lasting  $\geq 10$  seconds characterized by increasing respiratory effort or flattening of inspiratory portion of nasal pressure or PAP device flow that leads to arousal from sleep but doesn't meet criteria for hypopnea or apnea

# RERA



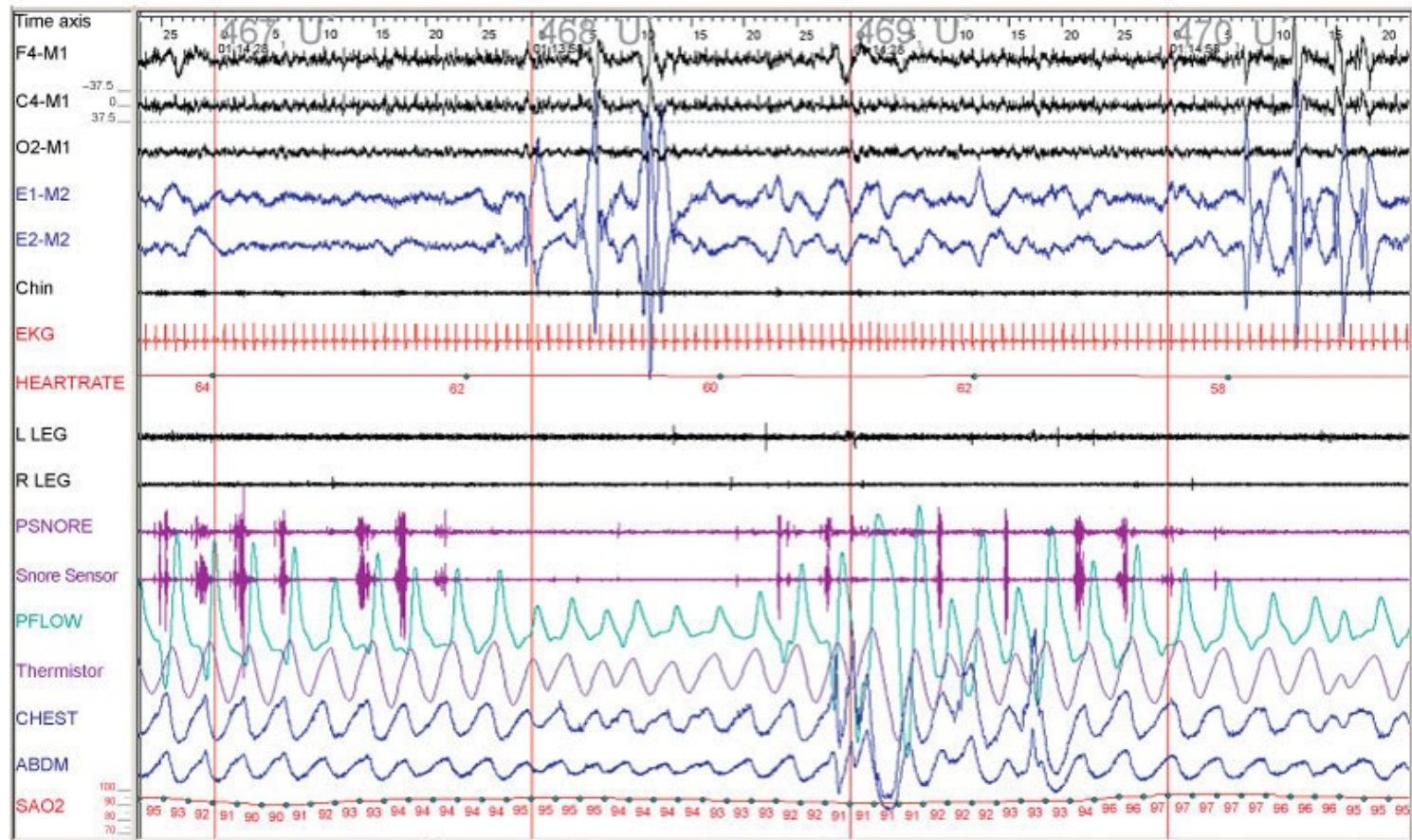
# Respiratory Examples

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- Hypopnea
  - Score if all present:
    - Signal drops  $\geq 30\%$  of pre-event baseline using nasal pressure, PAP device flow, or alternative hypopnea sensor
    - Duration of  $\geq 30\%$  drop is  $\geq 10$  seconds
    - $\geq 3\%$  O<sub>2</sub> desaturation from pre-event baseline
  - Score as obstructive hypopnea if above are met and any of the following are present:
    - Snoring during event
    - Increased inspiratory flattening of nasal pressure or PAP device flow signal
    - Thoracoabdominal paradox during event but not in pre-event breathing
  - Score as central hypopnea if none of the obstructive characteristics are present



# Hypopnea

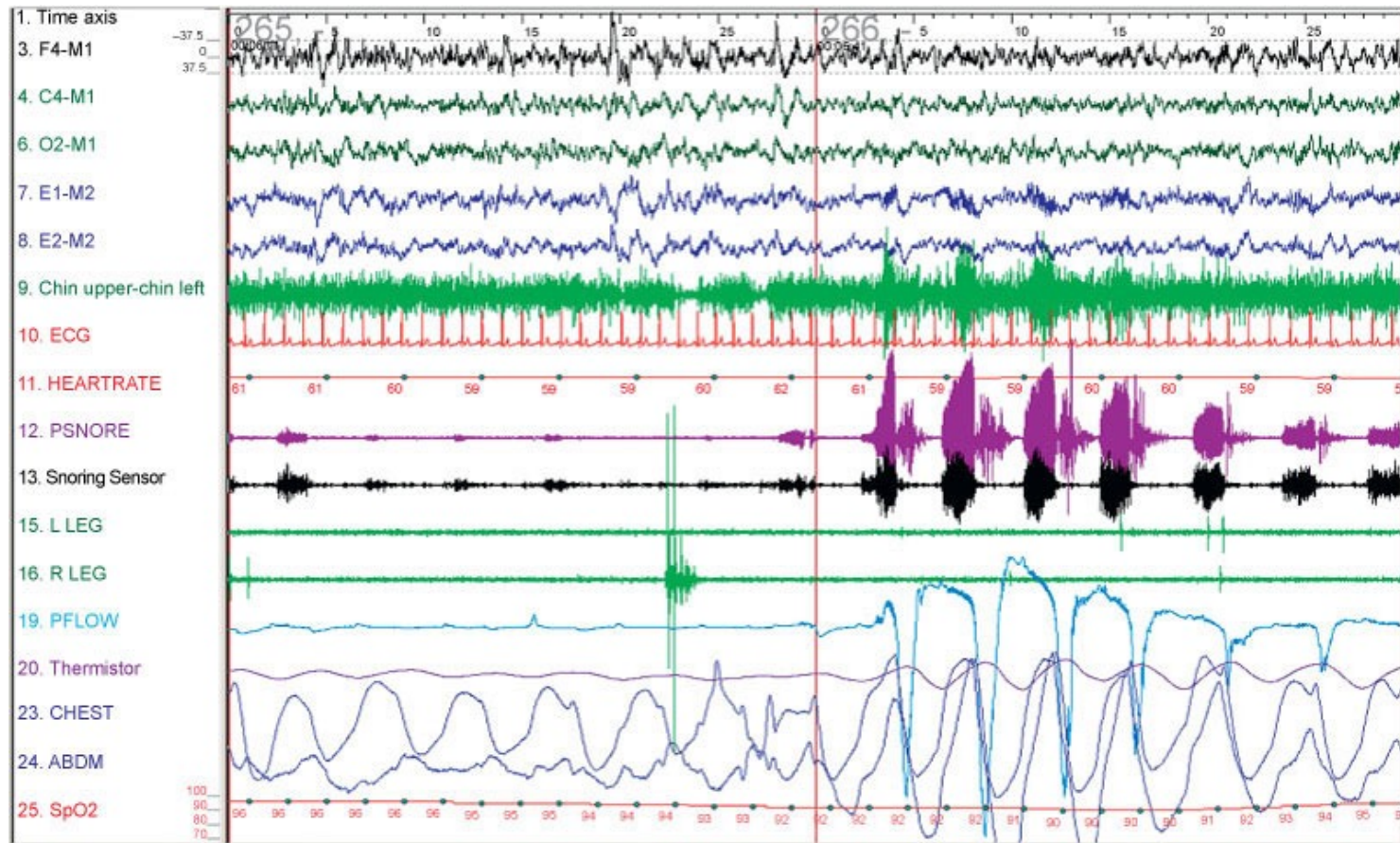


# Respiratory Examples

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- Apnea
  - Score when both of following present:
    - Drop in peak signal excursion by  $\geq 90\%$  of pre-event baseline using oronasal thermal sensor, PAP device flow, or alternative apnea sensor
    - Duration of  $\geq 90\%$  drop is  $\geq 10$  seconds
  - Score as obstructive if there is continued respiratory effort during absent airflow
  - Score as central if there is absent respiratory effort during absent airflow
  - Score as mixed if absent respiratory effort at beginning of event, followed by resumption of inspiratory effort in 2<sup>nd</sup> portion

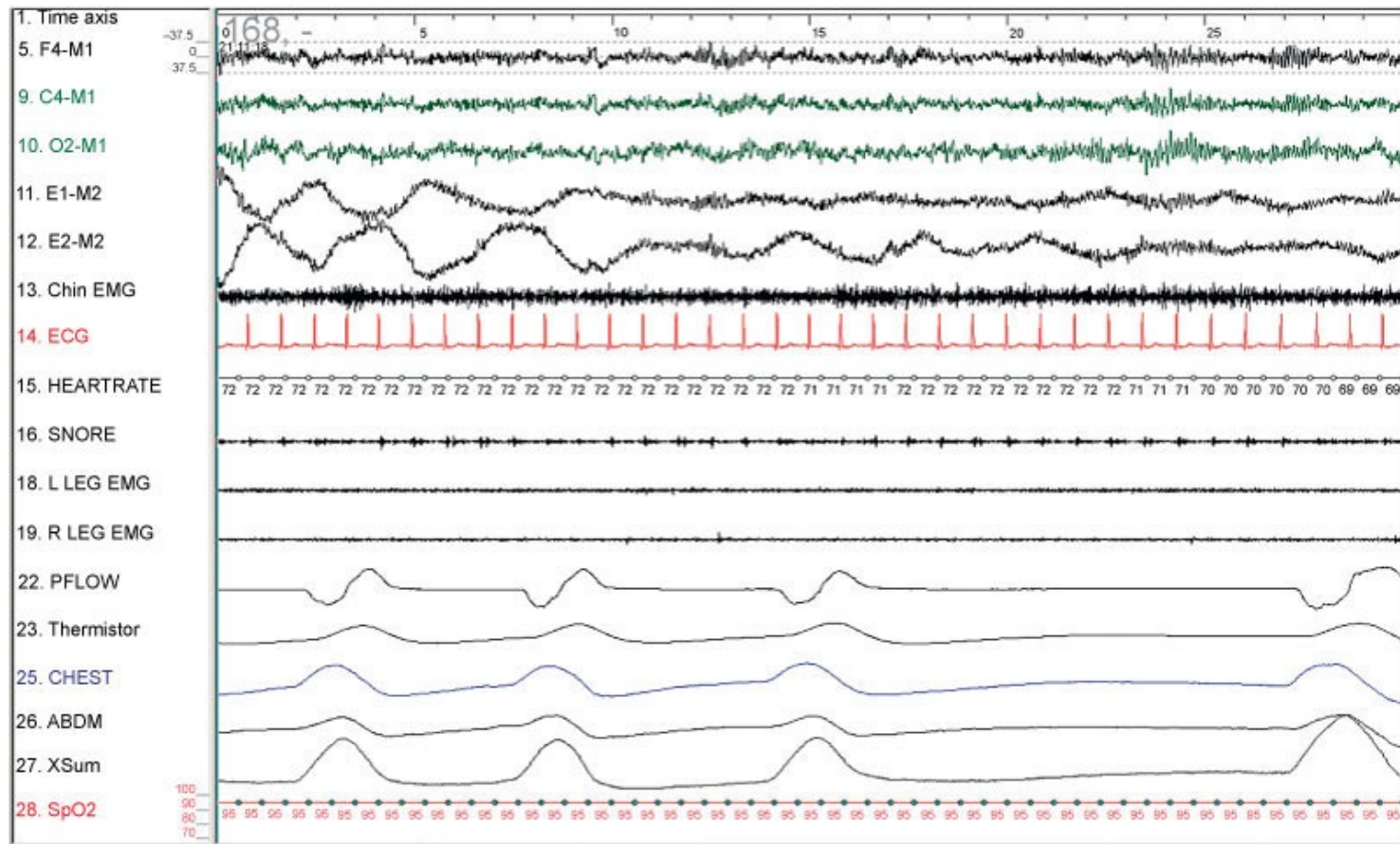
# Obstructive Apnea



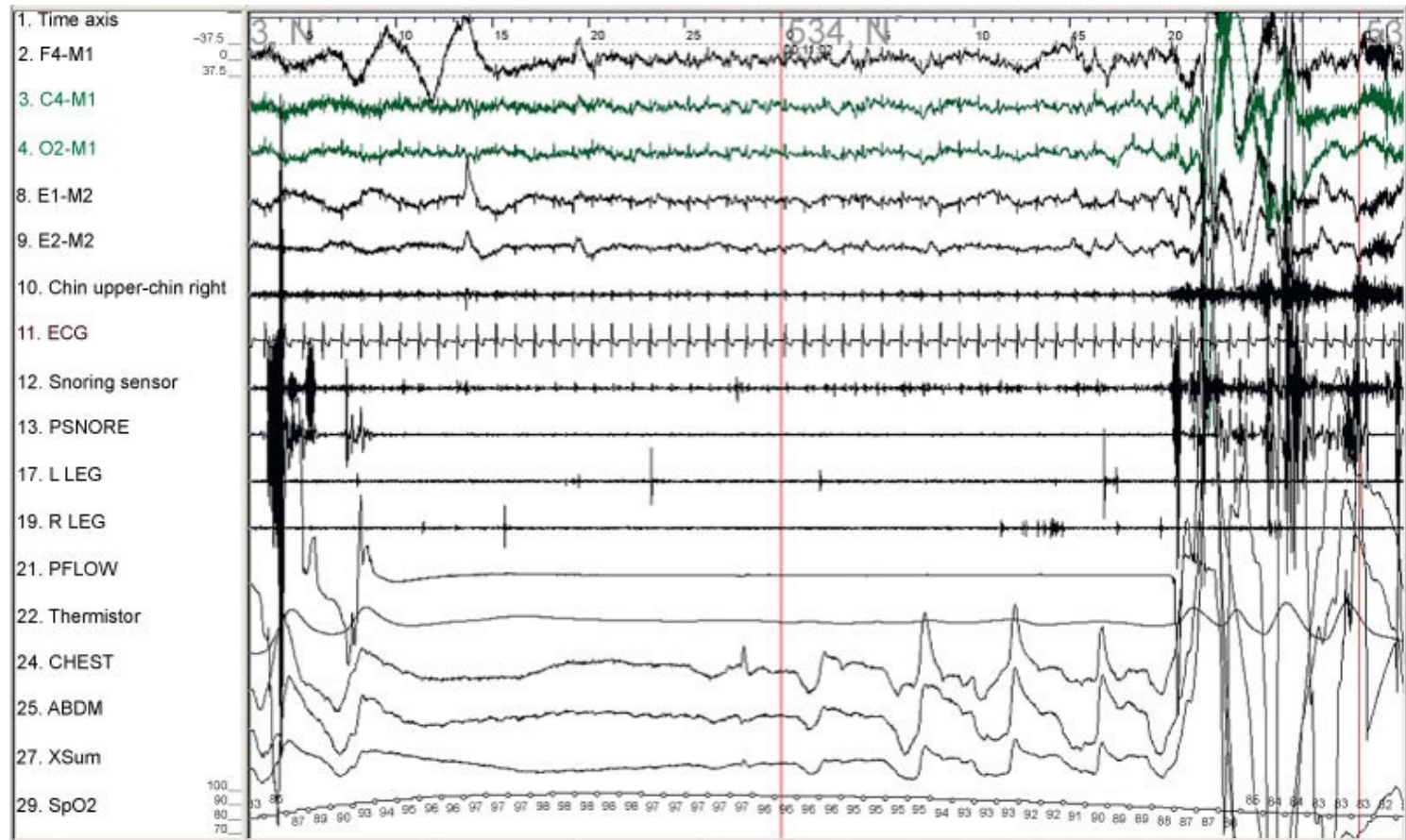
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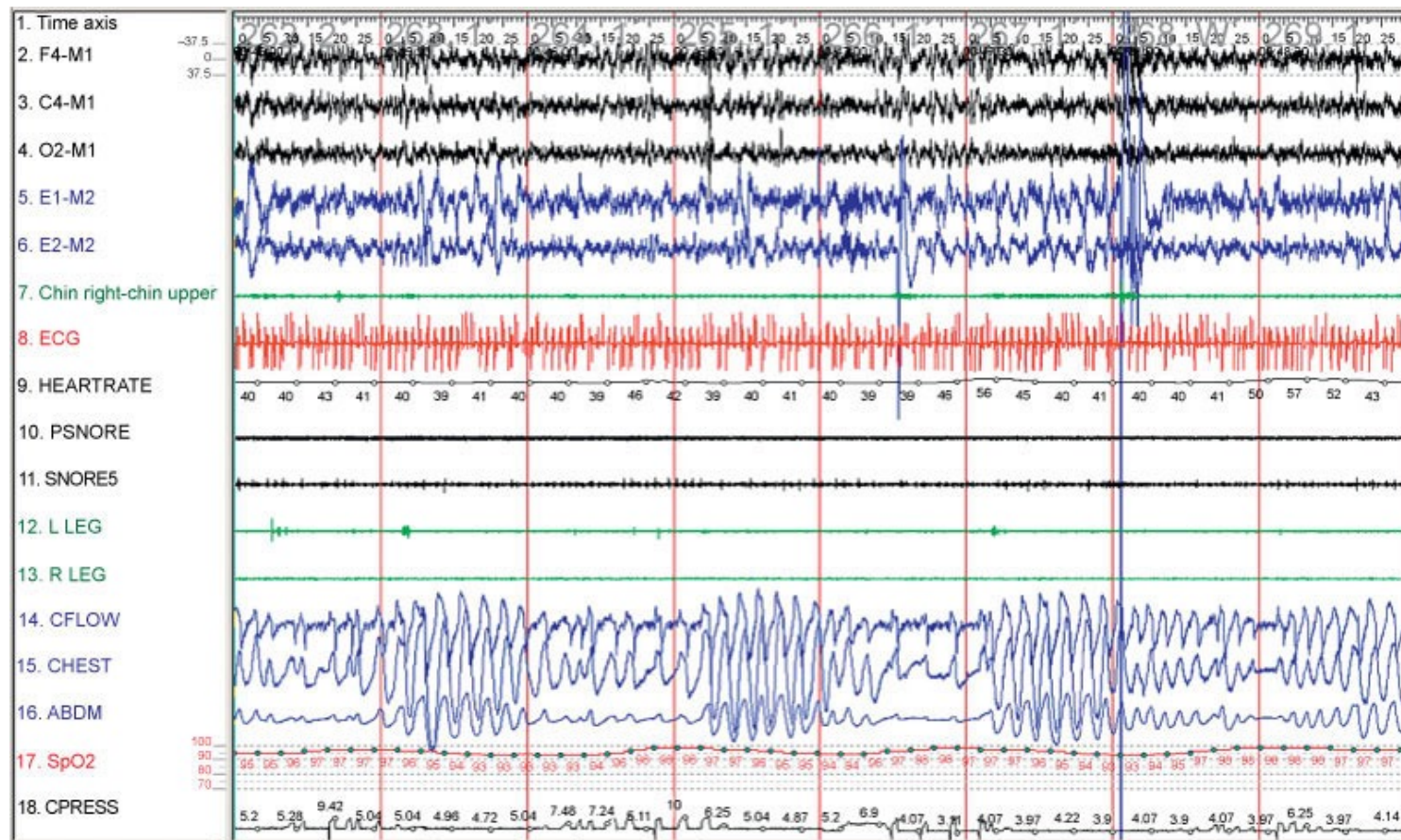
# Central Apnea



# Mixed Apnea



# Cheyne-Stokes Respiration



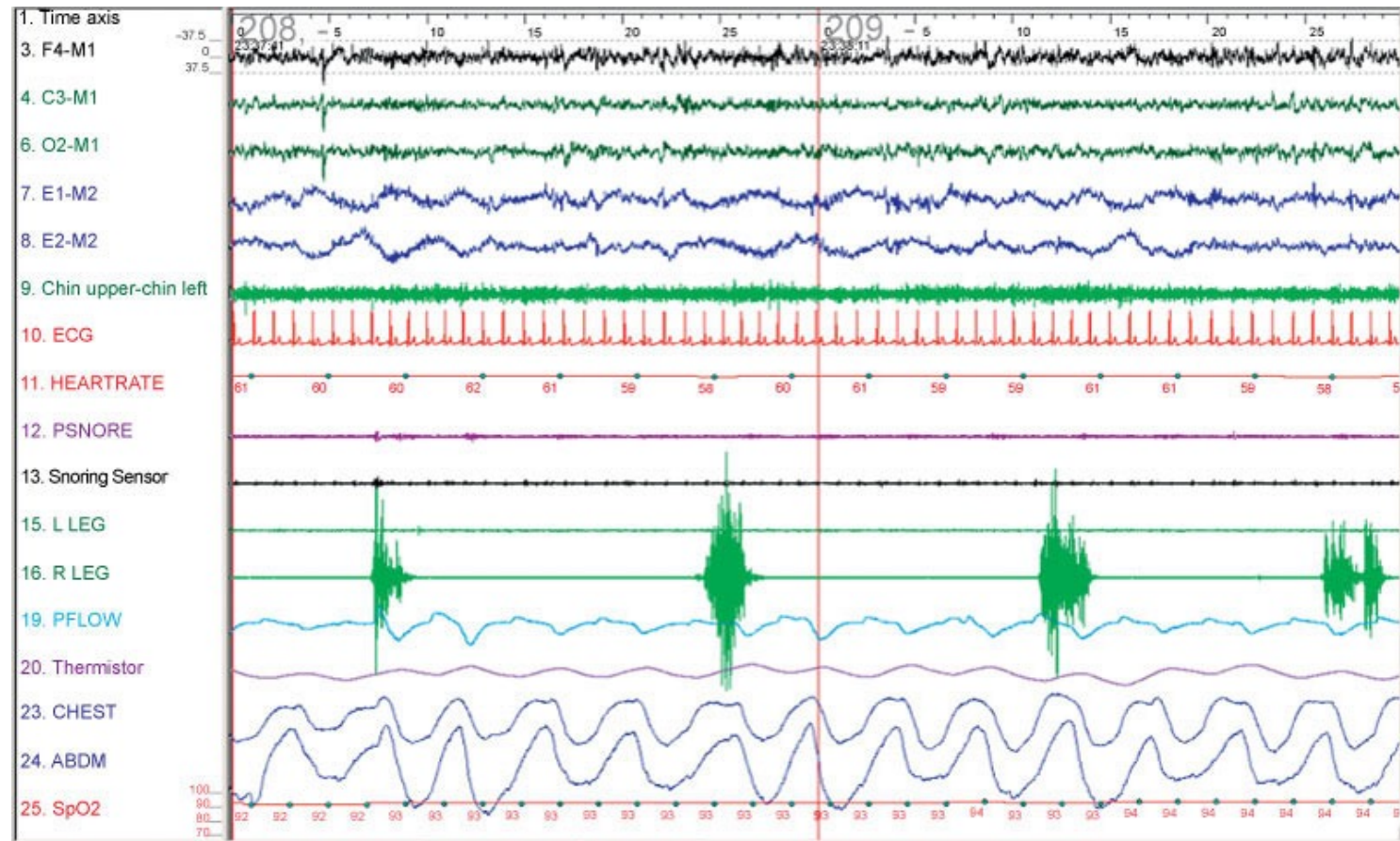
# Sleep-Related Movement Events

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- PLMS
  - Minimum duration = 0.5 second
  - Maximum duration = 10 seconds
  - Minimum amplitude = 8  $\mu$ V over resting EMG
  - PLM series = 4 limb movements
    - Minimum length between limb movements = 5 seconds
    - Maximum length between limb movements = 90 seconds
  - Leg movements on 2 different legs separated by  $< 5$  seconds = 1 leg movement



# PLMS

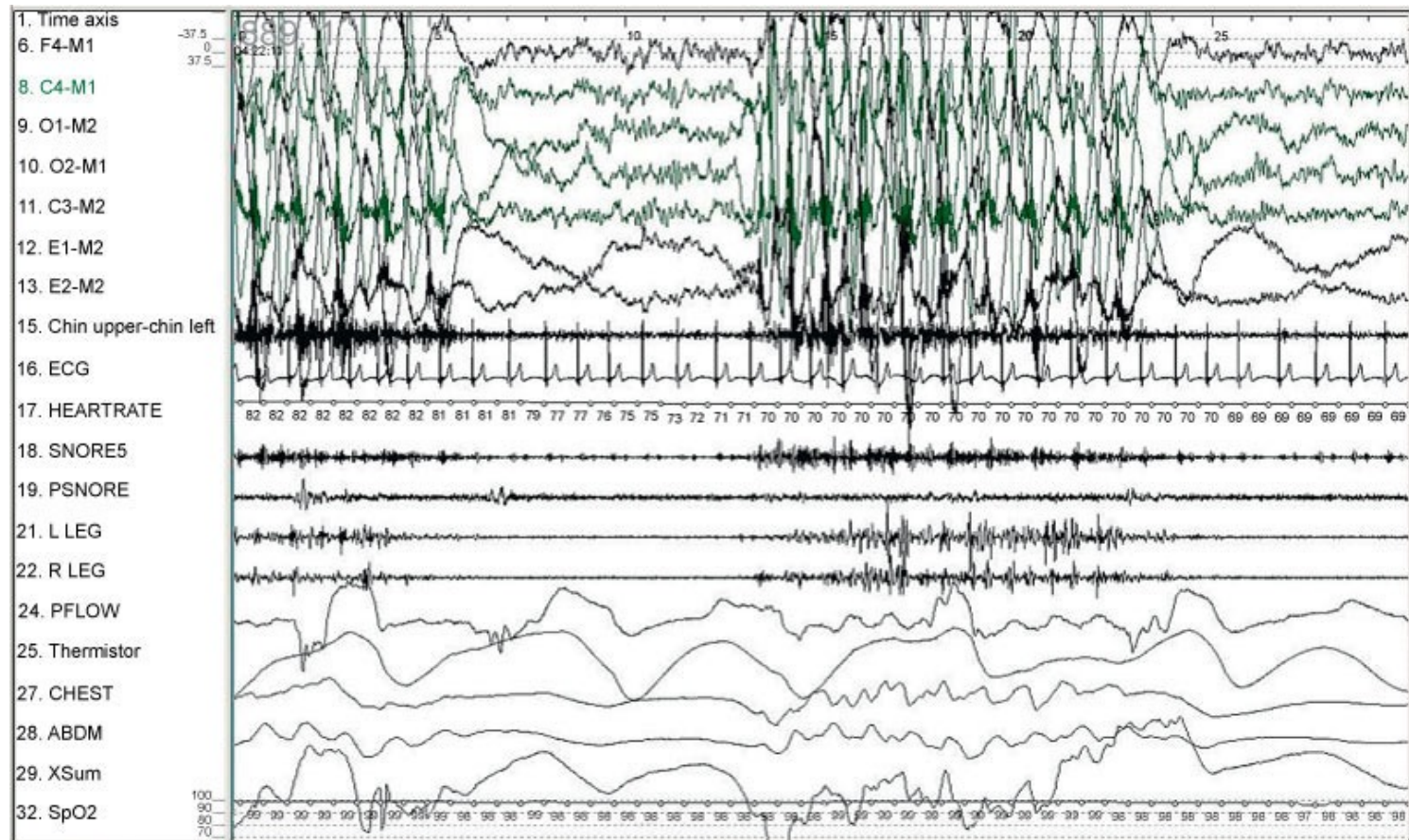


# Sleep-Related Movement Events

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- Rhythmic movement disorder
  - Minimum frequency = 0.5 Hz
  - Maximum frequency = 2 Hz
  - Minimum # of individual movements = 4 movements
  - Minimum amplitude of individual burst = 2x background EMG activity

# Rhythmic Movement Disorder



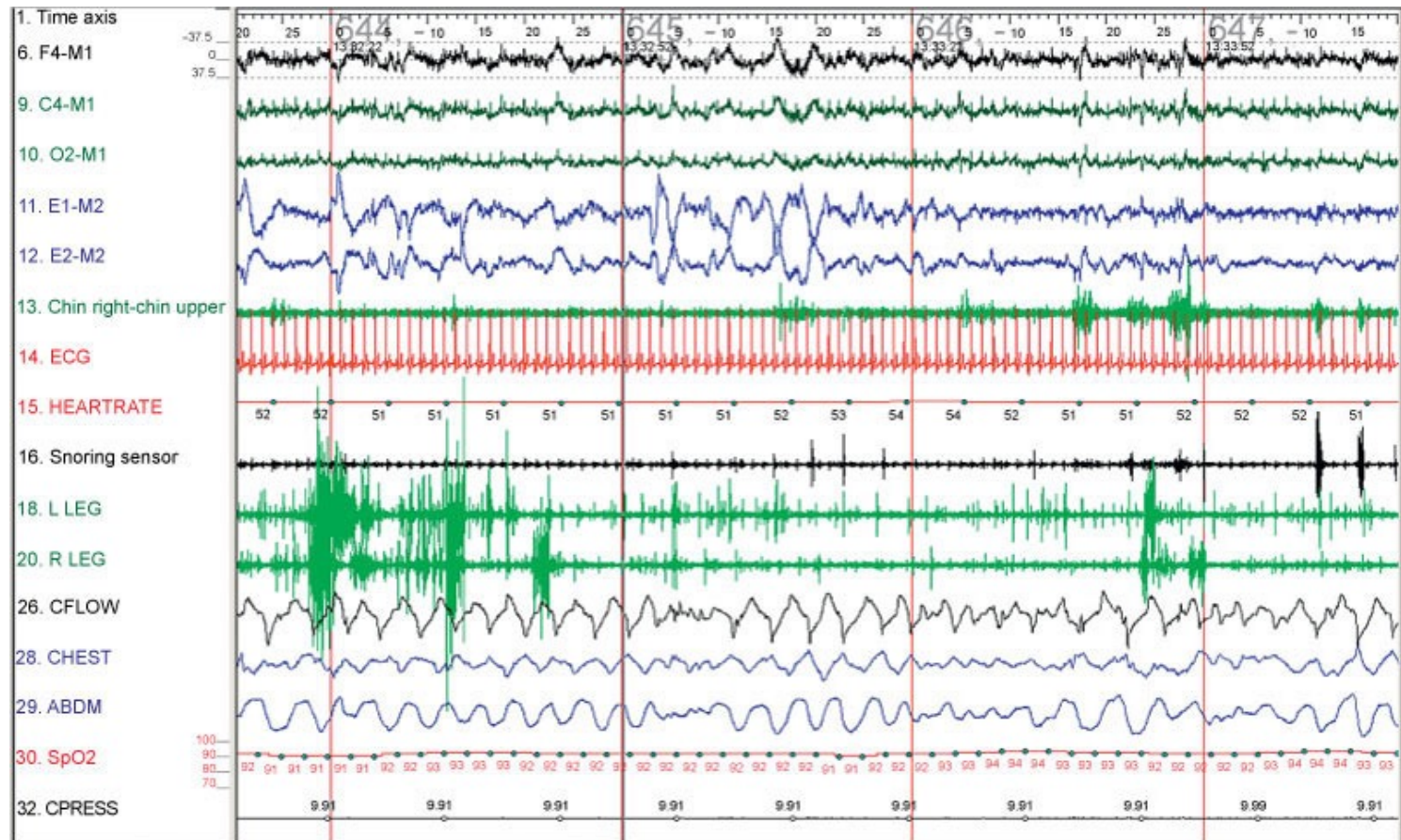
# Sleep-Related Movement Events

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- RBD
  - Body fails to suppress muscle activity during REM
  - Syndrome not event
  - Sustained muscle activity in REM = Epoch of REM with at least 50% of epoch having chin EMG amplitude greater than minimum amplitude in NREM
  - Excessive transient muscle activity in REM = 15 seconds in 30 second epoch; 0.1-5 seconds in duration for each burst; at least 4x as high in amplitude as background EMG
  - Either or both of following present:
    - Sustained muscle activity in REM in chin EMG
    - Excessive transient muscle activity during REM in chin or limb EMG



# RBD



# Advancements in Digital PSG

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- Wireless technologies
  - Primarily applied to transmission between jack box and amplifiers
    - Allows for greater freedom of movement for patient
    - Amplifiers can be moved farther from patient
- Spectral analysis of EEG data
  - Used to identify CNS arousals using cyclic alternating pattern and ANS arousals using ECG signals
  - Trying to quantify slow-wave activity to measure therapeutic response to PAP
  - Not fully validated yet and still being researched

# Advancements in Digital PSG

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- Portable PSG devices
  - Insurance companies pushing for increased use of these devices
  - Range from cardiorespiratory systems to full PSGs
- Remote monitoring
  - Broadband internet and mobile computing allows ability to monitor patients from remote locations
  - Remote monitoring is not considered “attended testing” for insurance reimbursement at this time