Scoring and Interpreting Pediatric Sleep Studies
or
And Now for Something Completely Different
or …….

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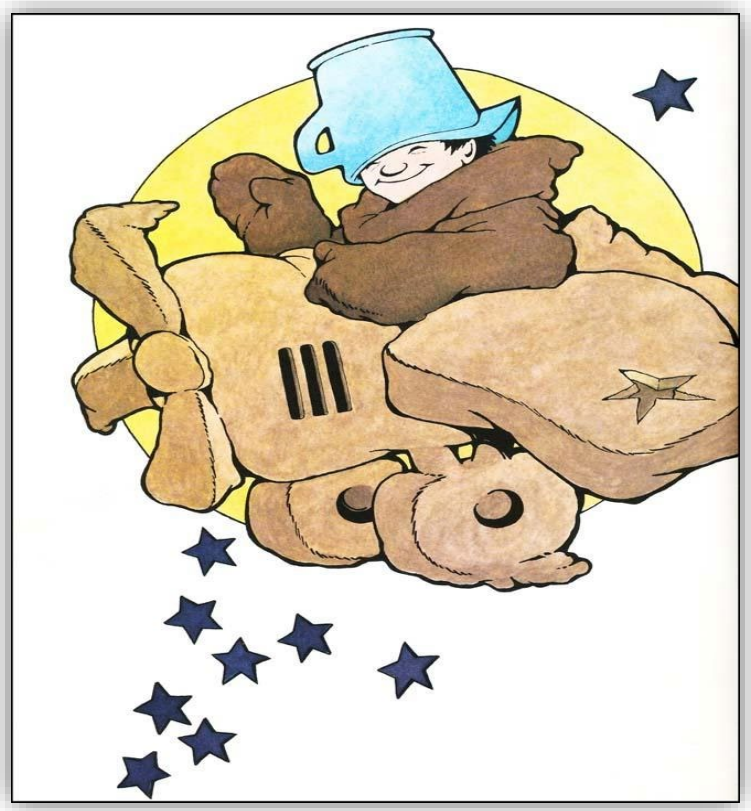
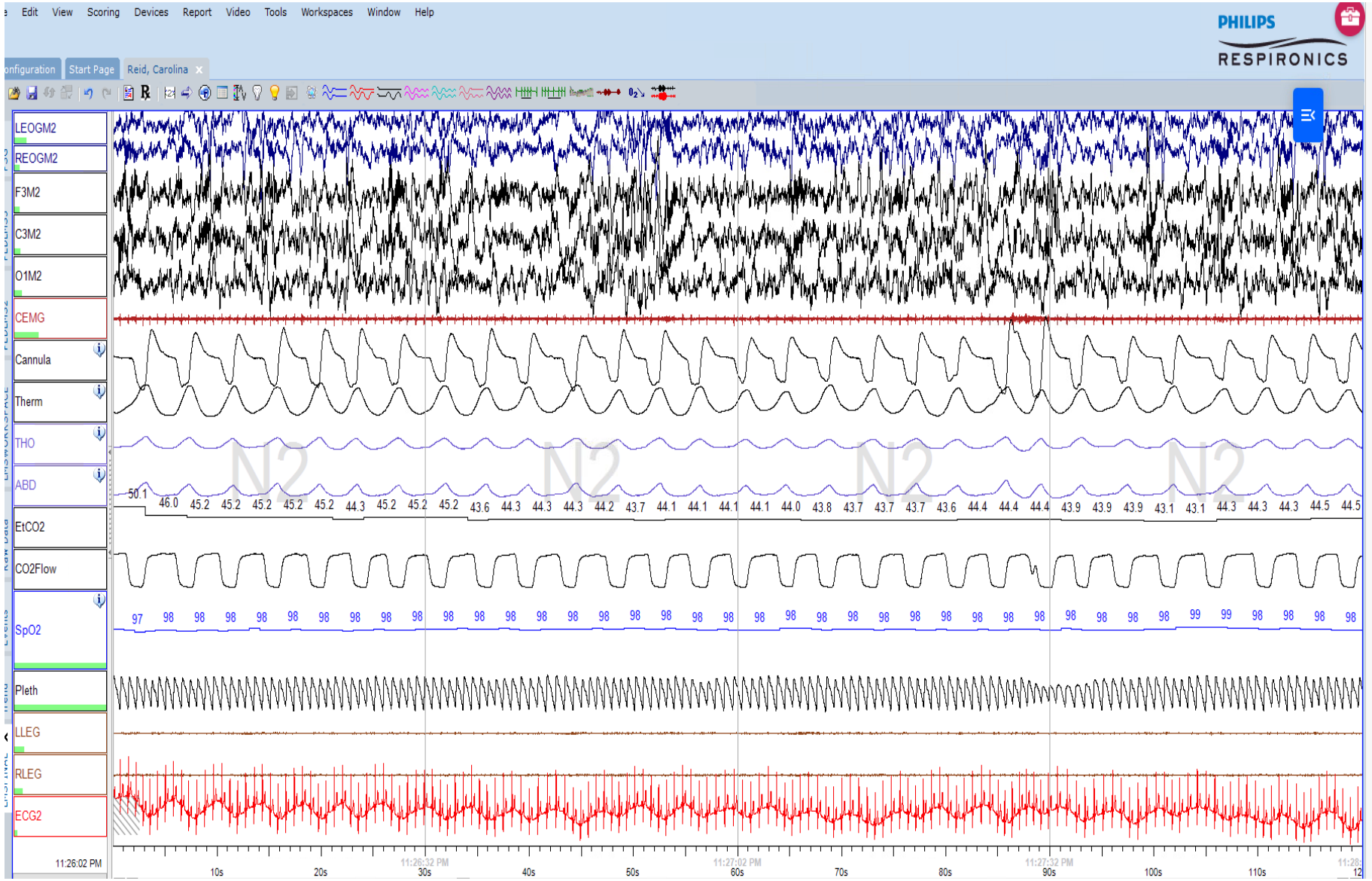
Associate Professor of Pediatrics

Children are Uncooperative and Parents are Tired!



The dream…….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N2
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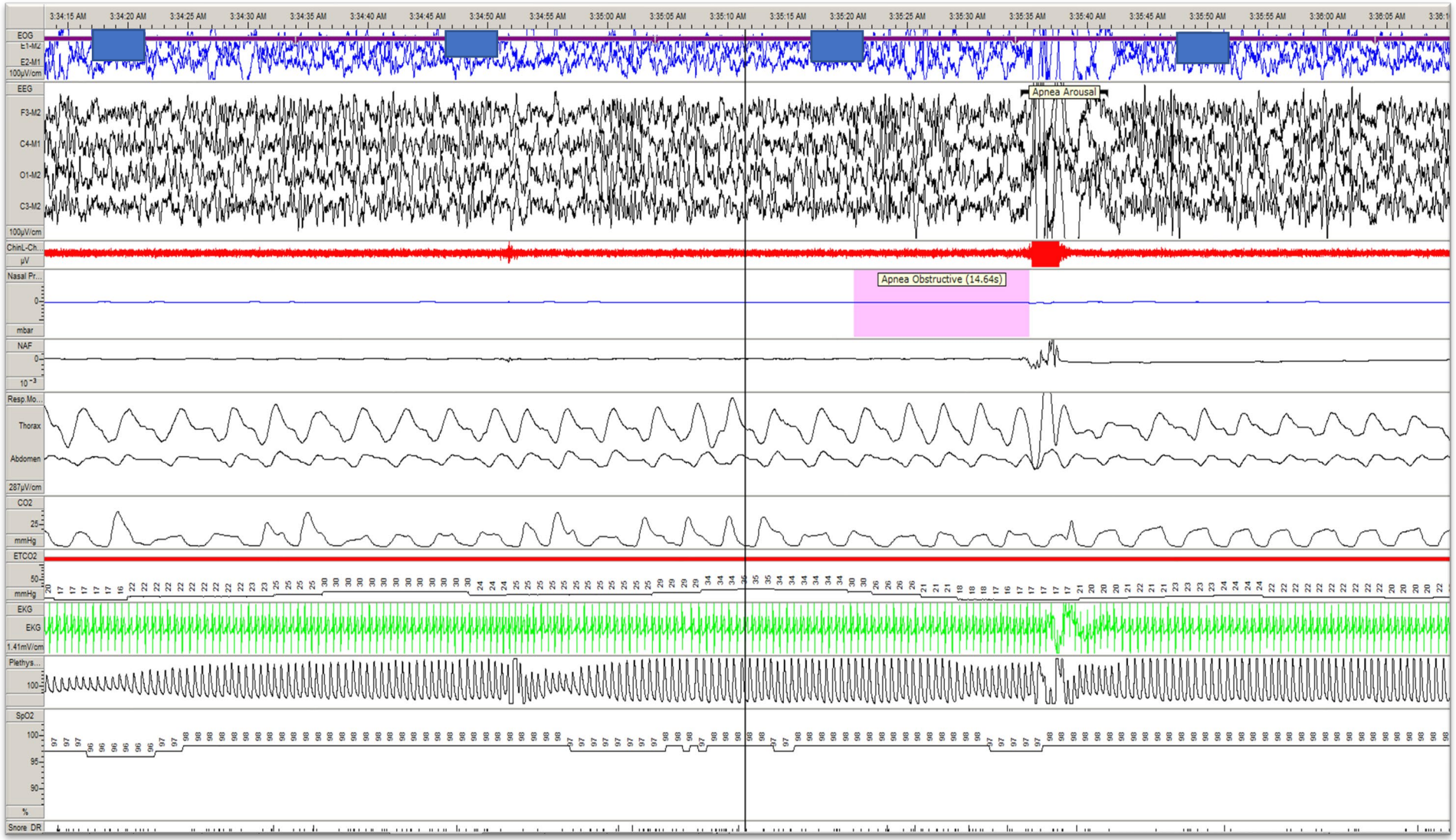
The reality!

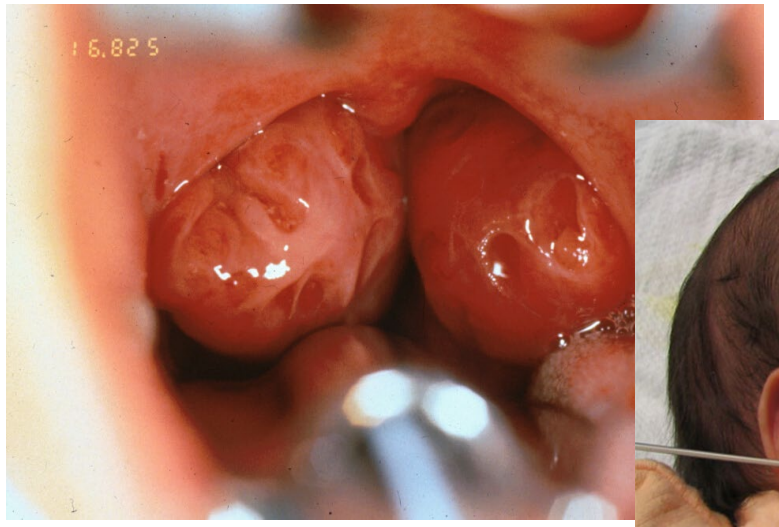

Apnea Arousal
Apnea Obstructive (14.64s)
EOG
EEG
F3-M2
C4-M1
O1-M2
C3-M2
ChinL-Ch
Nasal Pr...
NAF
Resp.Mo...
Thorax
Abdomen
CO2
ETCO2
EKG
Plethys...
SpO2
Snore
DR

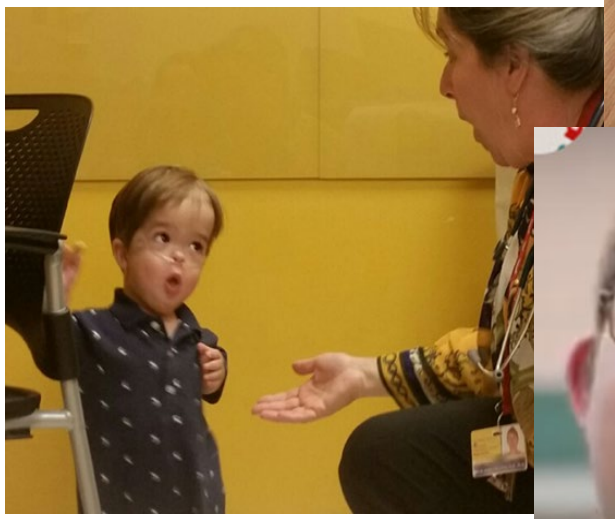
The pediatric sleep lab

- Serves a medically diverse group of patients
  - Obstructive sleep apnea syndrome
  - Respiratory control abnormalities
  - Neuromuscular disease
- A large number of our patients are medically complex
- Wide age and developmental range
- Patient + family!
- Pediatric criteria for scoring and interpretation recognize the less collapsible upper airways/ decreased pulmonary reserves of children

Obstructive Sleep Apnea in Children

- Up to 27% of all children snore, about 2-4% have OSA
- Adverse neurocognitive, behavioral, metabolic, cardiovascular and growth sequelae
- Risk factors include:
  - Adenotonsillar hypertrophy
  - **Obesity**
  - Craniofacial dysmorphology
  - Neuromuscular disorders
  - Prematurity
  - Asthma



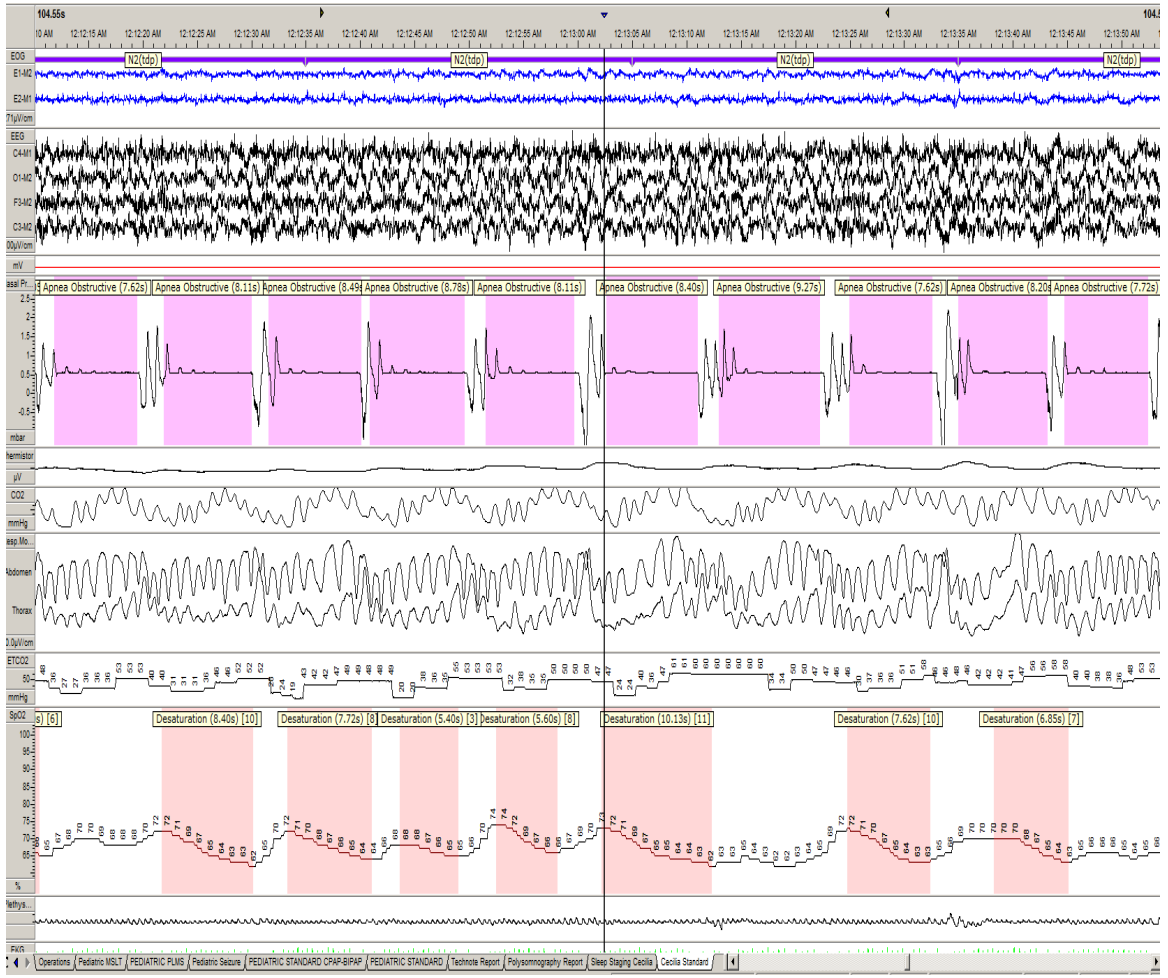


Childhood OSAS: Fast Facts

- Peak 2-8 years of age
- Male = Female until adolescence
- Underweight (until recently!)
- Excessive daytime sleepiness happens – but less frequently than in adults
- Obstructive hypoventilation important pattern
- OSAS is predominantly a REM phenomenon
- Surgical cure for most……

Diagnosis by Polysomnography

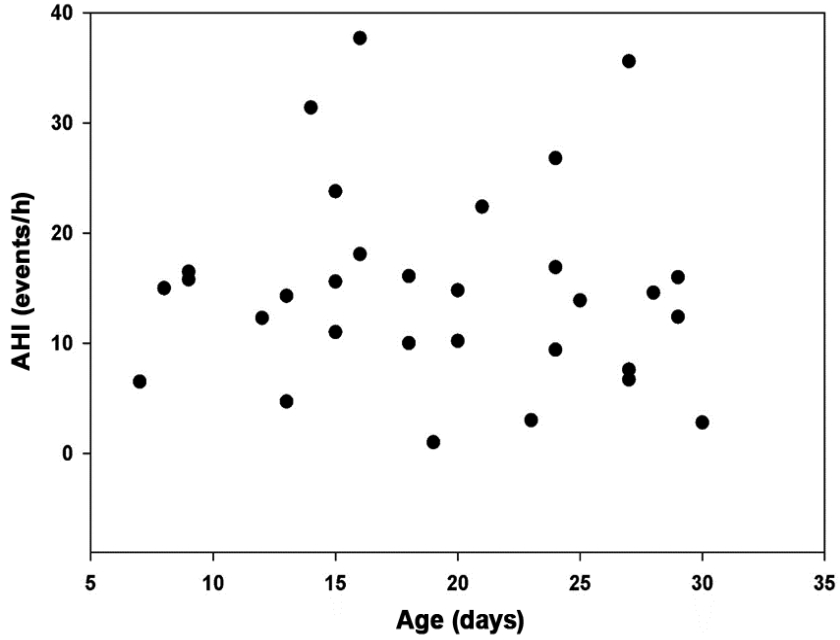
- OSAS diagnosed by the obstructive event index > 1 event / hour
  - Obstructive events = obstructive apnea, obstructive hypopneas, mixed apneas
- Obstructive hypoventilation: persistent hypercapnia (25% time > 50 mmHg) associated with paradoxing, snoring, inspiratory flow limitation
- No standard guidelines for severity classification Our lab:
  - 1.5 -5 /hour mild
  - 5-10 moderate
  - ➢10 severe



Polysomnography reference values in healthy newborns

Daftary AS et al. J of Clinical Sleep Medicine 2019

- 30 infants born between 37-42 wks, studied in first month
- Mean AHI = 14.9/hr
- Central = 5.4/hr, Obstructive =2.3/hr, Mixed = 1.2/hr, remainder hypopneas
- Saturation nadir=84.4%, 0.5% < 90%
- Oxygen desaturation event index = 17.6/hr
- Mean ETCO2 – 35mmHg
- AHI alone should not be used to make treatment decisions in infants



Sleep staging – Pediatric Highlights!

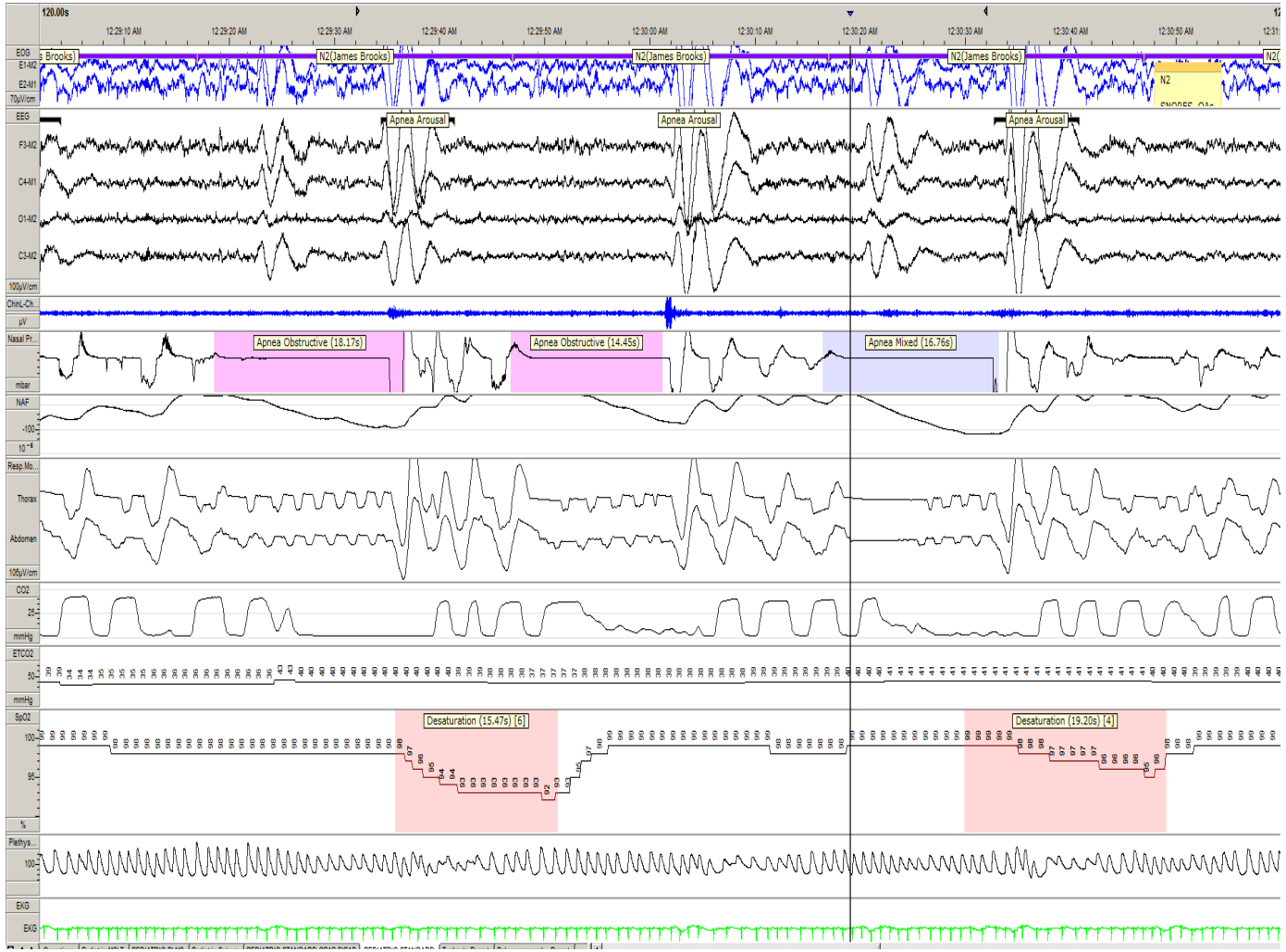
- Infants may (and often do) enter sleep in REM (2-3 months)
- Shorter sleep cycles (50 min versus 90-120 min)
- During the first few months of life sleep is staged as REM, NREM and transitional. Fully developed EEG patterns of NREM emerge in first 2-6 months
- At birth – 50% TST is REM, then declines over the first two years to 20-25%
- SWS maximal in young children (hard to wake them up!) decreases during adolescence

Who is a child?

- Pediatric scoring and interpretation rules can be applied to patients up to 18 years of age
- Adult criteria may be applied to patients ≥ 13 years of age with an adult body habitus

Obstructive apneas

- Drop in airflow signal ≥ 90% of the pre-event baseline
- Event duration at least 2 breaths during baseline breathing
- Ongoing respiratory effort during period of absent airflow
- Signals
  - Oronasal thermal sensor
  - Nasal pressure transducer
  - RIP sum or flow
  - ETCO2

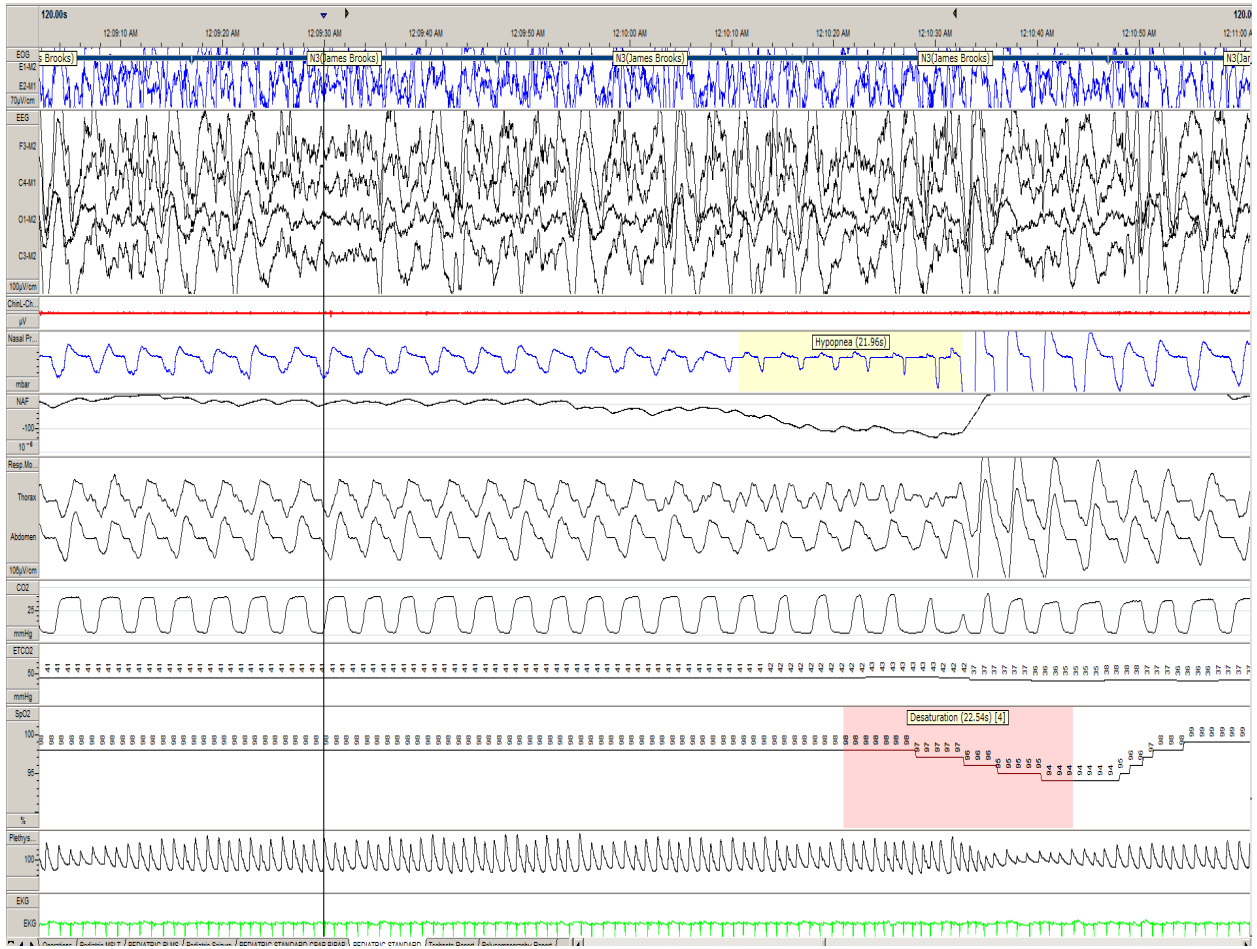


Mixed apneas

- Duration of 2 breaths with respiratory effort in one portion of the event and no respiratory effort and absent effort in another portion
- No consequence required
- Signals (apnea recommendations)
  - Oronasal thermal sensor
  - Nasal pressure transducer
  - RIP sum or flow
  - ETCO2

Hypopneas

- Peak signal fall by ≥ 30% of pre-event baseline
- **≥ 3% fall in pre-event saturations or arousal**
- Event duration greater than 2 breaths baseline breathing
- Ongoing respiratory effort
- Snoring, inspiratory flattening nasal pressure, paradoxical breathing = obstructive
- Signals
  - Nasal pressure transducer
  - Thermistor
  - RIP sum, flow



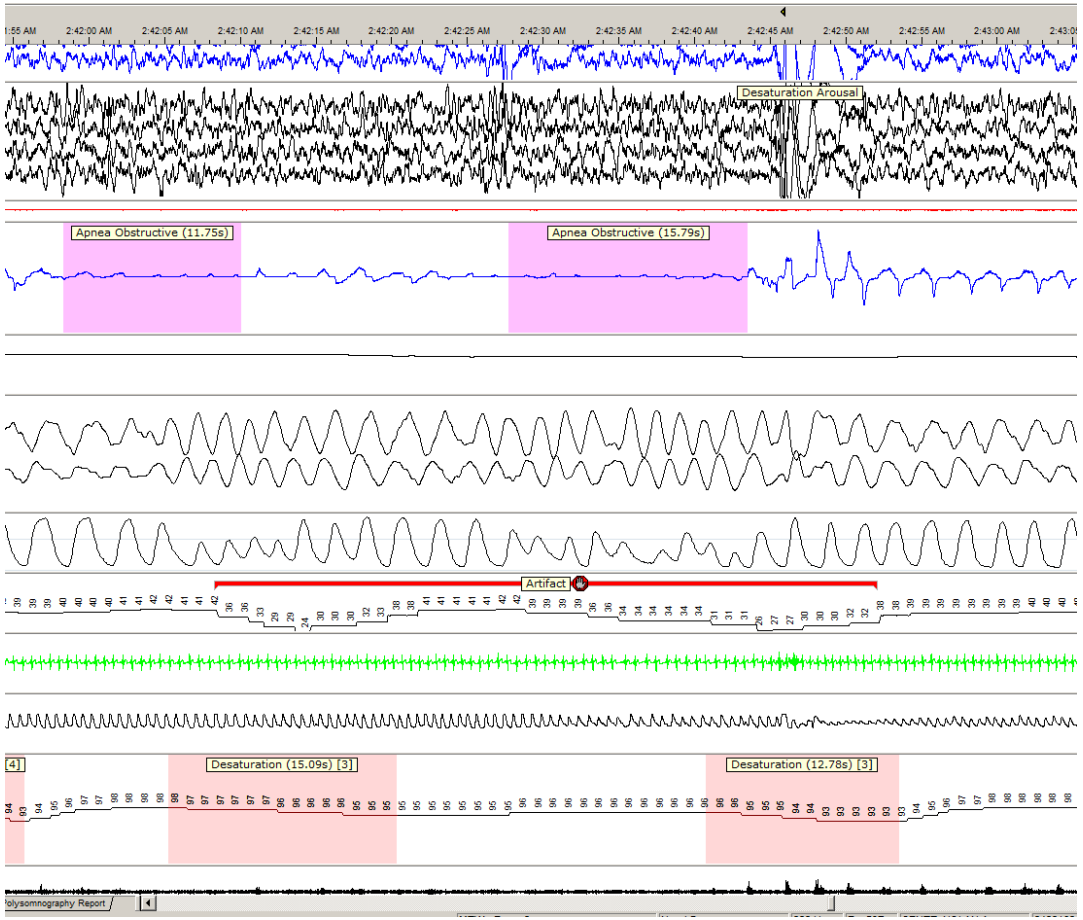
Respiratory Effort Related Arousals (RERA)

- Optional
- Sequence of breaths lasting 2 breaths (or duration of 2 breaths pre-event) that do not meet criteria for apnea or hypopnea leading to an arousal and
  - Increasing respiratory effort
  - Flattening of inspiratory portion of the nasal pressure
  - Snoring
  - Elevation of ETCO2 above baseline (no amount given)
- Kids are not comfortable in sleep labs!

Normal Respiratory Rates in Children

- **0 to 3 months:** 30–60 breaths per minute (bpm)
- **3 to 6 months:** 30–45 bpm
- **6 to 12 months:** 25–40 bpm
- **1 to 3 years:** 20–30 bpm
- **3 to 6 years:** 20–25 bpm
- **6 to 12 years:** 14–22 bpm
- **12 to 18 years:** 12–18 bpm

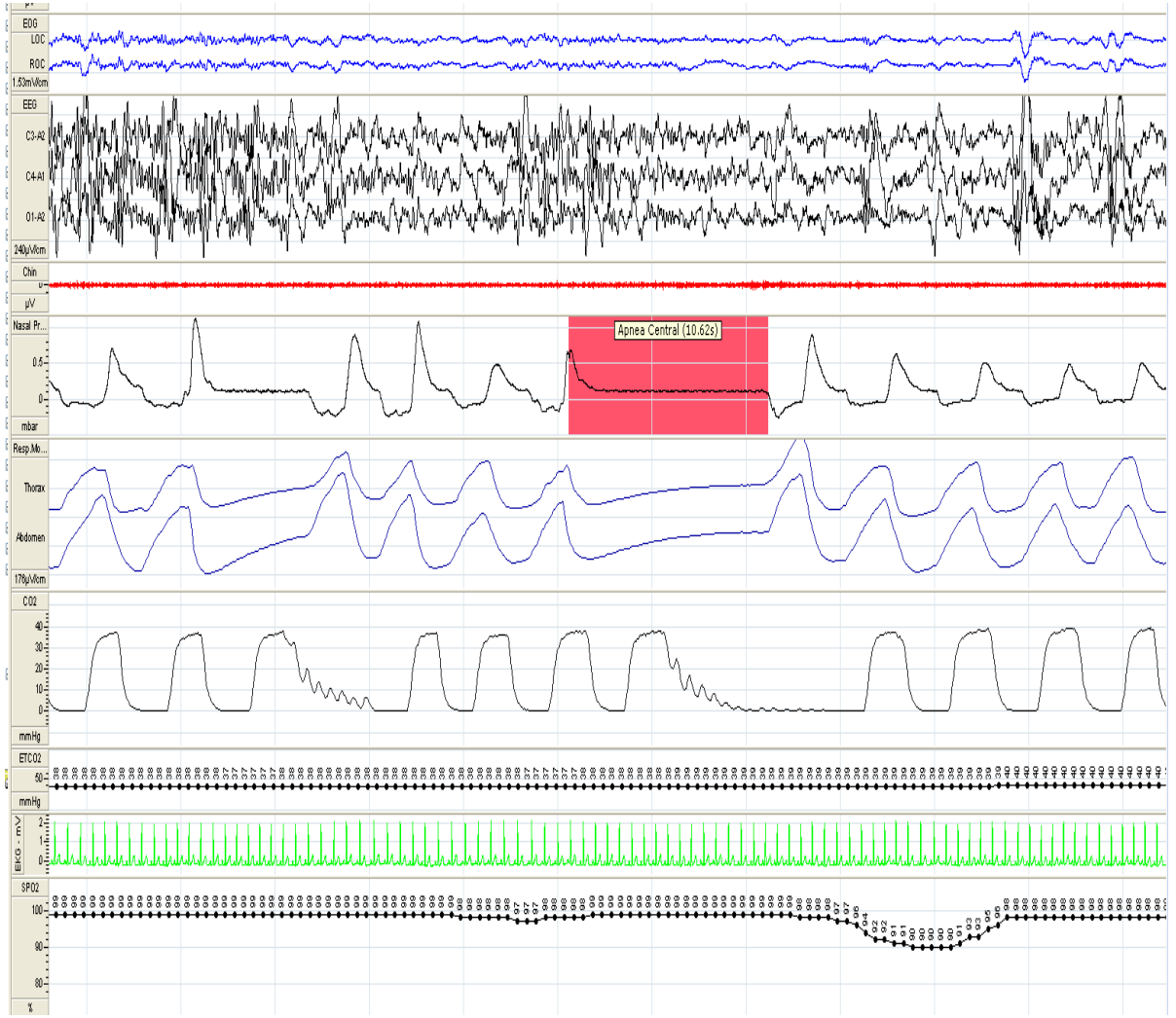
Paradoxical respiratory effort



- Out of phase motion of chest and abdomen
- In infants and young children - due to discoordination of chest and abdominal muscles, increased chest wall compliance
- NORMAL in REM up to 3 years of age
- In older otherwise healthy children = upper airway obstruction

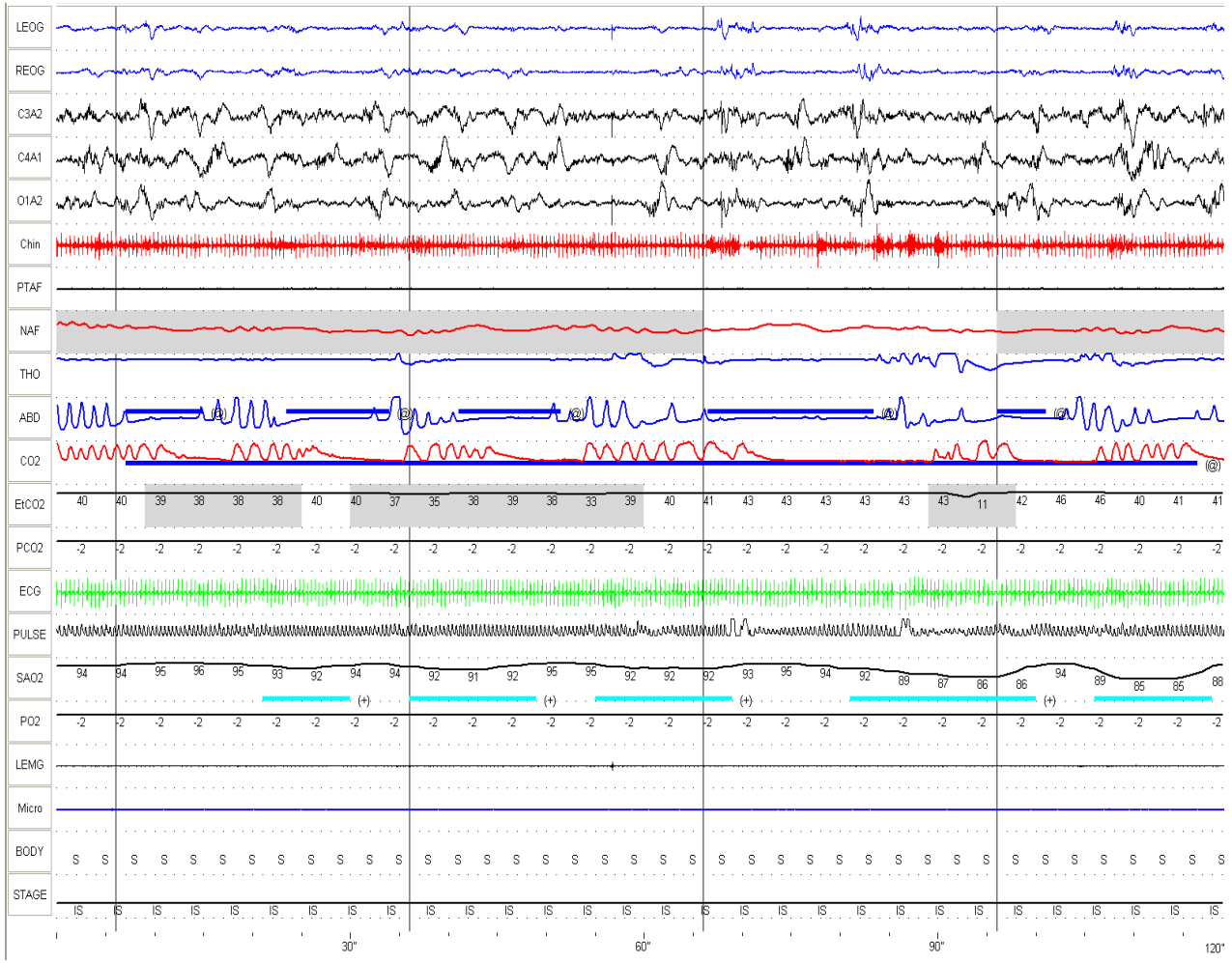
Central apnea

- Drop in airflow signal 90% associated with loss of respiratory effort
- Duration ≥ 20 seconds OR 2 breath duration associated with a ≥ 3% fall in saturation or arousal
- 2 breath duration associated with bradycardia (50 bpm for 5 sec or 60 bpm for 15 sec in infants < 1 year)



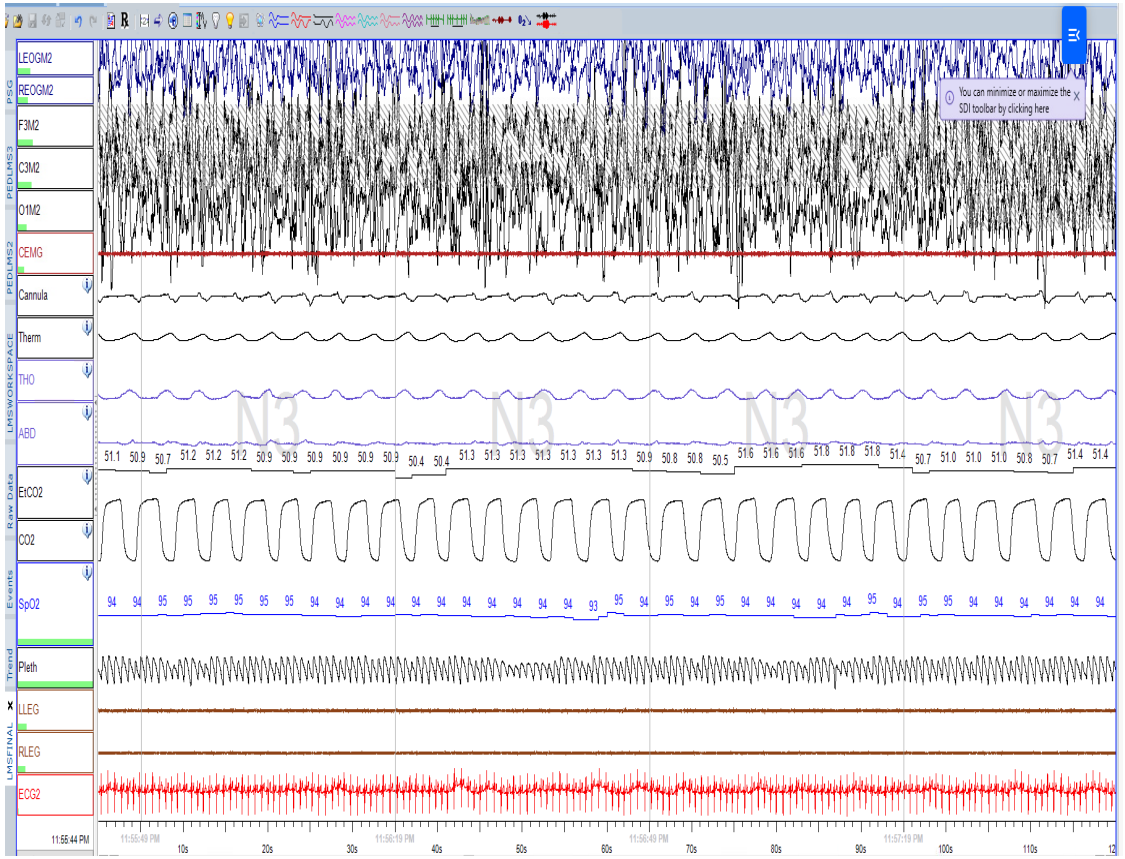
Periodic Breathing

- ≥ 3 central pauses in breathing lasting greater than 3 seconds and separated by no more than 20 seconds of normal breathing
- Central apneas within run of periodic breathing scored when appropriate
- Common in infants, decreases first year of life
- Enhanced by hypoxemia, hyperthermia, arousals, sleep state transitions



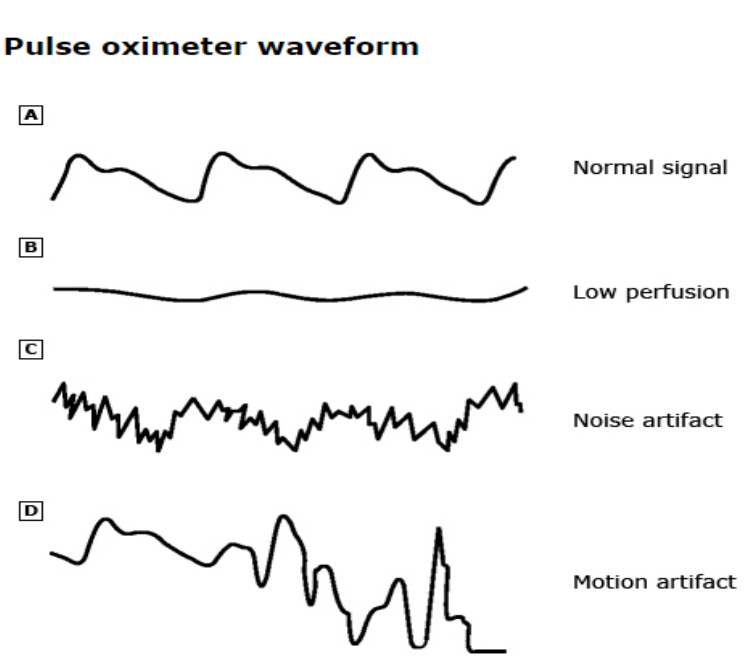
Hypoventilation (recommended)

- ≥ 25% of the total sleep time (with CO_2 measurements!) with a PCO_2 > 50 mmHg
- Obstructive versus non-obstructive
- End tidal PCO_2 or transcutaneous PCO_2
- Careful!!
  - ETCO2 affected by respiratory rate, nasal congestion, mouth breathing, use of oxygen
  - Young children paradox in REM
  - Calibration / judgement important



Oximetry

- Measures peripheral atrial oxygen saturation
- Continuous, rapid, non-invasive
- PRONE TO ARTIFACT – “best defense is high index of suspicion”
- Common problems in the lab:
  - Inadequate waveform (malposition of probe, motion artifact, hypoperfusion)
  - Falsely elevated – Ambient light
  - Falsely low – Ambient light, nail polish



Common pulsatile signals on a pulse oximeter.

(A) Normal signal showing the sharp waveform with a clear dicrotic notch.

(B) Pulsatile signal during low perfusion showing a typical sine wave.

(C) Pulsatile signal with superimposed noise artifact giving a jagged appearance.

(D) Pulsatile signal during motion artifact showing an erratic waveform.

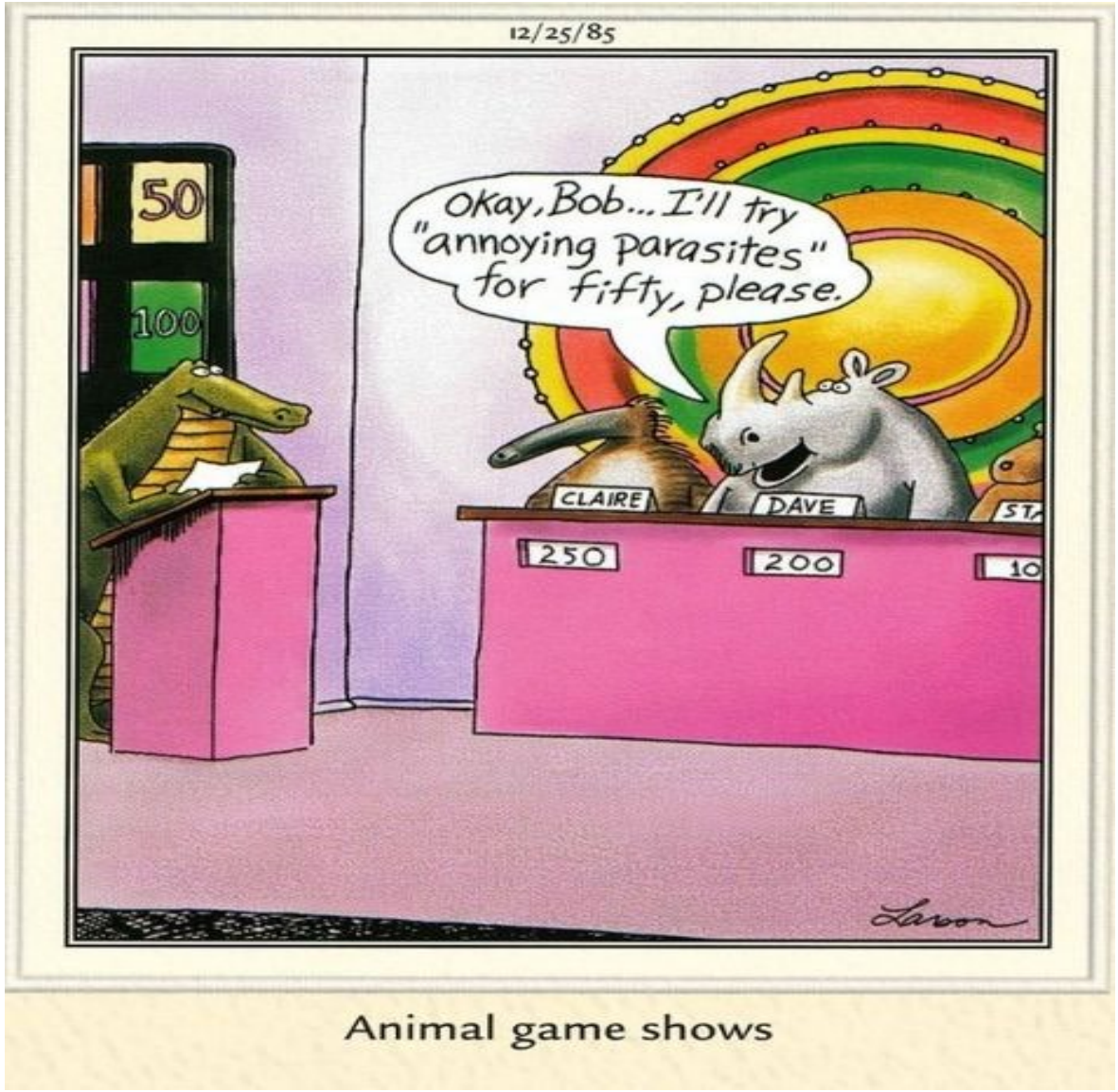
From: Jubran A. Pulse oximetry. Crit Care 2015; 19:272. Copyright © Jubran 2015. Reproduced under the terms of the Creative Commons Attribution License (CC BY 4.0). Available at: http://ccforum.biomedcentral.com/articles/10.1186/s13054-015-0984-8 (Accessed on May 17, 2016).

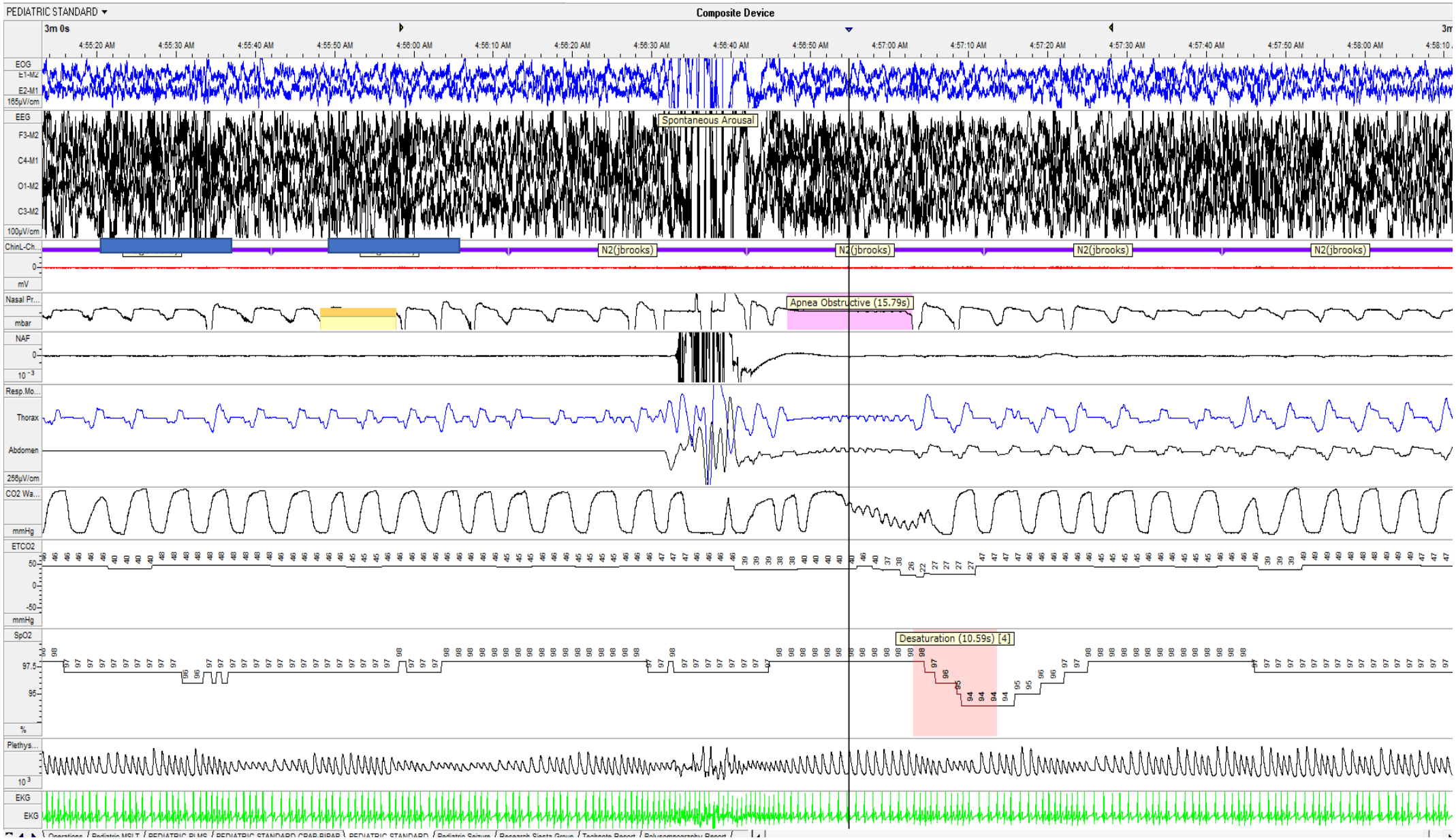
UpToDate®

Things to think about

- If every study is positive you are probably over-scoring!
- If all your events are found during movement and arousals – probably overscoring
- Arousals must be proceeded by 10 seconds of stable sleep
- Use all the channels you have!

Keep, Delete or Add!

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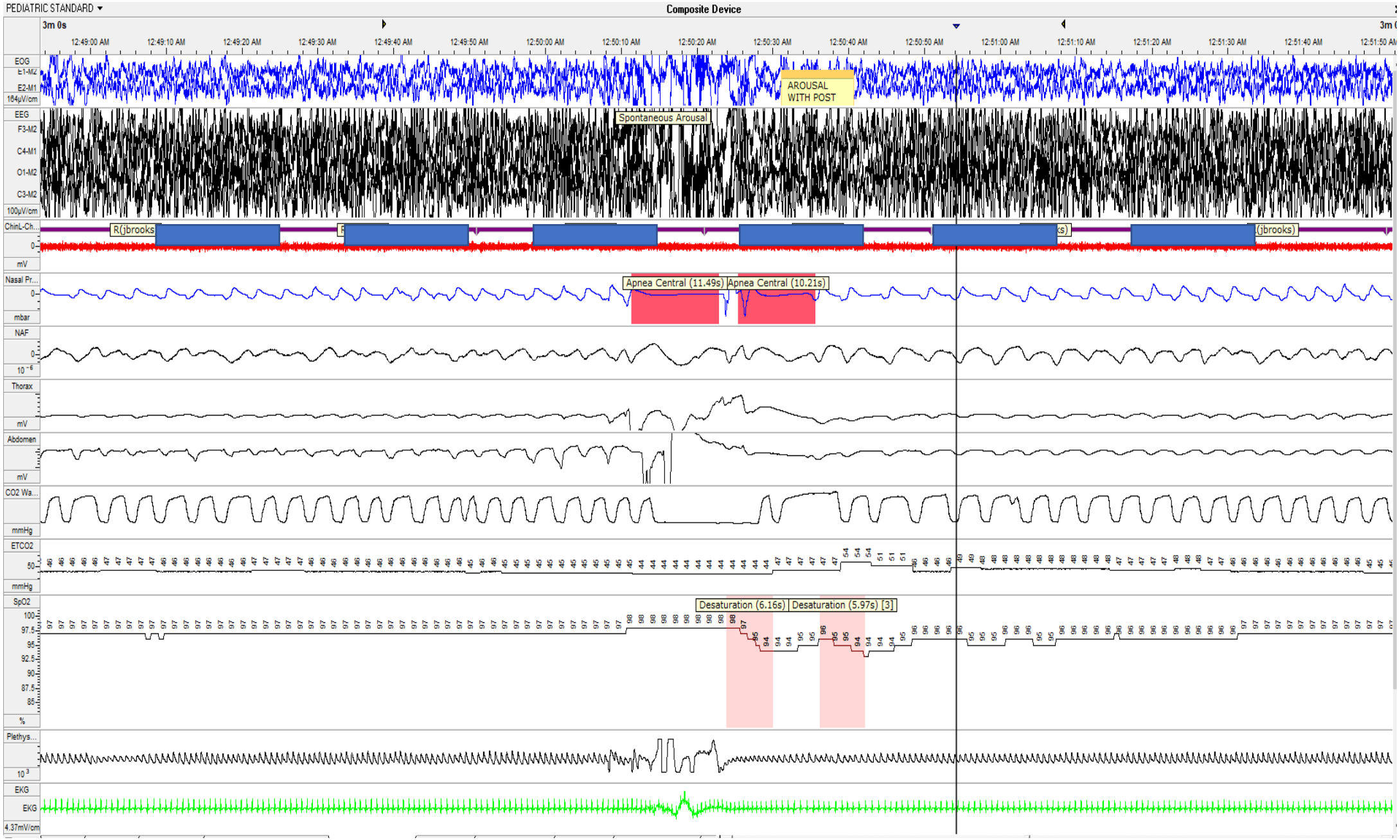
4:57:30 AM
4:57:40 AM
4:57:50 AM
4:58:00 AM
EOG
E1-M2
E2-M1
165µV/cm
EEG
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
Spontaneous Arousal
ChinL-Ch...
N2(jbrooks)
N2(jbrooks)
N2(jbrooks)
N2(jbrooks)
mV
Nasal Pr...
mbar
Apnea Obstructive (15.79s)
NAF
Resp.Mo...
Thorax
Abdomen
256µV/cm
CO2 Wa...
mmHg
ETCO2
mmHg
SpO2
Desaturation (10.59s) [4]
%
Plethys...
EKG
EKG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12:51:50 AM
EOG
E1-M2
E2-M1
164µV/cm
AROUSAL
WITH POST
EEG
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
Spontaneous Arousal
ChinL-Ch...
R(jbrooks
(jbrooks)
0
mV
Nasal Pr...
Apnea Central (11.49s)
Apnea Central (10.21s)
mbar
NAF
10 -6
Thorax
Abdomen
CO2 Wa...
mmHg
ETCO2
50
SpO2
Desaturation (6.16s)
Desaturation (5.97s) [3]
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90
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85
%
Plethys...
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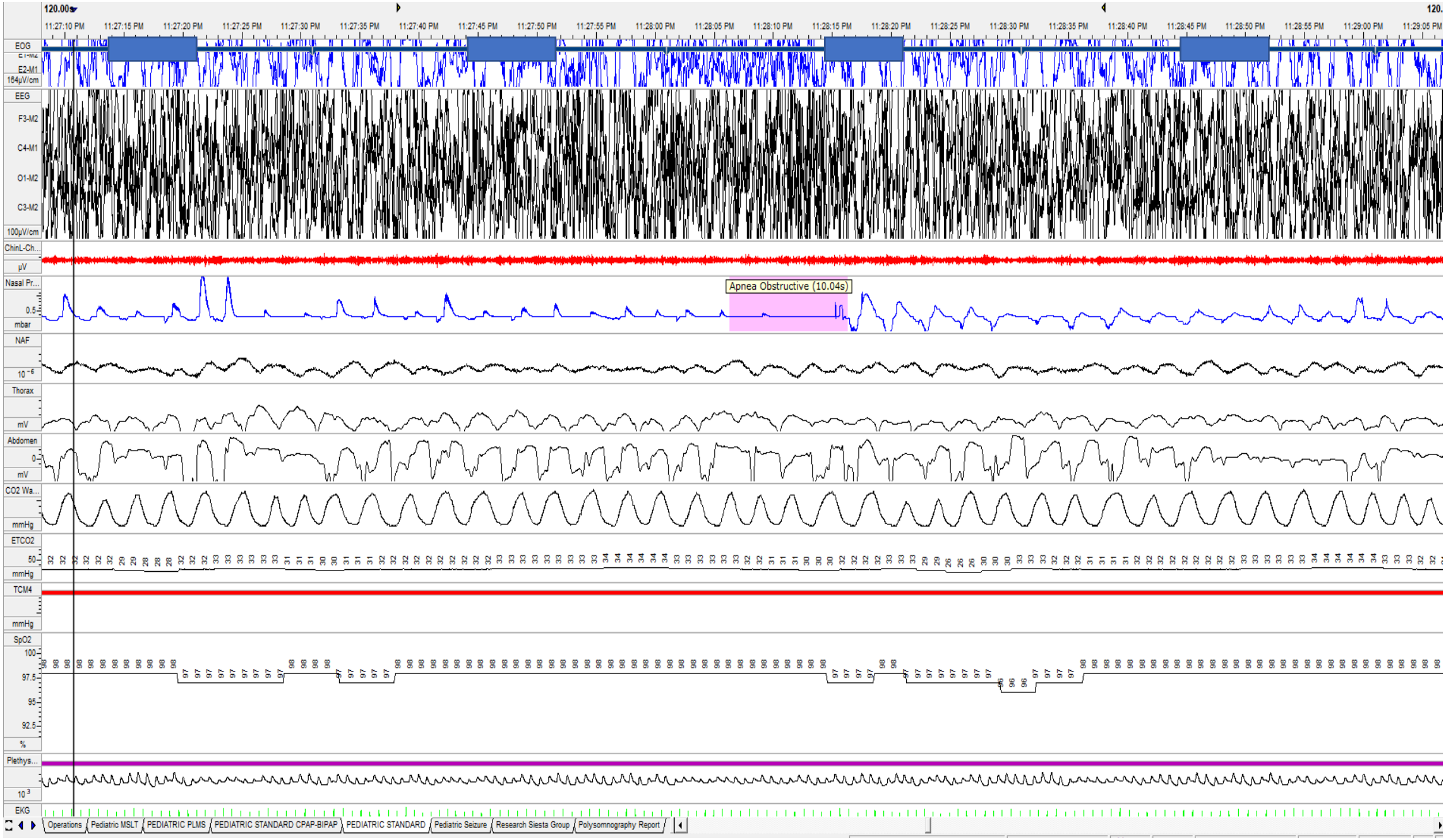
EKG
4.37mV/cm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11:29:00 PM
11:29:05 PM
EOG
E2-M1
164µV/cm
EEG
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
ChinL-Ch...
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Apnea Obstructive (10.04s)
NAF
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Thorax
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Abdomen
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mmHg
ETCO2
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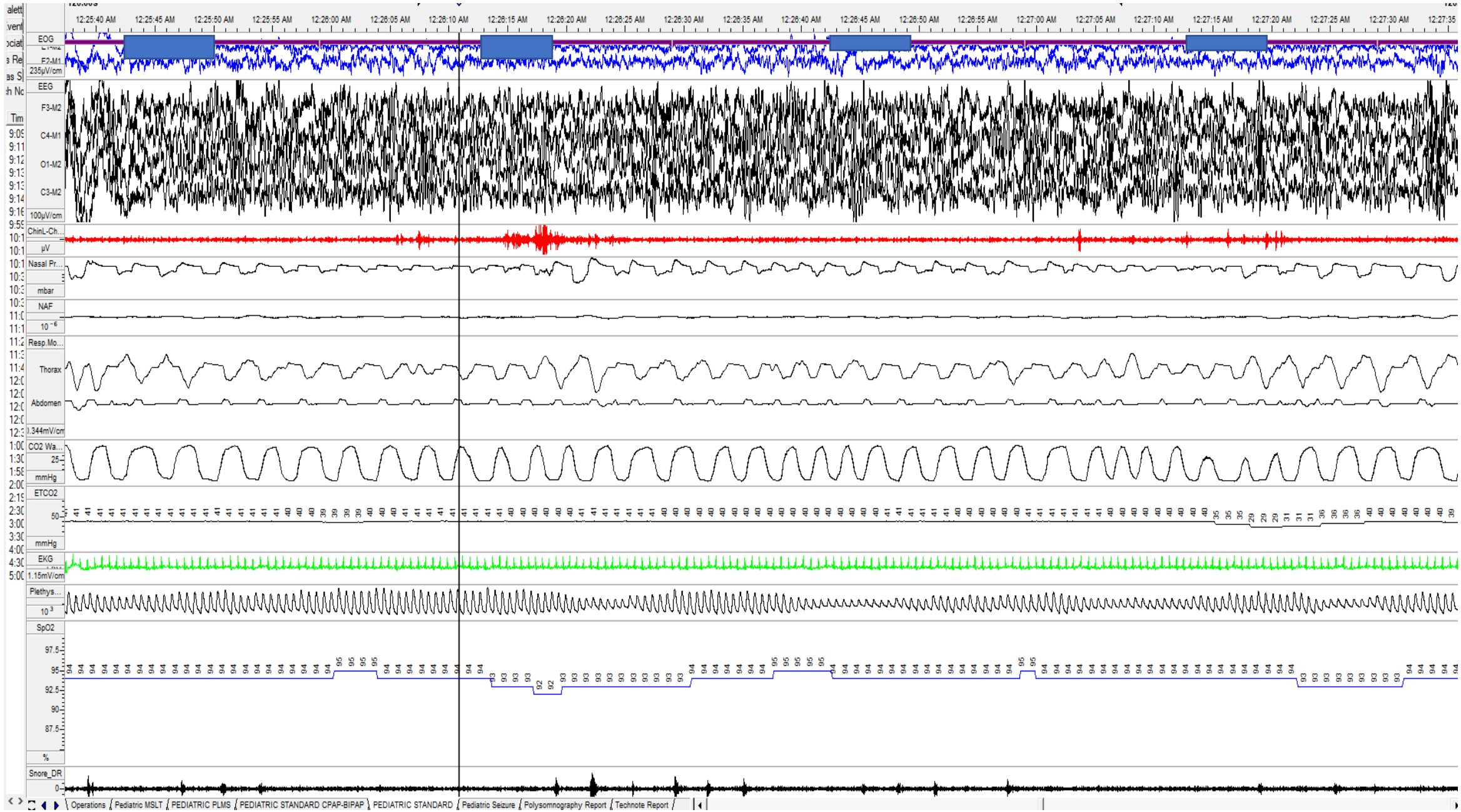
mmHg
TCM4
mmHg
SpO2
100
97.5
95
92.5
%
Plethys...
10³
EKG
Operations
Pediatric MSLT
PEDIATRIC PLMS
PEDIATRIC STANDARD CPAP-BIPAP
PEDIATRIC STANDARD
Pediatric Seizure
Research Siesta Group
Polysomnography Report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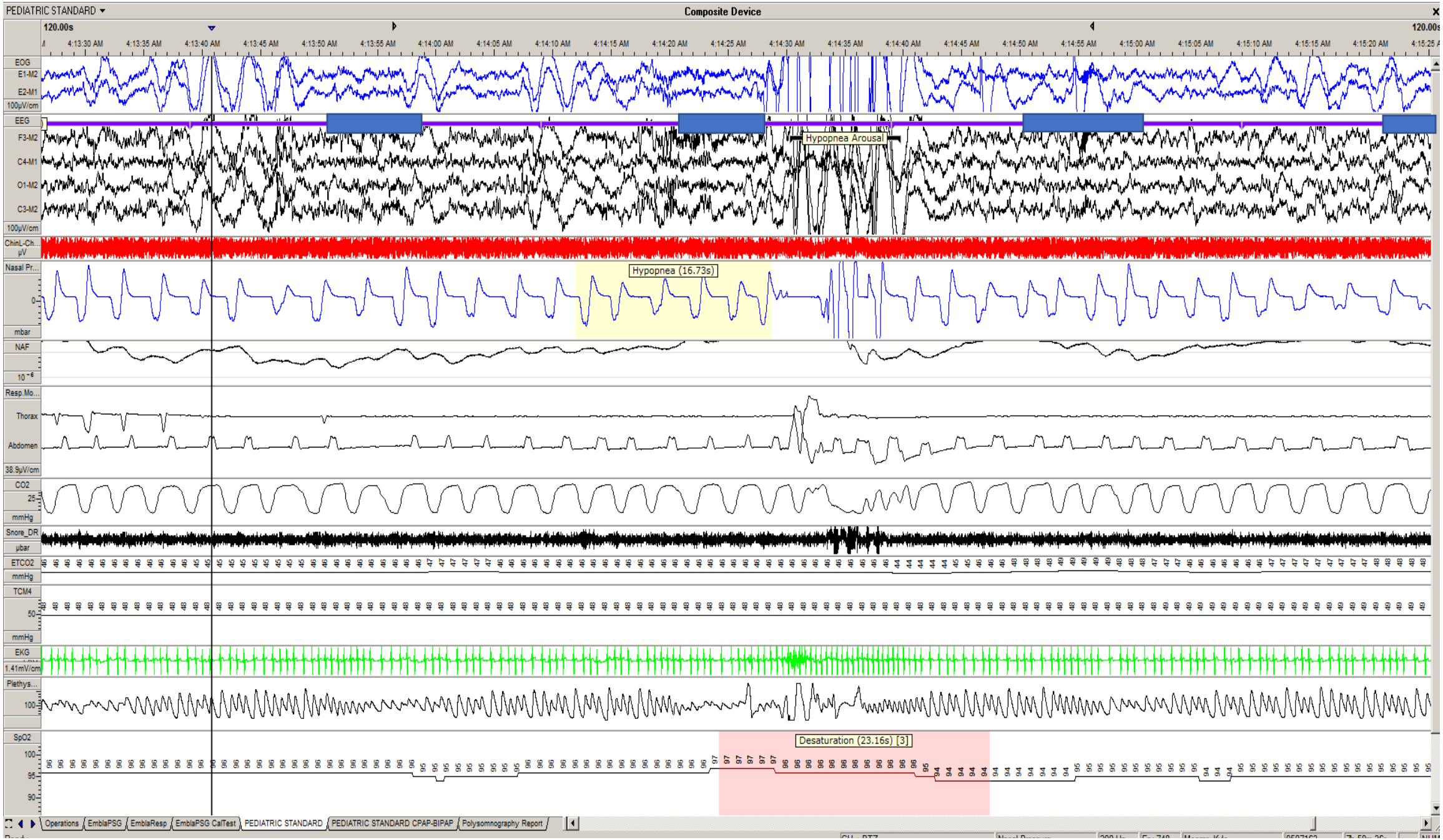
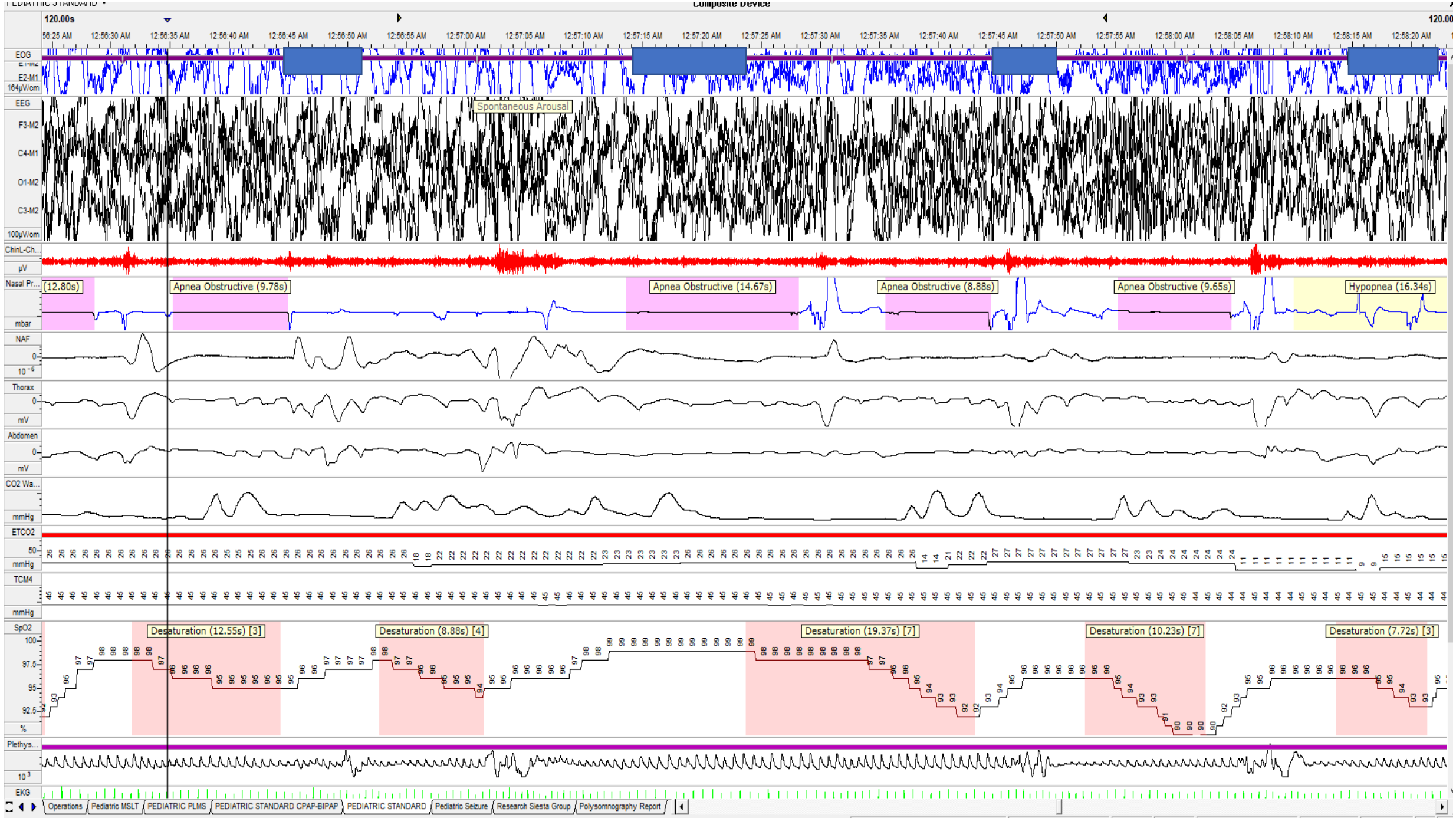
EOG
F2-M1
235µV/cm
EEG
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
ChinL-Ch...
µV
Nasal Pr...
mbar
NAF
10⁻⁶
Resp.Mo...
Thorax
Abdomen
.344mV/cm
CO2 Wa...
25
mmHg
ETCO2
50
mmHg
EKG
1.15mV/cm
Plethys...
10³
SpO2
97.5
95
92.5
90
87.5
%
Snore_DR
0
Operations
Pediatric MSLT
PEDIATRIC PLMS
PEDIATRIC STANDARD CPAP-BIPAP
PEDIATRIC STANDARD
Pediatric Seizure
Polysomnography Report
Technote Report


PEDIATRIC STANDARD
Composite Device
120.00s
EOG
E1-M2
E2-M1
100µV/cm
EEG
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
ChinL-Ch...
µV
Hypopnea Arousal
Nasal Pr...
Hypopnea (16.73s)
mbar
NAF
Resp.Mo...
Thorax
Abdomen
38.9µV/cm
CO2
mmHg
Snore_DR
µbar
ETCO2
mmHg
TCM4
mmHg
EKG
1.41mV/cm
Plethys...
SpO2
Desaturation (23.16s) [3]
Operations
EmblaPSG
EmblaResp
EmblaPSG CalTest
PEDIATRIC STANDARD
PEDIATRIC STANDARD CPAP-BIPAP
Polysomnography Report


Composite Device
120.00s
EOG
E2-M1
164µV/cm
EEG
Spontaneous Arousal
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
ChinL-Ch...
µV
Nasal Pr...
(12.80s)
Apnea Obstructive (9.78s)
Apnea Obstructive (14.67s)
Apnea Obstructive (8.88s)
Apnea Obstructive (9.65s)
Hypopnea (16.34s)
mbar
NAF
Thorax
Abdomen
mV
CO2 Wa...
mmHg
ETCO2
TCM4
SpO2
Desaturation (12.55s) [3]
Desaturation (8.88s) [4]
Desaturation (19.37s) [7]
Desaturation (10.23s) [7]
Desaturation (7.72s) [3]
%
Plethys...
EKG
Operations
Pediatric MSLT
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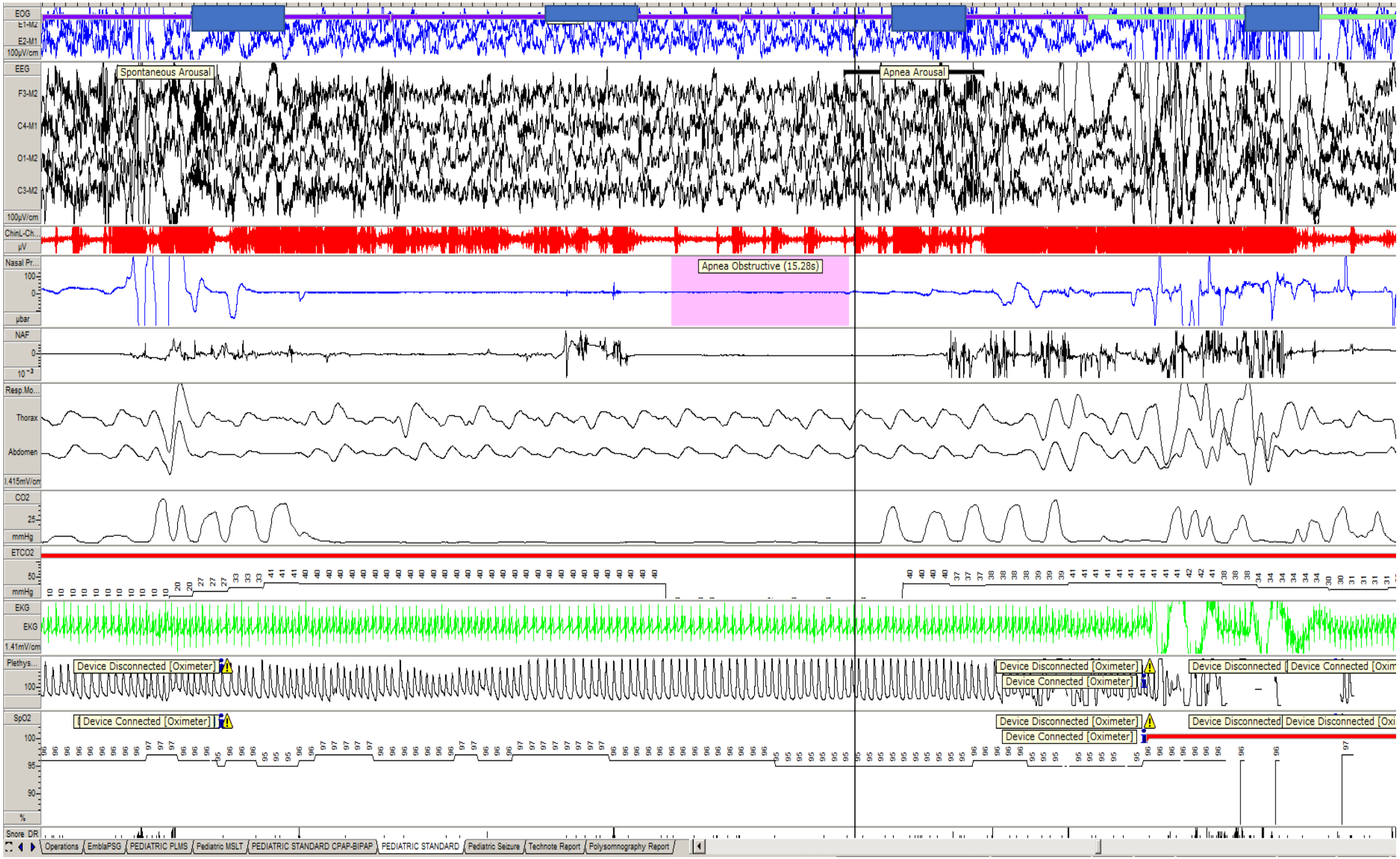
EOG
E1-M2
E2-M1
100µV/cm
EEG
Spontaneous Arousal
Apnea Arousal
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
ChinL-Ch...
µV
Nasal Pr...
100
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µbar
Apnea Obstructive (15.28s)
NAF
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10⁻³
Resp.Mo...
Thorax
Abdomen
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CO2
25
mmHg
ETCO2
50
mmHg
EKG
EKG
1.41mV/cm
Plethys...
100
Device Disconnected [Oximeter]
Device Connected [Oximeter]
SpO2
100
95
90
%
Snore DR
Operations
EmblaPSG
PEDIATRIC PLMS
Pediatric MSLT
PEDIATRIC STANDARD CPAP-BIPAP
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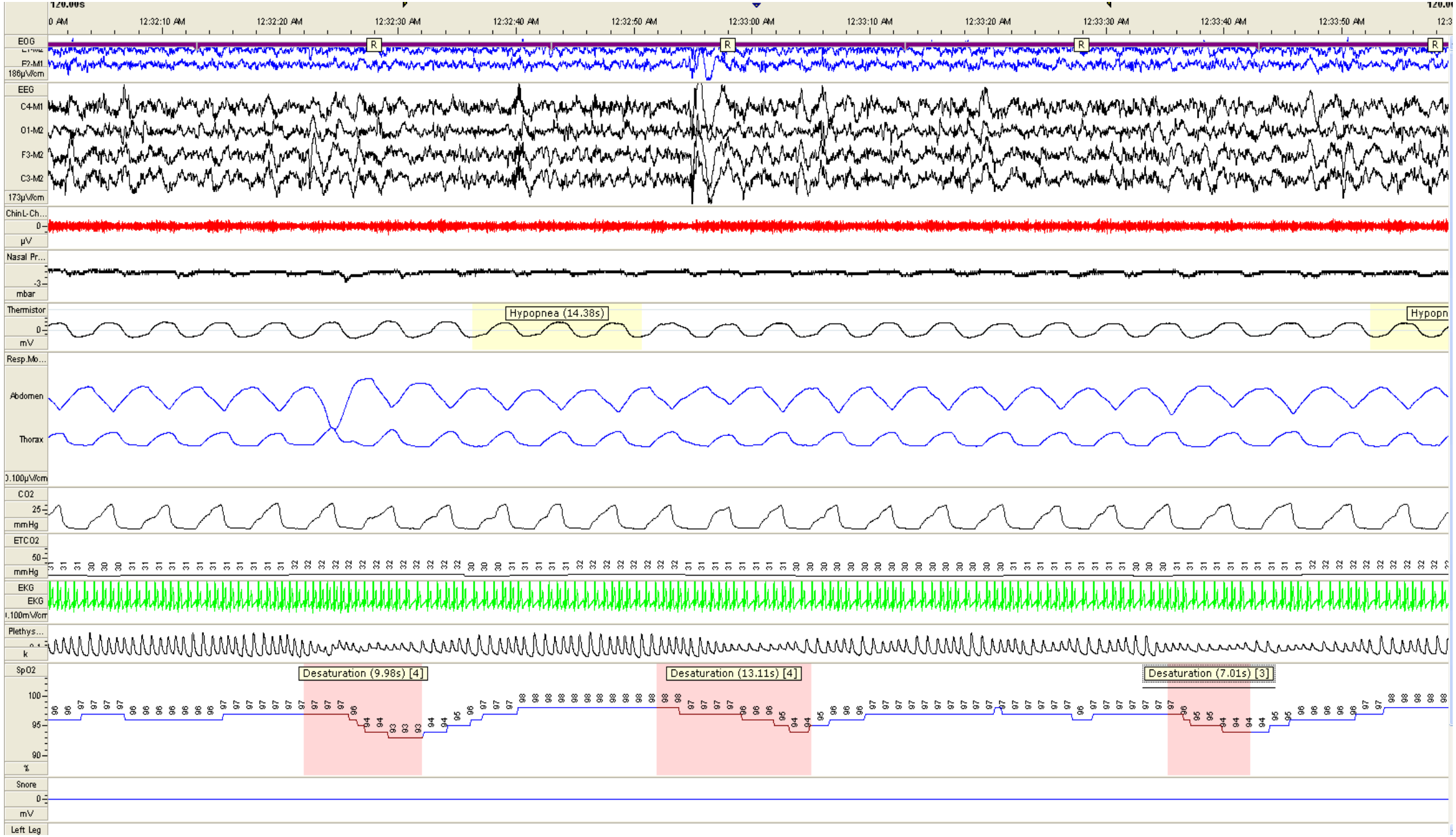
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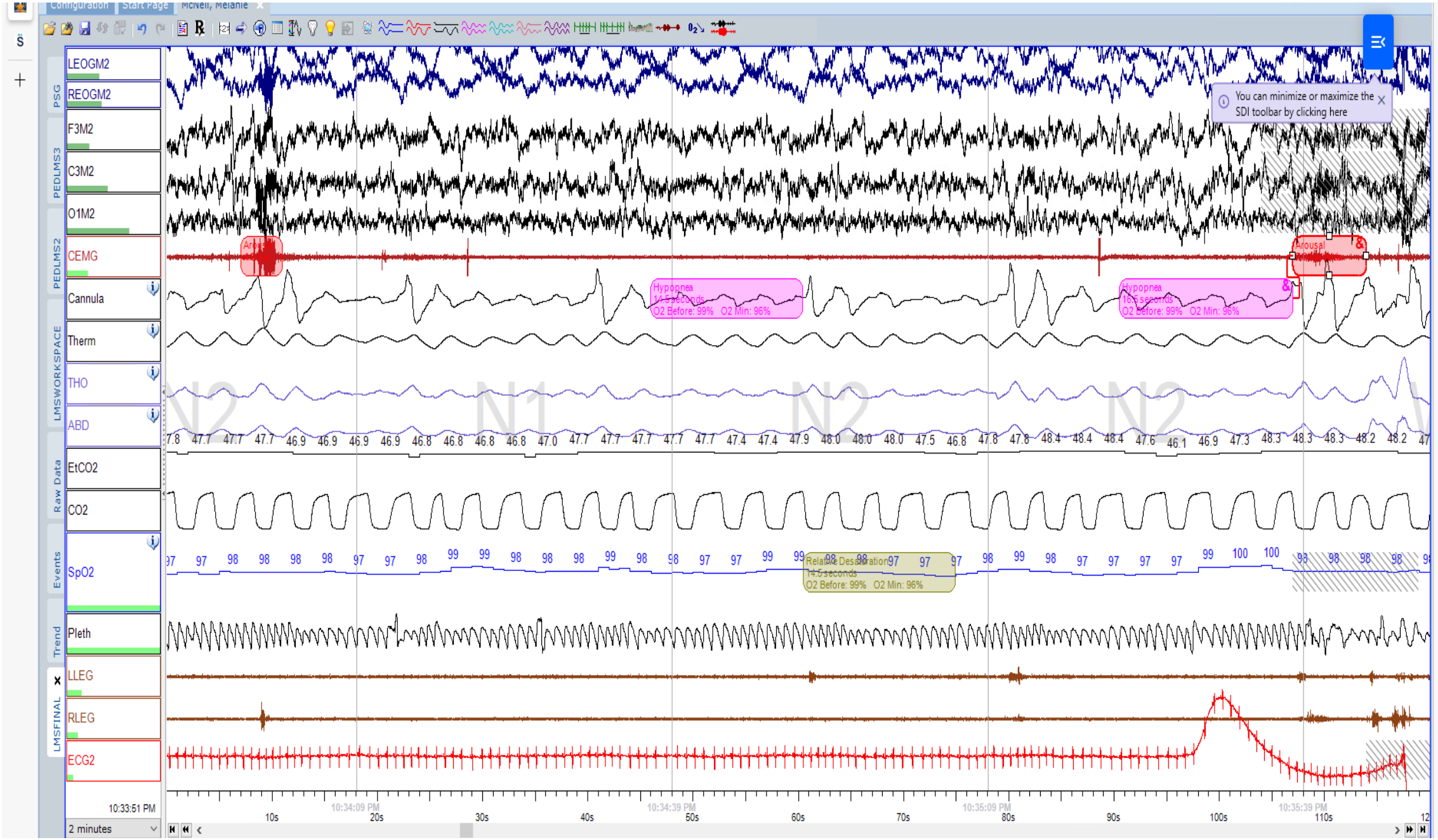
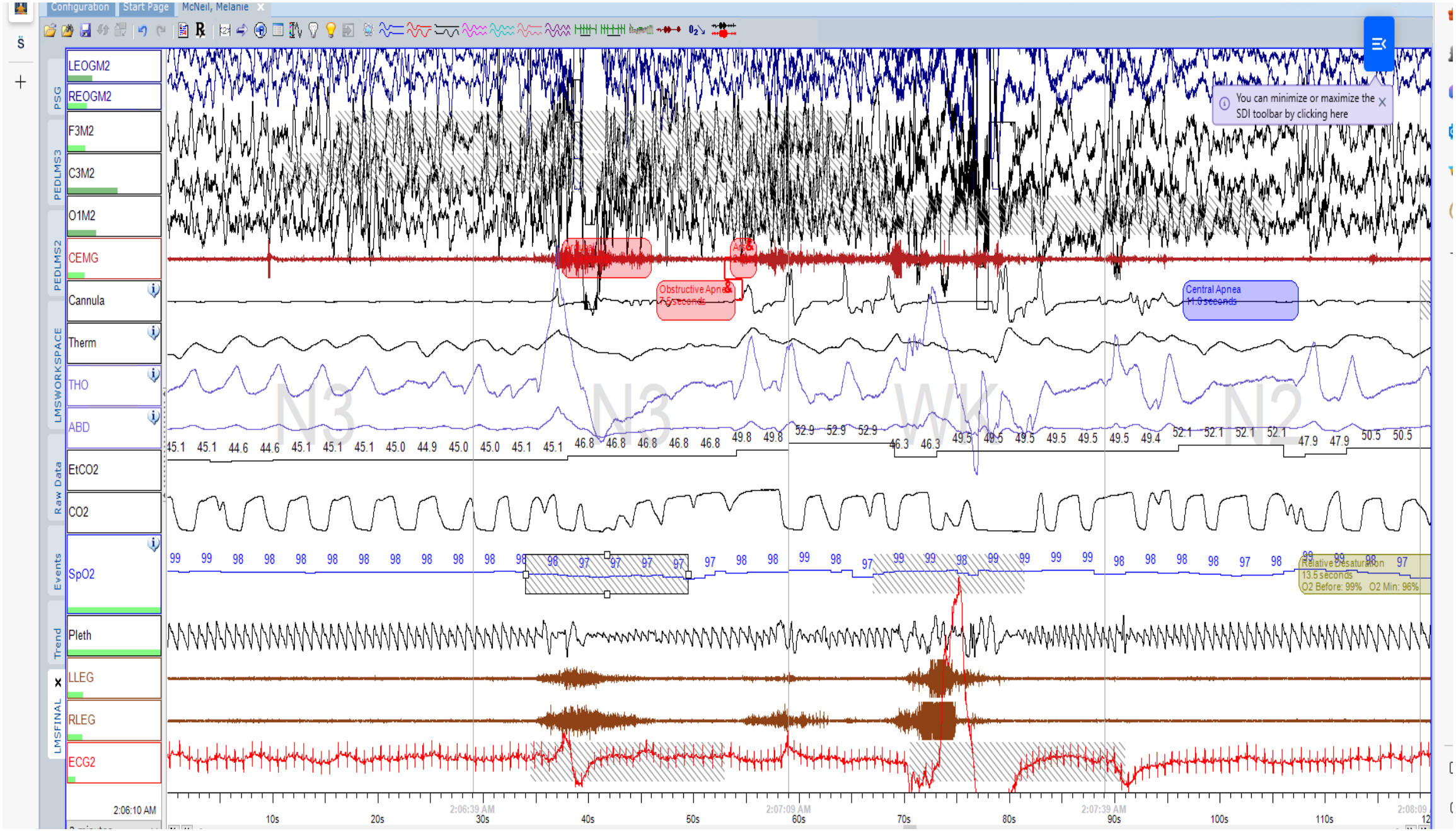
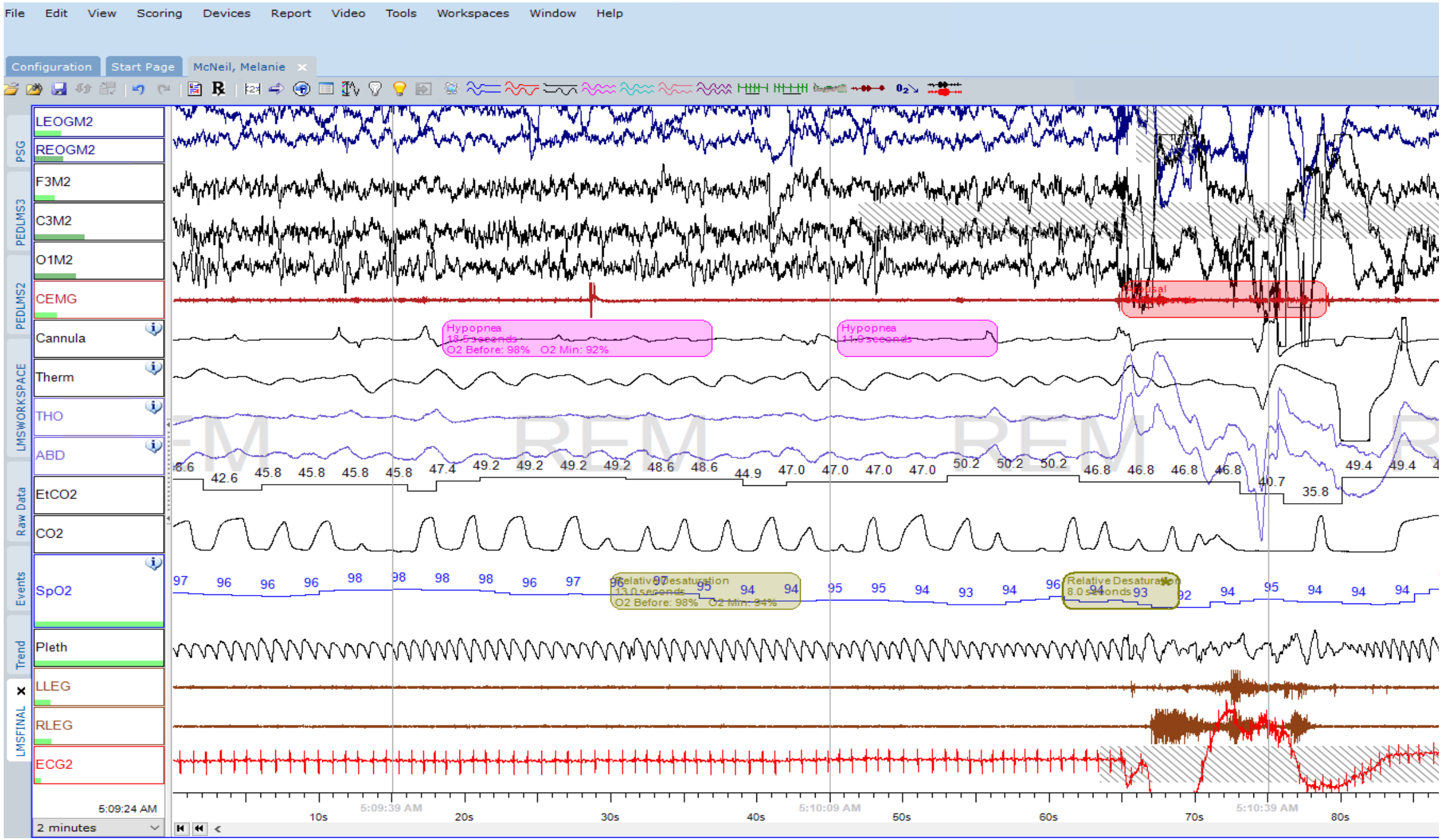
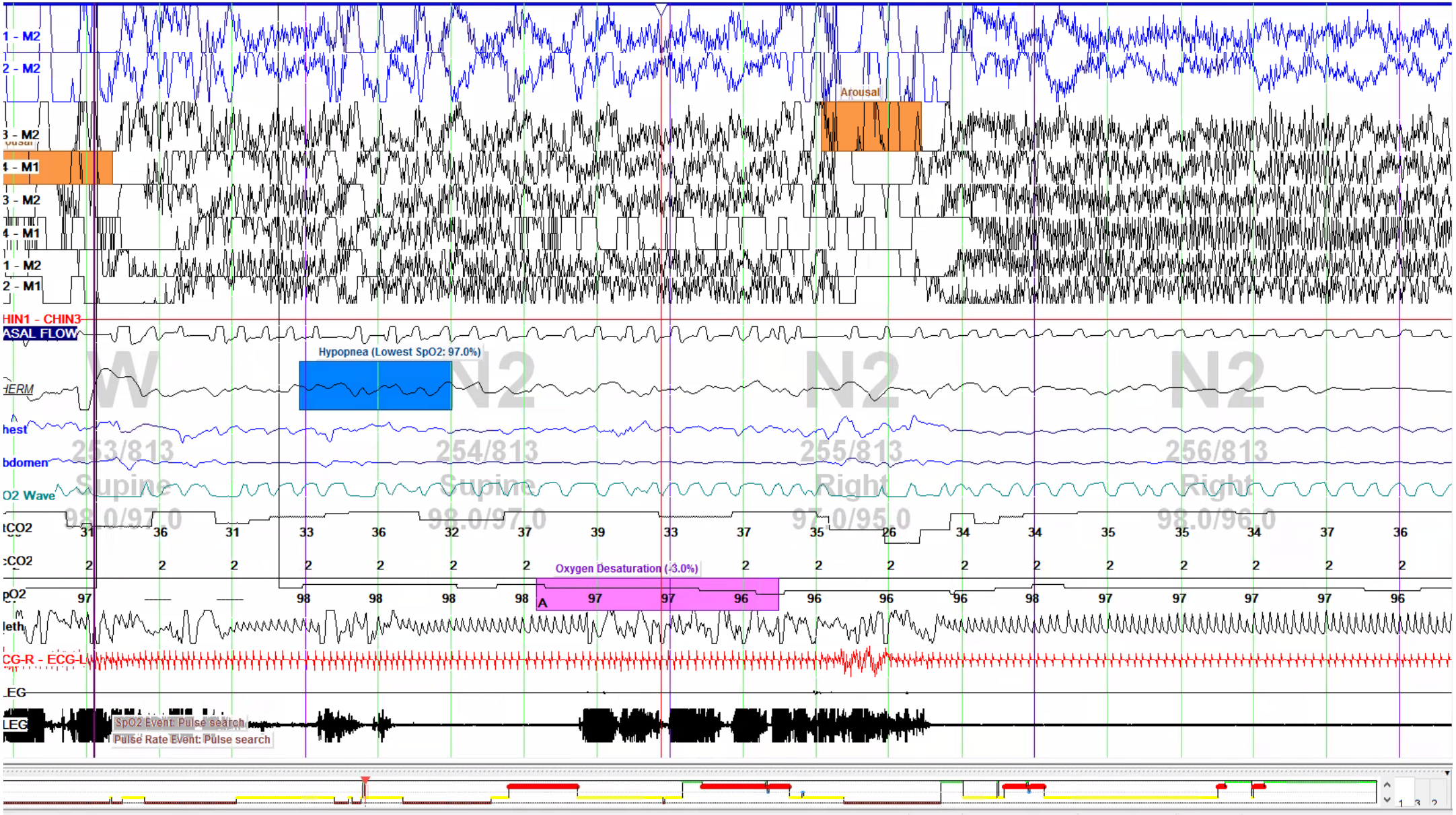
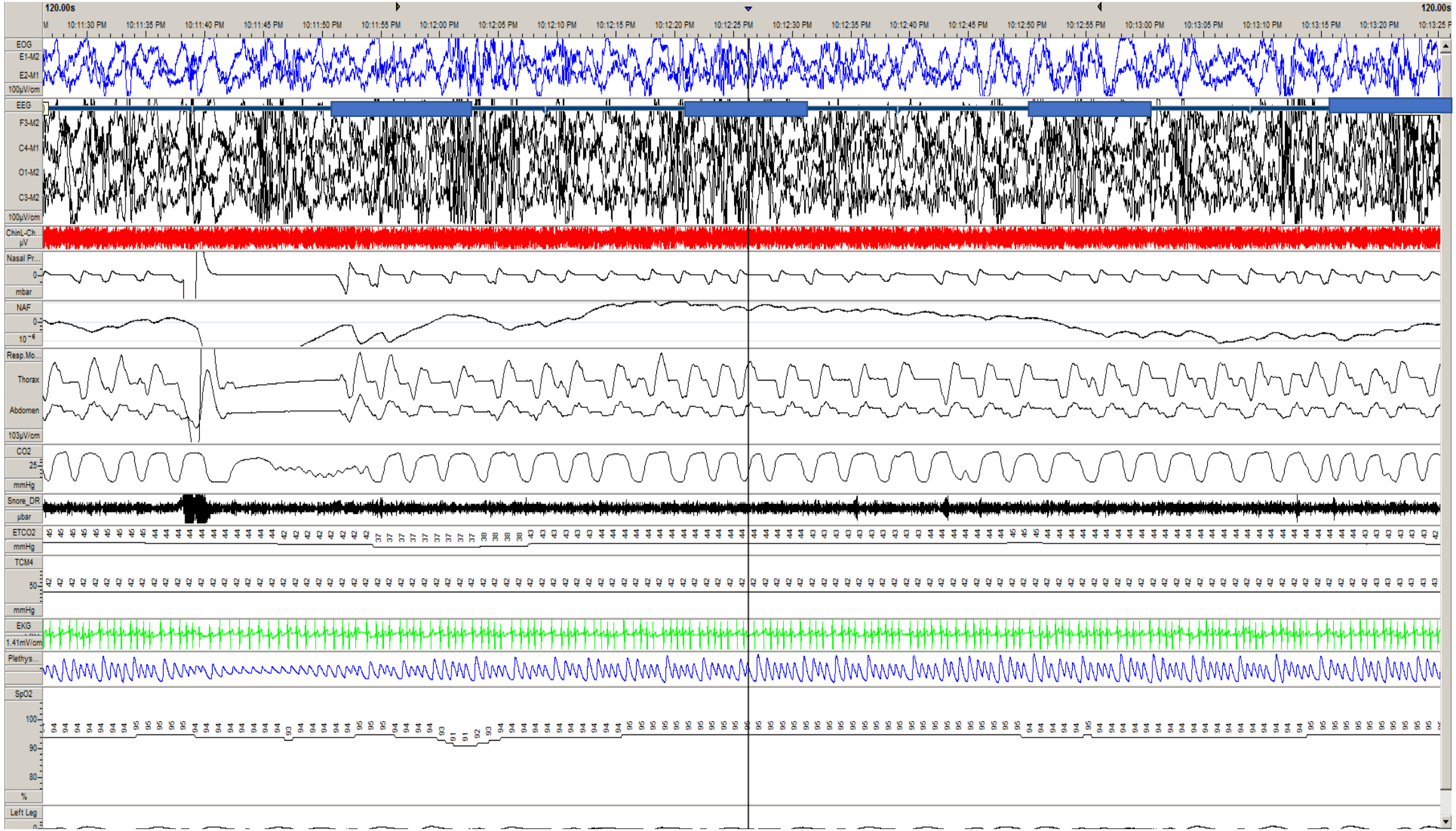
12:33:40 AM
12:33:50 AM
EOG
186µV/cm
EEG
C4-M1
O1-M2
F3-M2
C3-M2
173µV/cm
ChinL-Ch...
µV
Nasal Pr...
mbar
Thermistor
mV
Hypopnea (14.38s)
Hypopn
Resp.Mo...
Abdomen
Thorax
CO2
mmHg
ETCO2
EKG
Plethys...
SpO2
%
Desaturation (9.98s) [4]
Desaturation (13.11s) [4]
Desaturation (7.01s) [3]
Snore
Left Leg

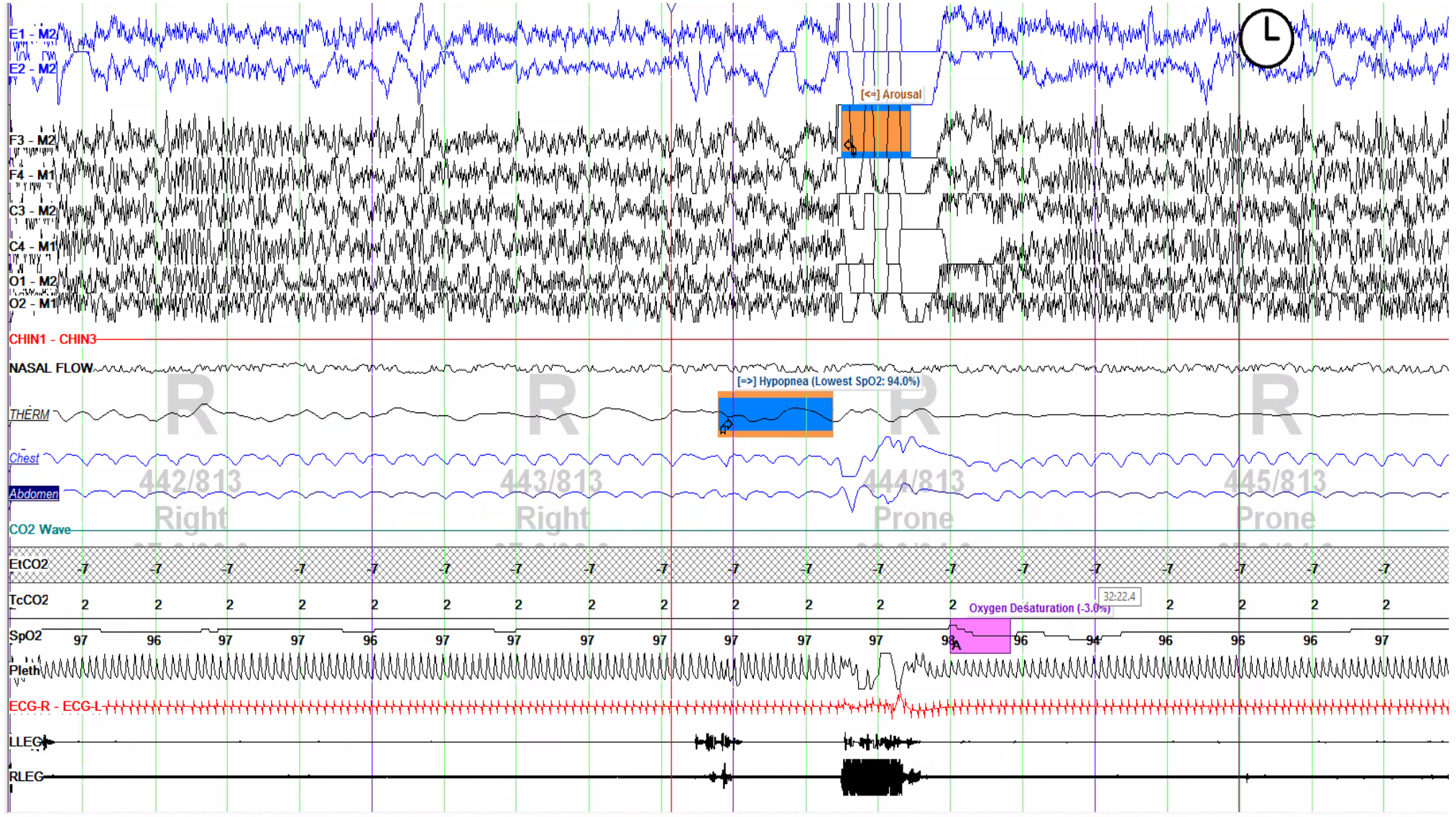

Configuration
Start Page
McNeil, Melanie
LEOGM2
REOGM2
F3M2
C3M2
O1M2
CEMG
Cannula
Therm
THO
ABD
EtCO2
CO2
SpO2
Pleth
LLEG
RLEG
ECG2
PSG
PEDLMS3
PEDLMS2
LMSWORKSPACE
Raw Data
Events
Trend
LMSFINAL
You can minimize or maximize the SDI toolbar by clicking here
Hypopnea
14.5 seconds
O2 Before: 99% O2 Min: 96%
Arousal
Hypopnea
16.5 seconds
O2 Before: 99% O2 Min: 96%
Relative Desaturation
14.5 seconds
O2 Before: 99% O2 Min: 96%
N2 N1 N2 N2
10:33:51 PM
2 minutes
10:34:09 PM
10:34:39 PM
10:35:09 PM
10:35:39 PM

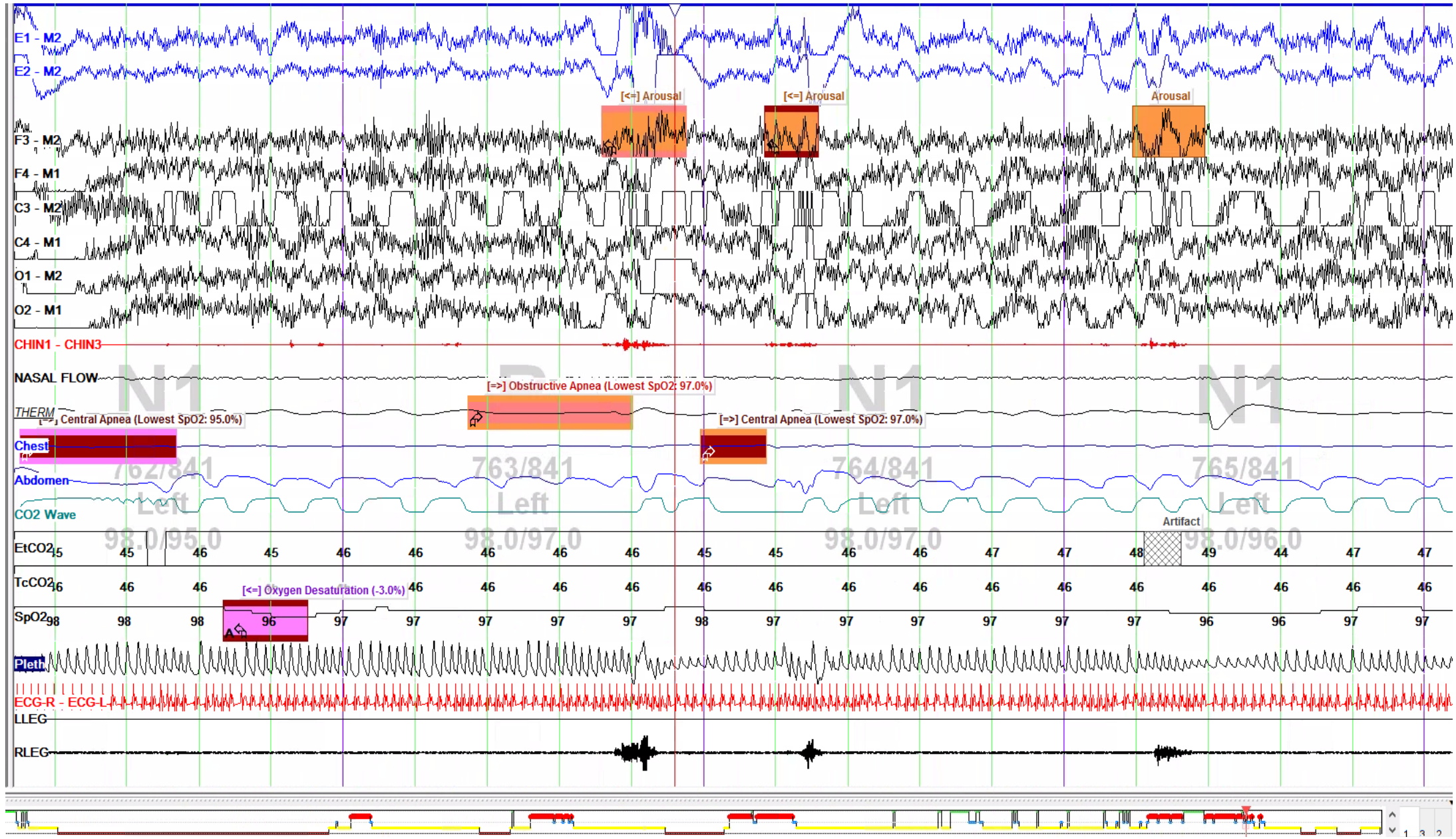

Configuration
Start Page
McNeil, Melanie
LEOGM2
REOGM2
F3M2
C3M2
O1M2
CEMG
Cannula
Therm
THO
ABD
EtCO2
CO2
SpO2
Pleth
LLEG
RLEG
ECG2
PSG
PEDLMS3
PEDLMS2
LMSWORKSPACE
Raw Data
Events
Trend
LMSFINAL
You can minimize or maximize the SDI toolbar by clicking here
Obstructive Apnea
Central Apnea
11.0 seconds
Relative Desaturation
13.5 seconds
O2 Before: 99%
O2 Min: 96%
N3
N3
WK
N2
2:06:10 AM
2:06:39 AM
2:07:09 AM
2:07:39 AM
2:08:09
10s
20s
30s
40s
50s
60s
70s
80s
90s
100s
110s

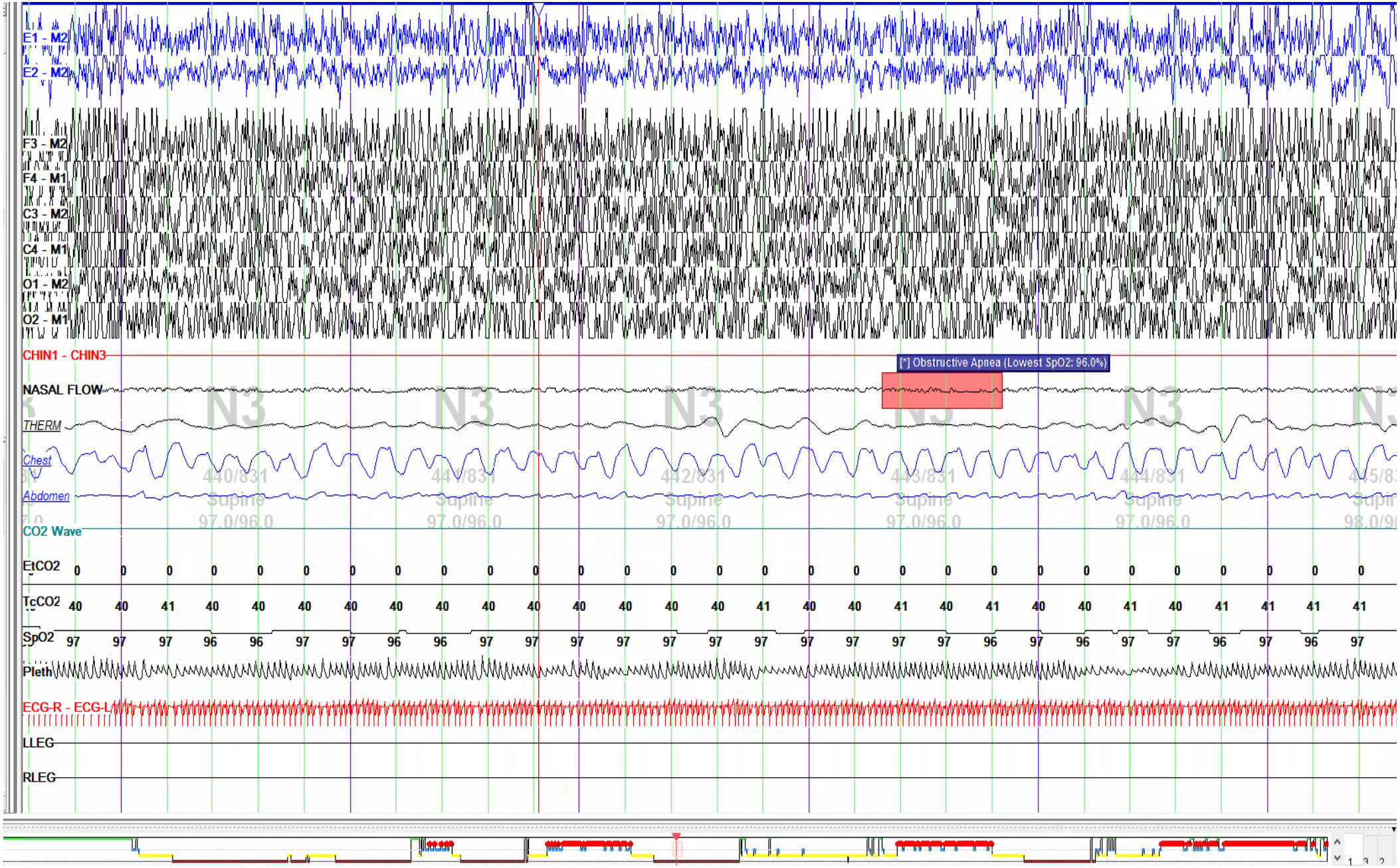

File
Edit
View
Scoring
Devices
Report
Video
Tools
Workspaces
Window
Help
Configuration
Start Page
McNeil, Melanie
PSG
PEDLMS3
PEDLMS2
LMSWORKSPACE
Raw Data
Events
Trend
LMSFINAL
LEOGM2
REOGM2
F3M2
C3M2
O1M2
CEMG
Cannula
Therm
THO
ABD
EtCO2
CO2
SpO2
Pleth
LLEG
RLEG
ECG2
Hypopnea
18.5 seconds
O2 Before: 98% O2 Min: 92%
Hypopnea
11.0 seconds
Relative Desaturation
13.0 seconds
O2 Before: 98% O2 Min: 94%
Relative Desaturation
8.0 seconds
5:09:24 AM
5:09:39 AM
5:10:09 AM
5:10:39 AM
10s
20s
30s
40s
50s
60s
70s
80s
2 minutes


Arousal
Hypopnea (Lowest SpO2: 97.0%)
Oxygen Desaturation (-3.0%)
W
N2
N2
N2
253/813
Supine
98.0/97.0
254/813
Supine
98.0/97.0
255/813
Right
97.0/95.0
256/813
Right
98.0/96.0
SpO2 Event: Pulse search
Pulse Rate Event: Pulse search


120.00s
120.00s
10:11:30 PM
10:11:35 PM
10:11:40 PM
10:11:45 PM
10:11:50 PM
10:11:55 PM
10:12:00 PM
10:12:05 PM
10:12:10 PM
10:12:15 PM
10:12:20 PM
10:12:25 PM
10:12:30 PM
10:12:35 PM
10:12:40 PM
10:12:45 PM
10:12:50 PM
10:12:55 PM
10:13:00 PM
10:13:05 PM
10:13:10 PM
10:13:15 PM
10:13:20 PM
EOG
E1-M2
E2-M1
100µV/cm
EEG
F3-M2
C4-M1
O1-M2
C3-M2
100µV/cm
ChinL-Ch...
µV
Nasal Pr...
0
mbar
NAF
0
10⁻⁶
Resp.Mo...
Thorax
Abdomen
103µV/cm
CO2
25
mmHg
Snore_DR
µbar
ETCO2
mmHg
TCM4
50
mmHg
EKG
1.41mV/cm
Plethys...
SpO2
100
90
80
%
Left Leg


E1 - M2
E2 - M2
[<=] Arousal
F3 - M2
F4 - M1
C3 - M2
C4 - M1
O1 - M2
O2 - M1
CHIN1 - CHIN3
NASAL FLOW
[=>] Hypopnea (Lowest SpO2: 94.0%)
THERM
Chest
Abdomen
CO2 Wave
442/813
Right
443/813
Right
444/813
Prone
445/813
Prone
EtCO2
TcCO2
32:22.4
Oxygen Desaturation (-3.0%)
SpO2
Pleth
ECG-R - ECG-L
LLEG
RLEG


E1 - M2
E2 - M2
F3 - M2
F4 - M1
C3 - M2
C4 - M1
O1 - M2
O2 - M1
CHIN1 - CHIN3
NASAL FLOW
THERM
Chest
Abdomen
CO2 Wave
EtCO2
TcCO2
SpO2
Pleth
ECG-R - ECG-L
LLEG
RLEG
[<=] Arousal
[<=] Arousal
Arousal
[=>] Obstructive Apnea (Lowest SpO2: 97.0%)
[=>] Central Apnea (Lowest SpO2: 95.0%)
[=>] Central Apnea (Lowest SpO2: 97.0%)
[<=] Oxygen Desaturation (-3.0%)
Artifact
N1
762/841
763/841
764/841
765/841
Left
98.0/95.0
98.0/97.0
98.0/97.0
98.0/96.0


E1 - M2
E2 - M2
F3 - M2
F4 - M1
C3 - M2
C4 - M1
O1 - M2
O2 - M1
CHIN1 - CHIN3
[*] Obstructive Apnea (Lowest SpO2: 96.0%)
NASAL FLOW
THERM
Chest
Abdomen
CO2 Wave
EtCO2
TcCO2
SpO2
Pleth
ECG-R - ECG-L
LLEG
RLEG
N3
Supine