

Intracranial Pressure Monitoring in Intracranial Hypotension

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- Continuous ICP Monitoring Setup
- cICP in skull based CSF leaks
- cICP normative data in upright position
- cICP in spontaneous spinal CSF leaks
- cICP guided percutaneous intervention

- Units: 1 mm Hg = 1.3 cm of Water

Limitations of measuring opening pressure during lumbar puncture

- Improper positioning, especially when performed under fluoroscopic guidance
- Diurnal variation, increased pressure with sleep-disordered breathing (apnea or hypopnea)
- Hyperventilation due to anxiety and/or pain lower ICP
- Pressures often normal in lateral decubitus position – not surprising since the majority of leak patients have abnormal pressures only during upright position when they are most symptomatic

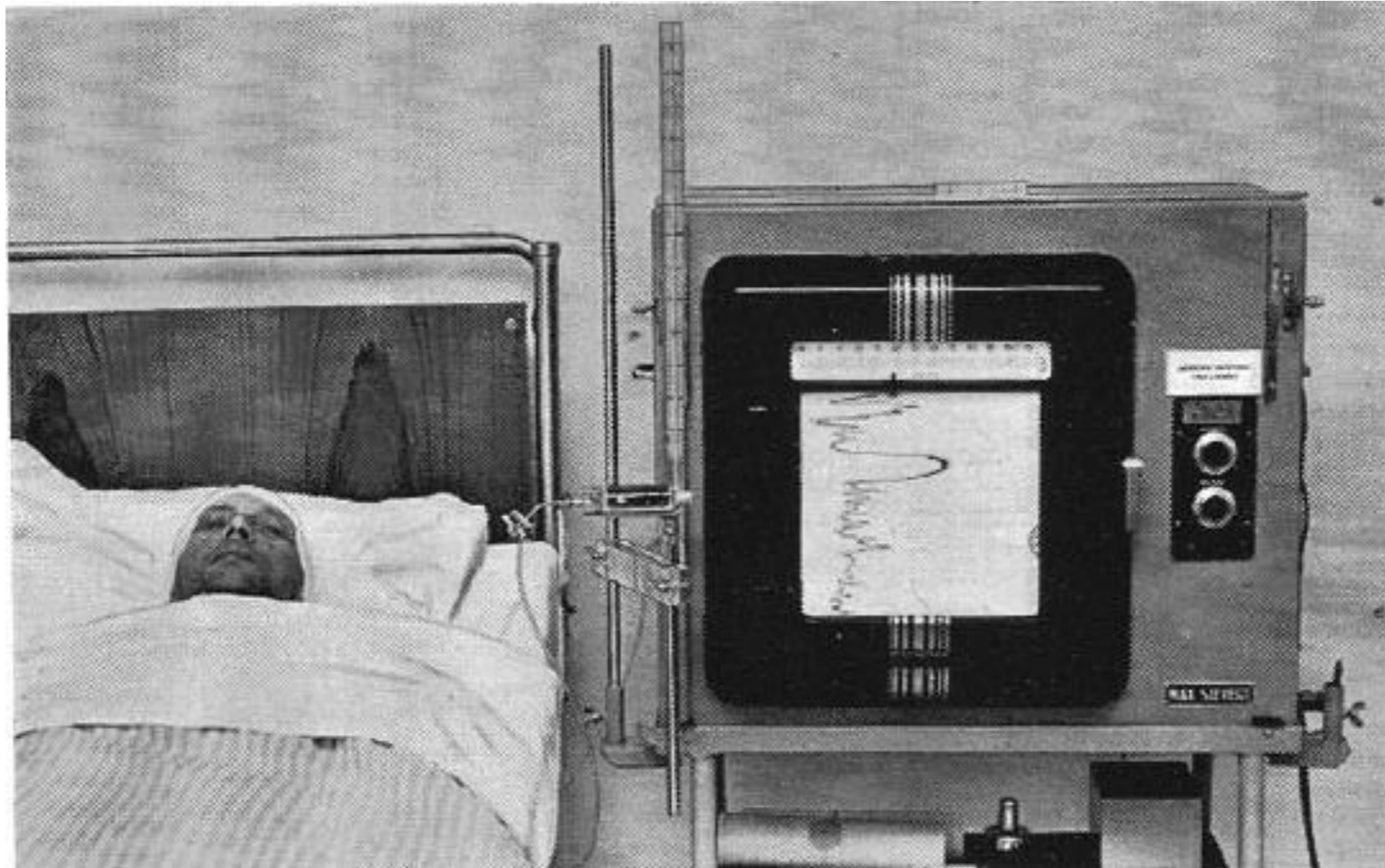
Guy's cerebrospinal manometer



- Direct measurement and graphic recording of intracranial pressure through a trephined opening was described by LEYDEN in 1866.
- KEY & RETZIUS (1875) were the first to measure CSF pressure in animals, and KNOLL (1886) produced the first graphic records CSF pressure
- Lumbar puncture as a clinical method introduced by QUINCKE in 1891

Bedside continuous CSF pressure monitoring

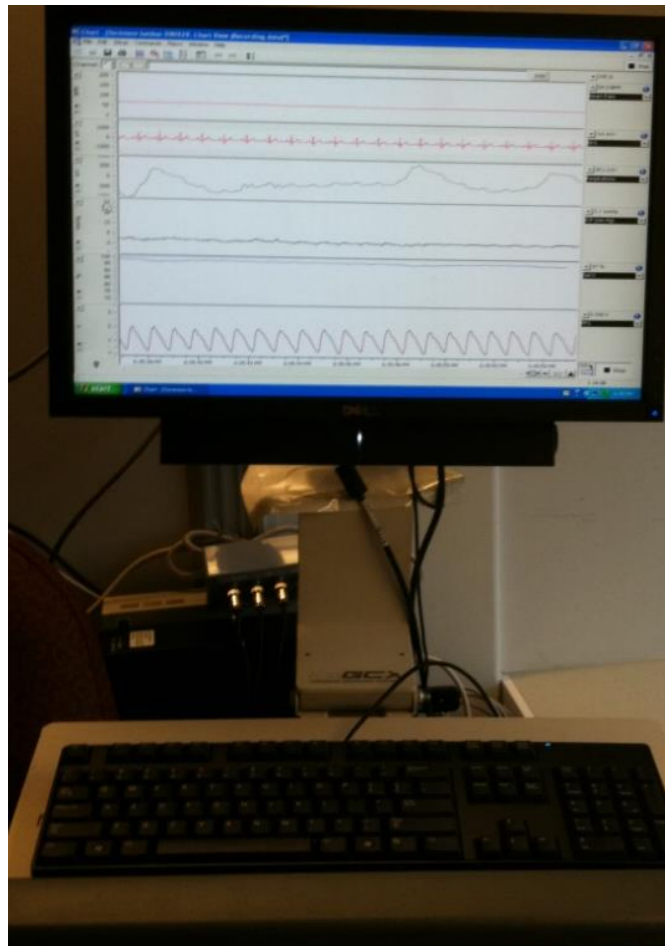
Then...



and
now...



Heart rate, EKG, respirations, and oxygen saturation are recorded in addition to CSFP referenced to the external auditory meatus. Signals are amplified and conditioned using a standard physiology monitoring system (Solar 8000M, GE Healthcare, Waukesha, WI). Analog voltages are sampled at 100 Hz and digital data are logged on a bedside computer (PowerLab data acquisition system and LabChart Pro software; ADInstruments, Colorado Springs, CO).



CSF Pressure values in mm H2O measured @ LP*

	Acute IIH	Chronic IIH	Normal Obese	Normal Lean
Average	343.9	253	167 SD 36.46	136 SD37.6
Range	200-550(100%)			
	>250 (90%)	>250 (28%)		
		200-250(44%)	200-250(25%)	
		<200 (28%)		

*no sedation, local, 22-gauge needle, <1 ml of CSF loss,
left lateral decubitus, head and legs extended, pressure recorded for 1'

Revised Criteria: Adults: 5-25 cm, Children: 5-28 cm

Normal continuous Intracranial Pressure

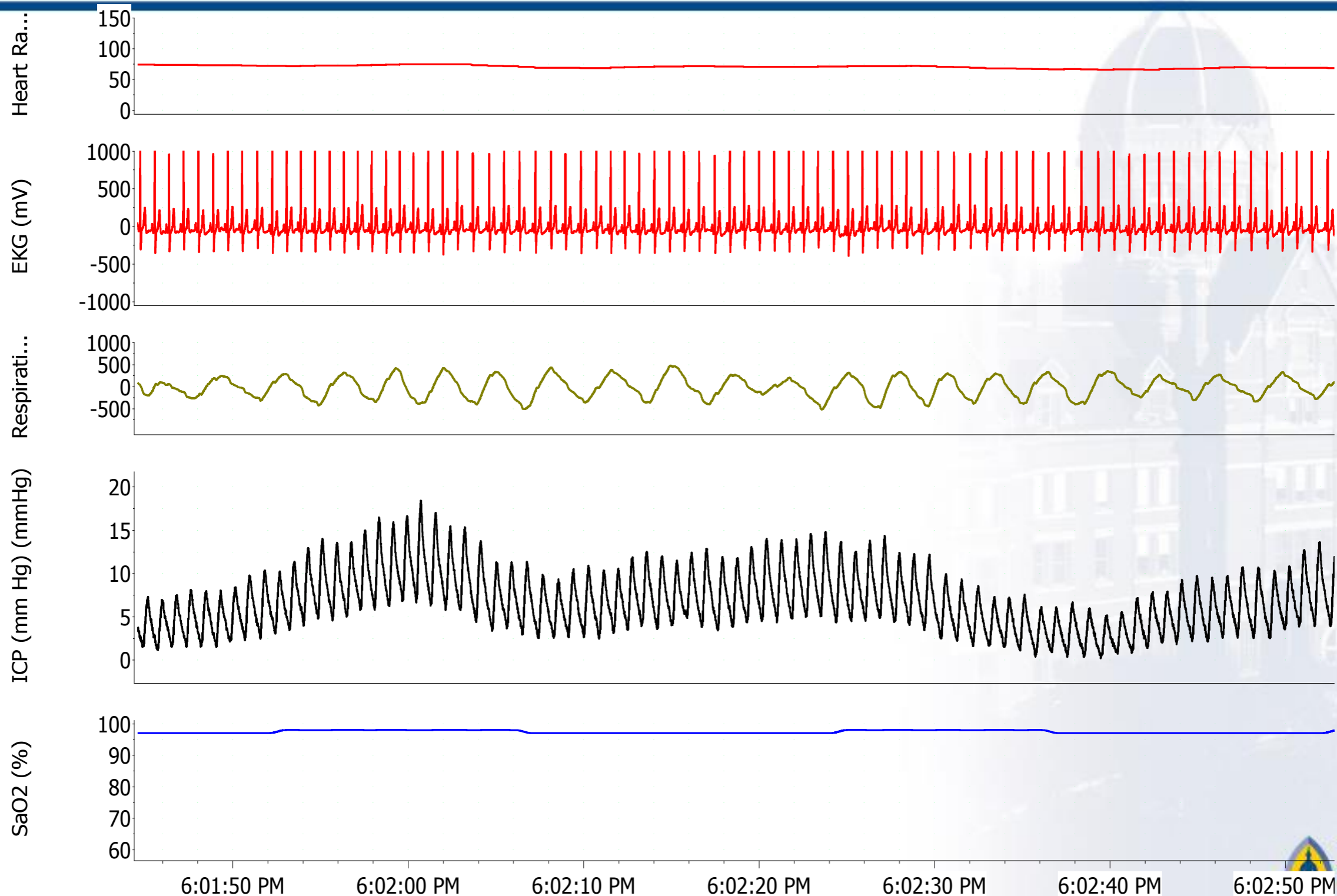


Chart Window

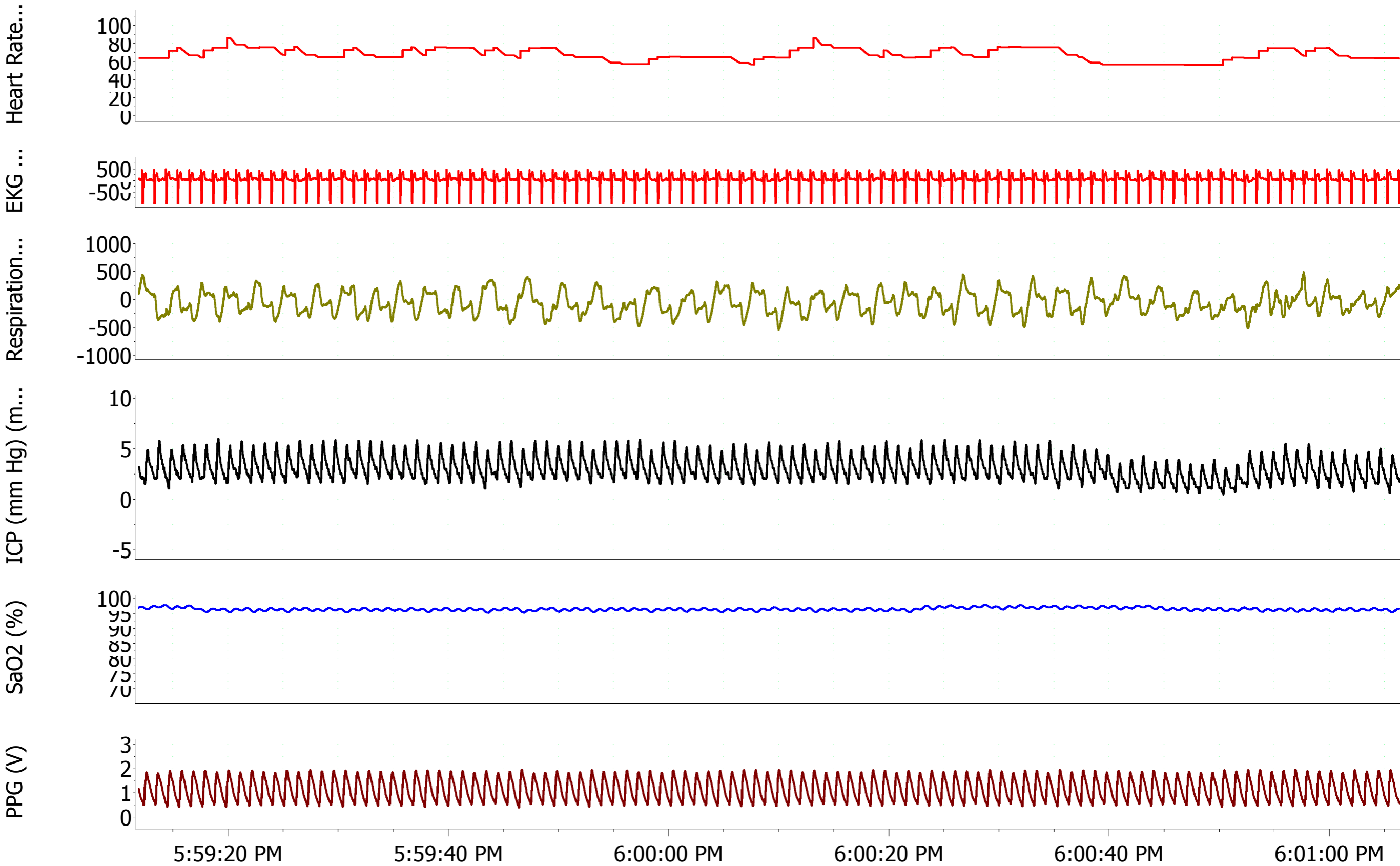


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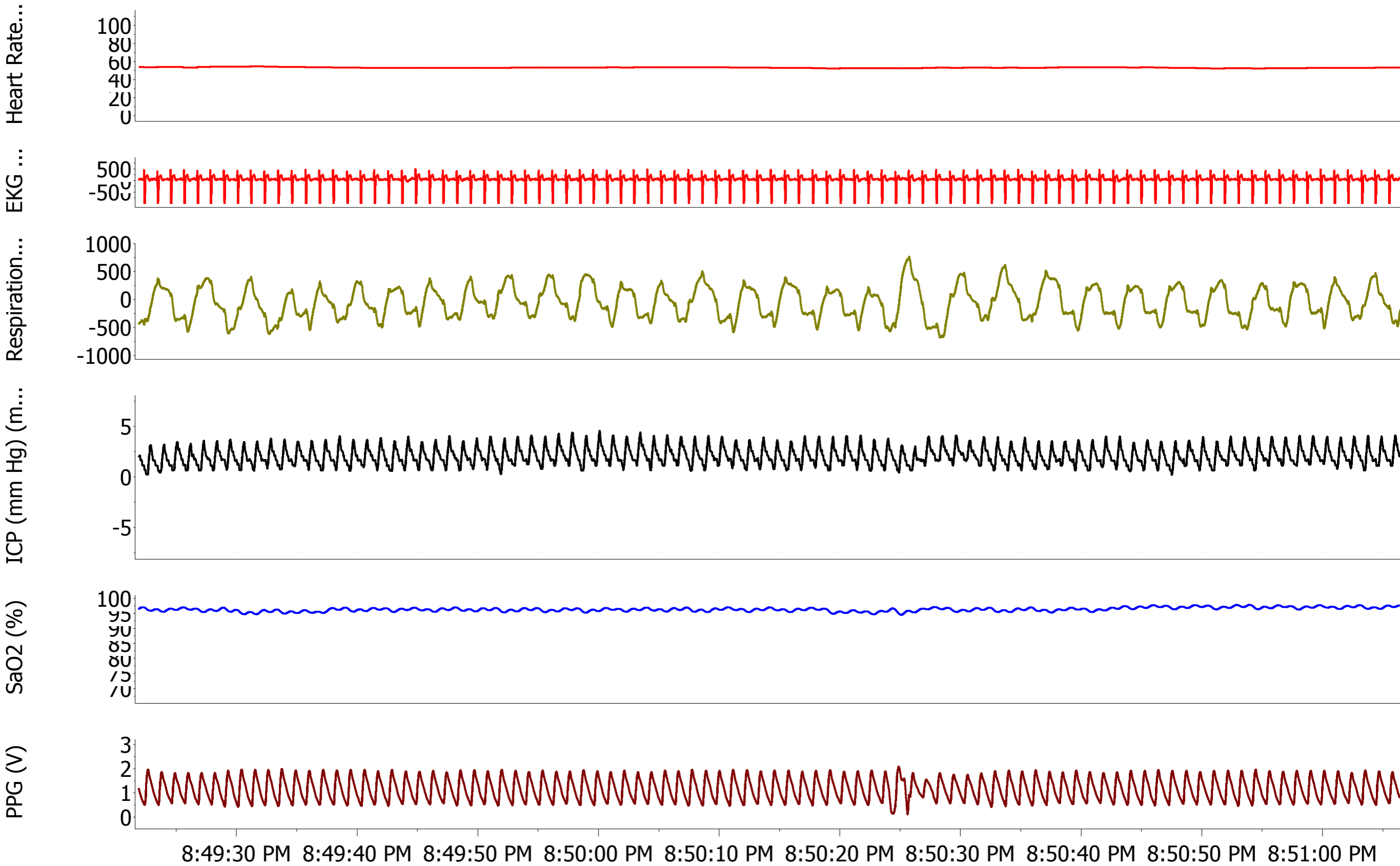


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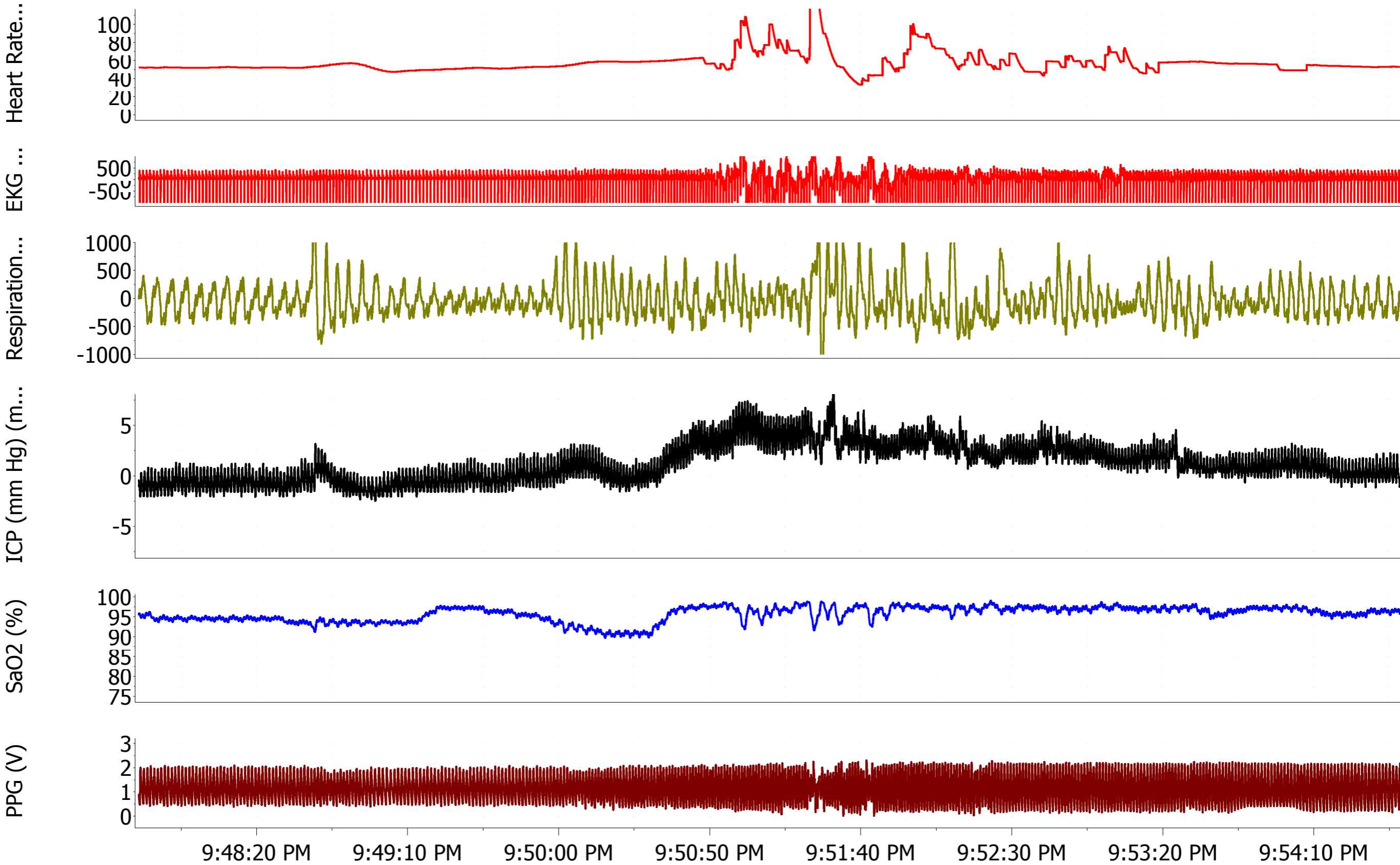


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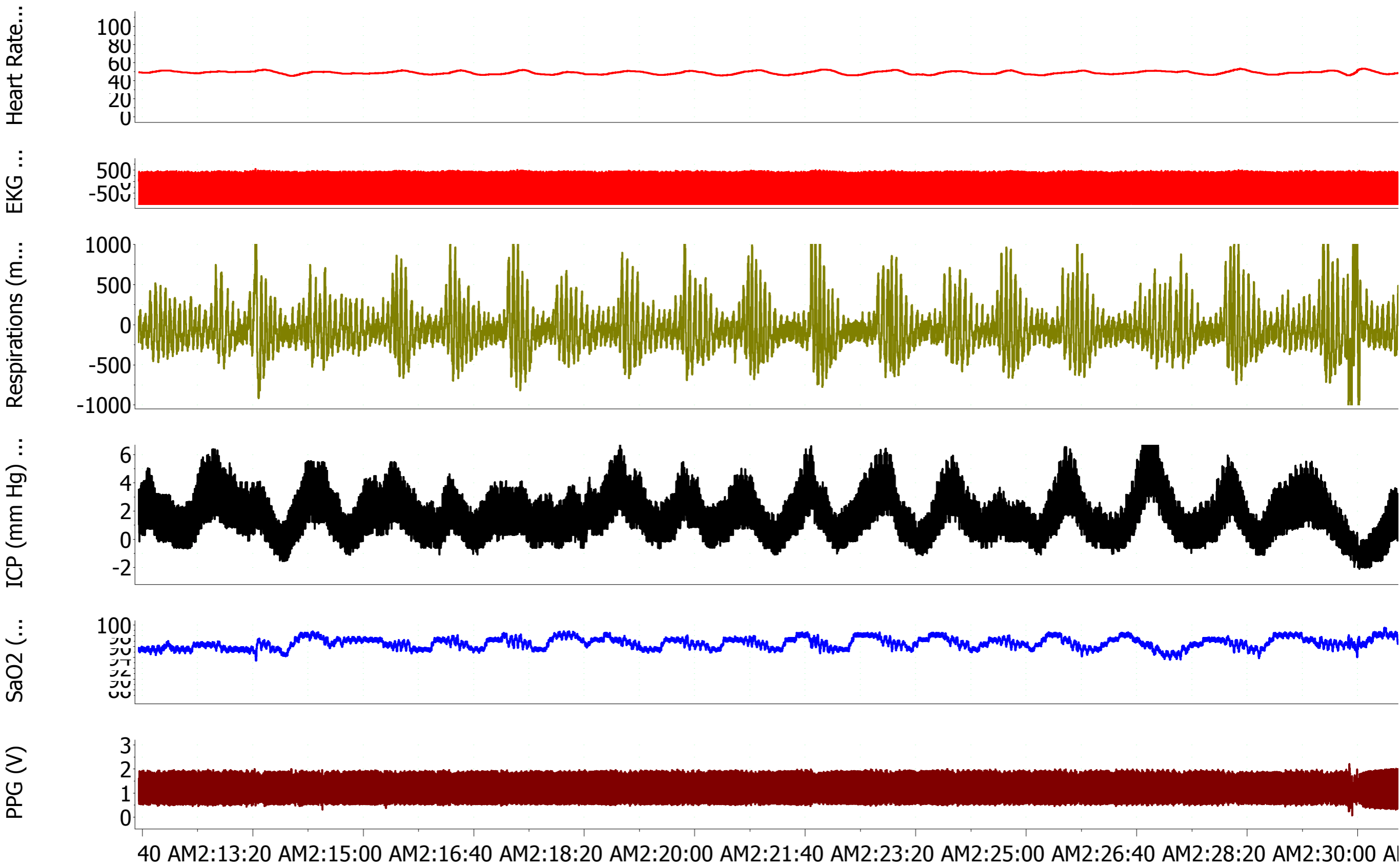
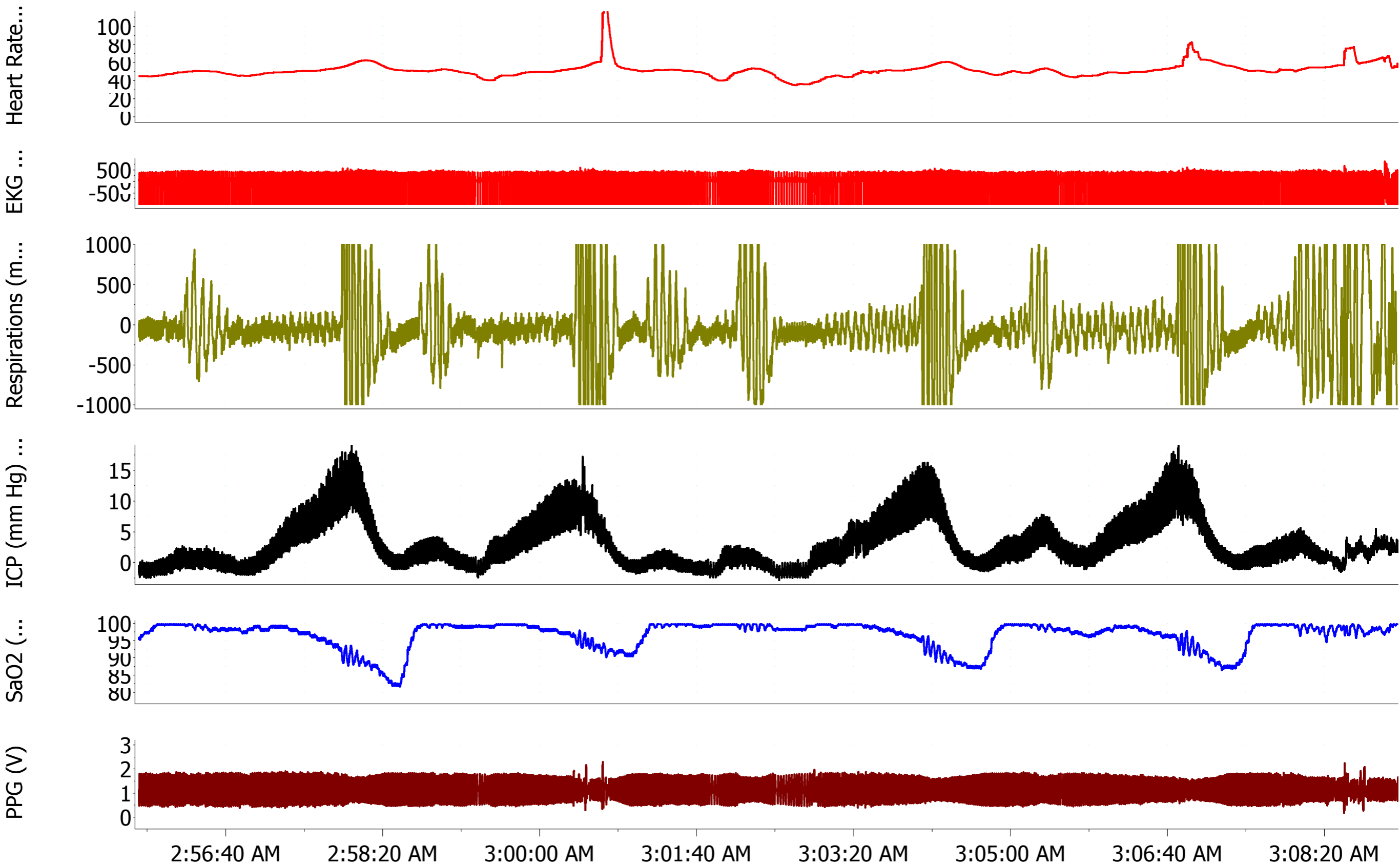
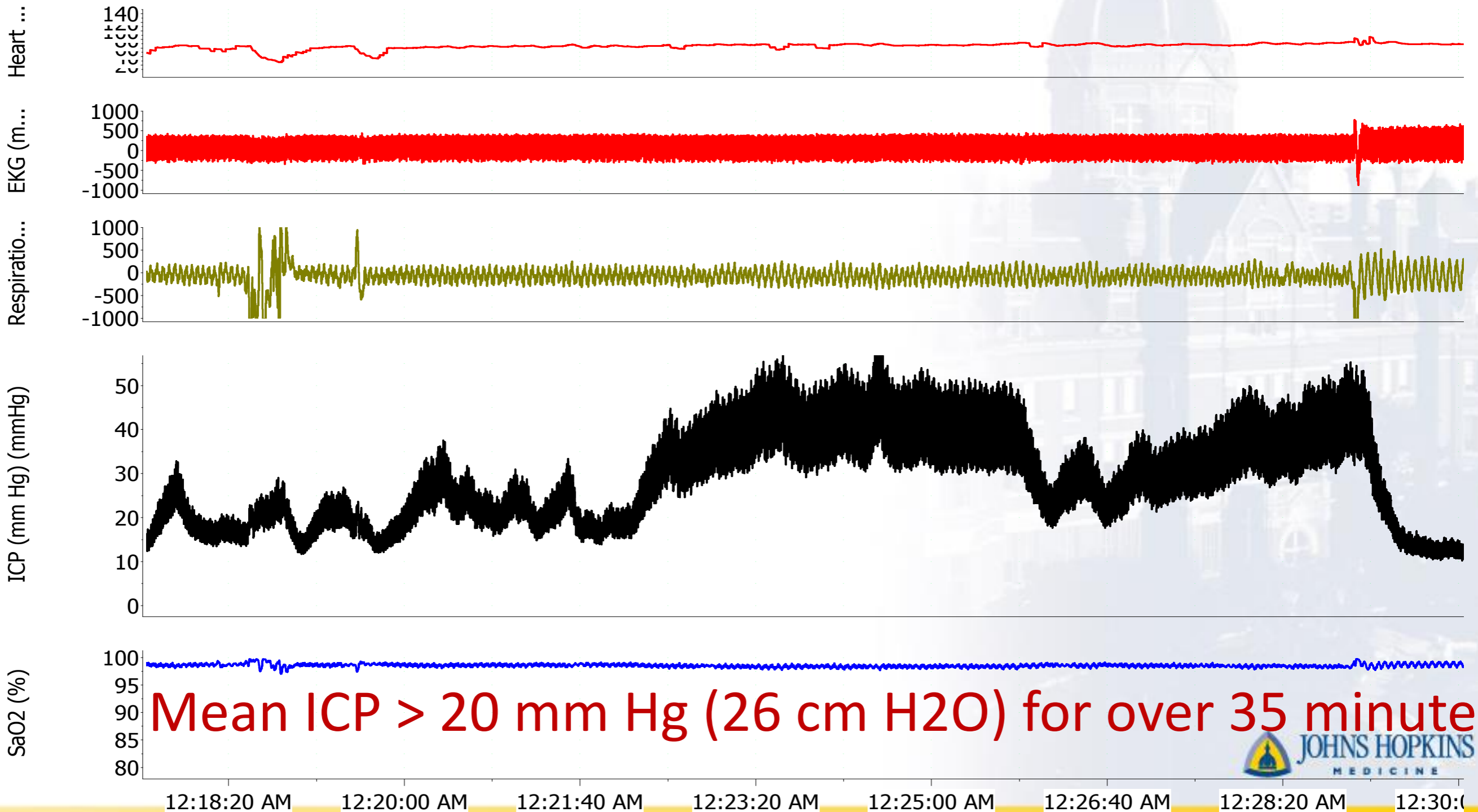


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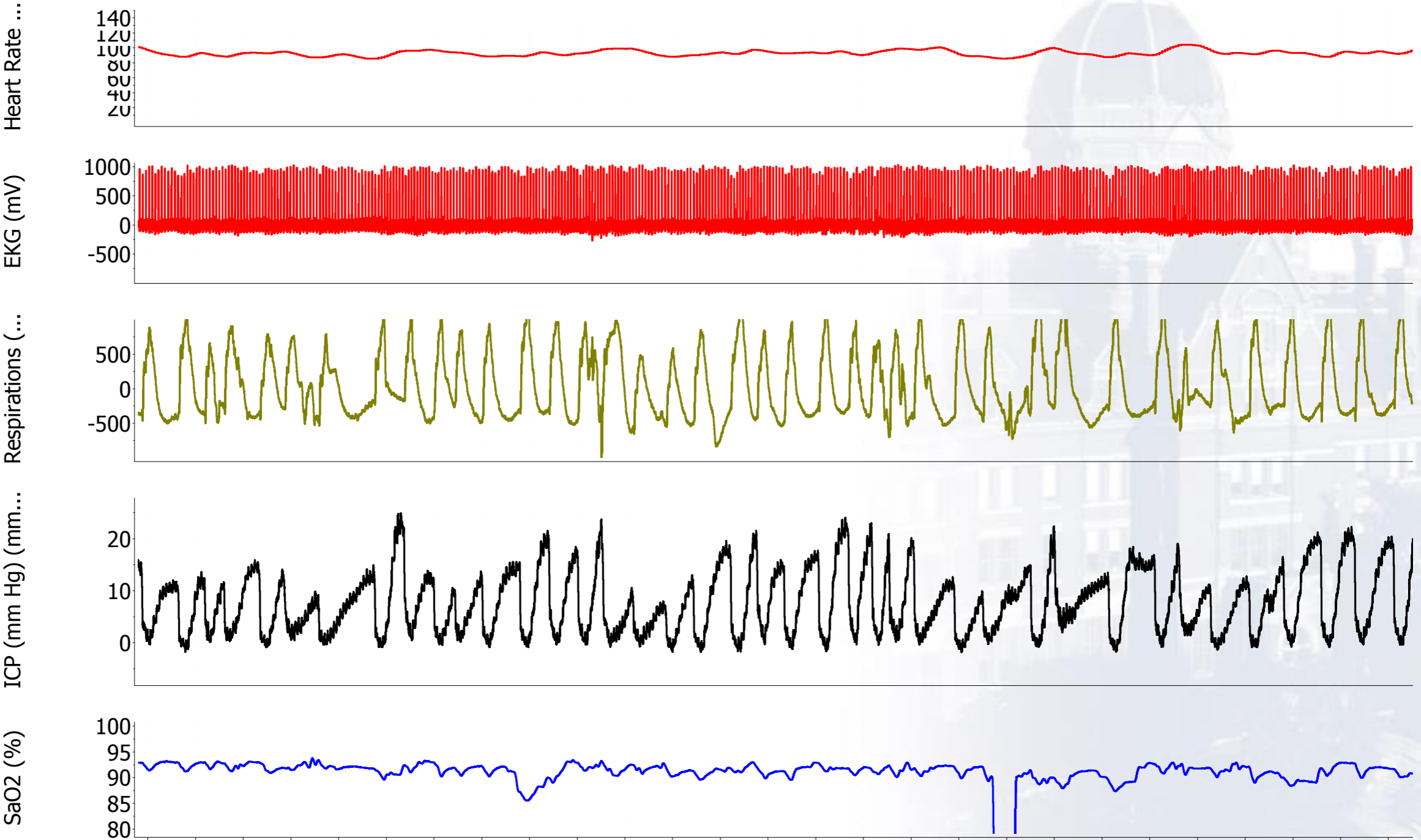
Continuous ICP Monitoring – IH (LP opening pressure: 19 cm H₂O)

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? IIHWOP, multiple shunts: Headache – 10/10, no papilledema, normal cICP recording

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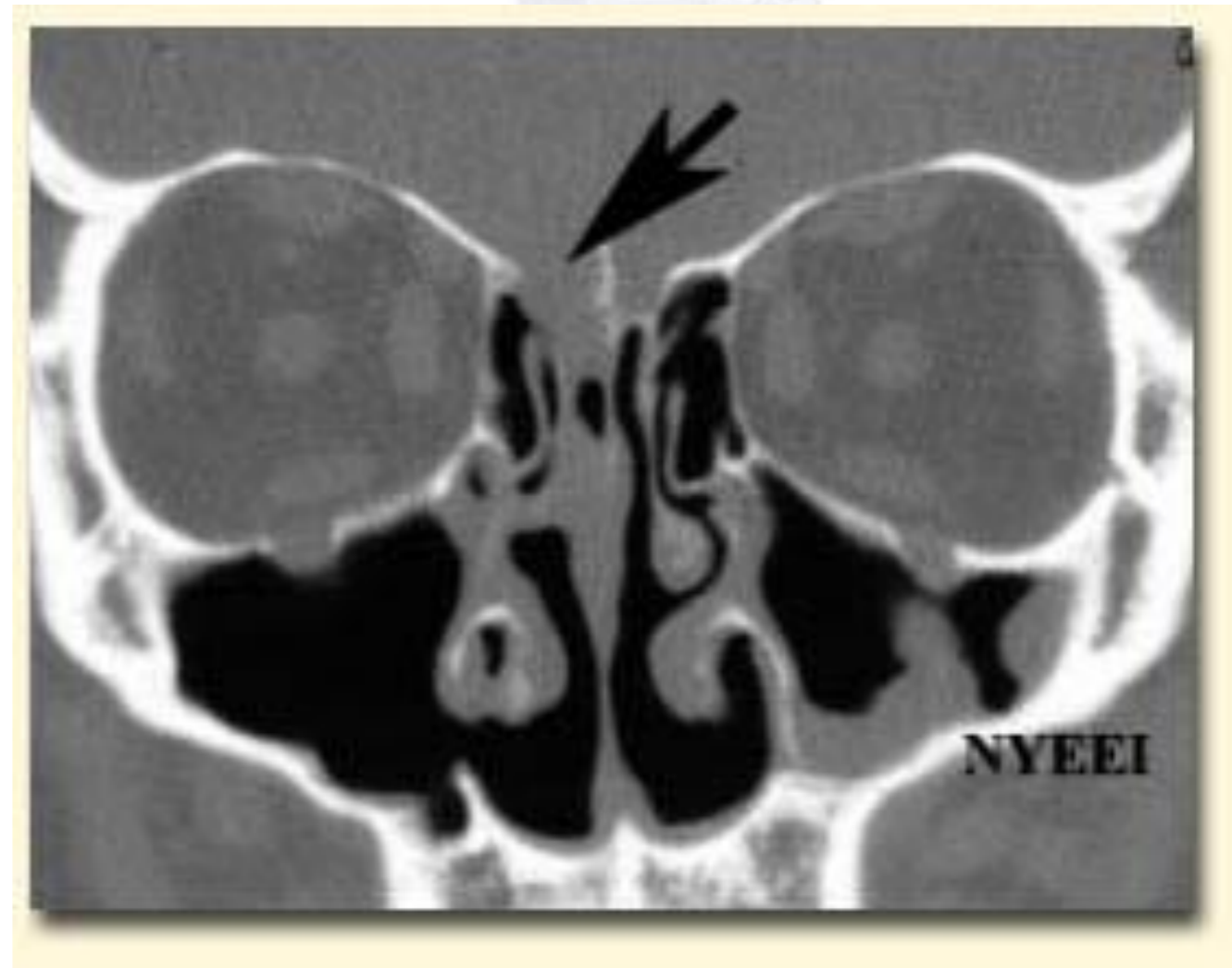


Skull based CSF Leaks

- CSF otorrhea and rhinorrhea can be congenital, post blunt head trauma, cranial or endoscopic surgery, or spontaneous
- Spontaneous idiopathic CSF leaks are 25–87% more likely to recur after surgical closure
 - Hubbard et al, Spontaneous cerebrospinal fluid rhinorrhea: Evolving concepts in diagnosis and surgical management based on the Mayo Clinic experience from 1970 through 1981. *Neurosurgery* 16:314–321, 1985
 - Ommaya et al, Nontraumatic cerebrospinal fluid rhinorrhea. *J Neurol Neurosurg Psychiatr* 31:214–215, 1968
- Pseudotumor cerebri and spontaneous CSF leak share common risk factors

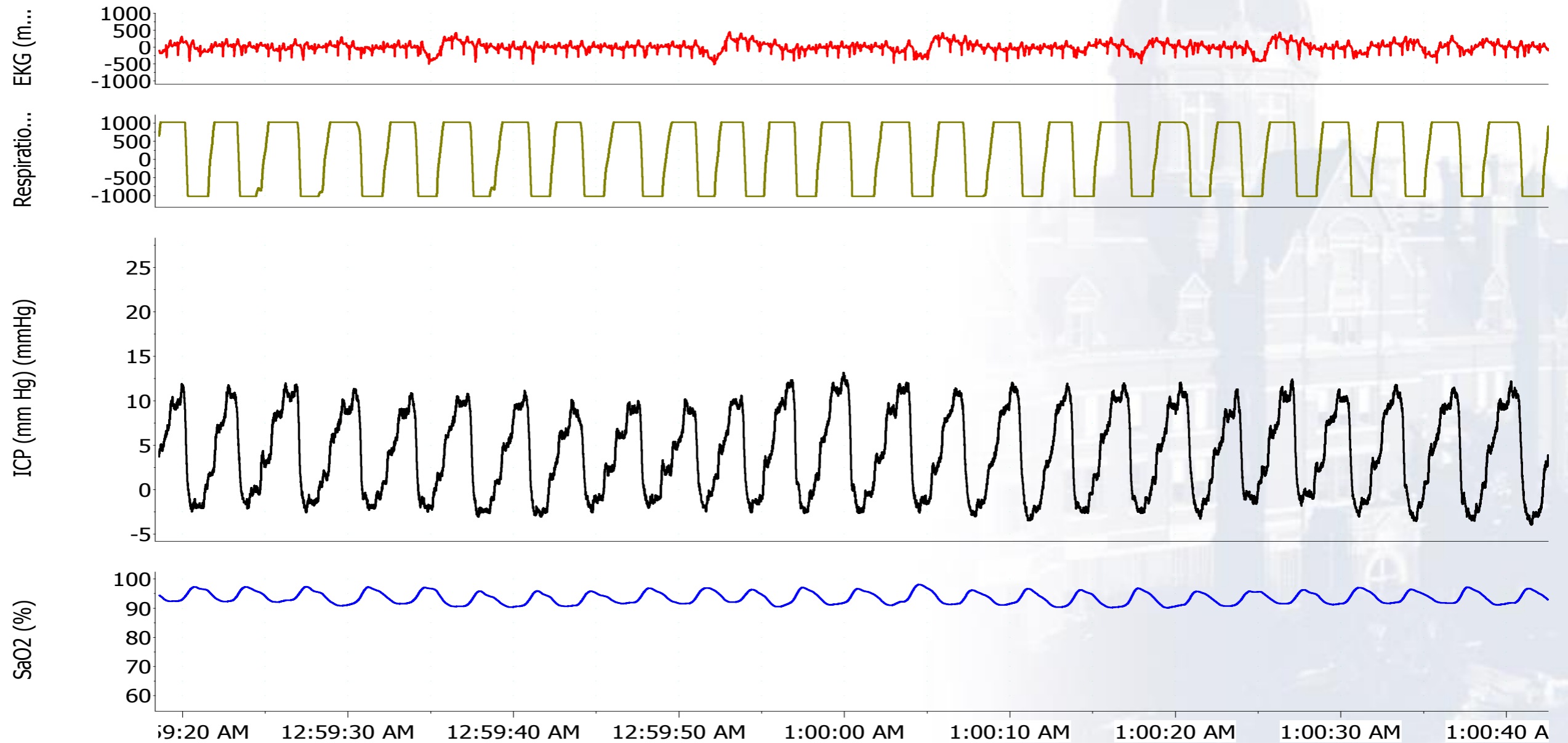
CSF Otorrhea & Rhinorrhea

- Non-traumatic cases have higher incidence of surgical failure
- Some have findings of empty sella - ?forme fruste of PTC



CSF Otorrhea & Rhinorrhea - preop

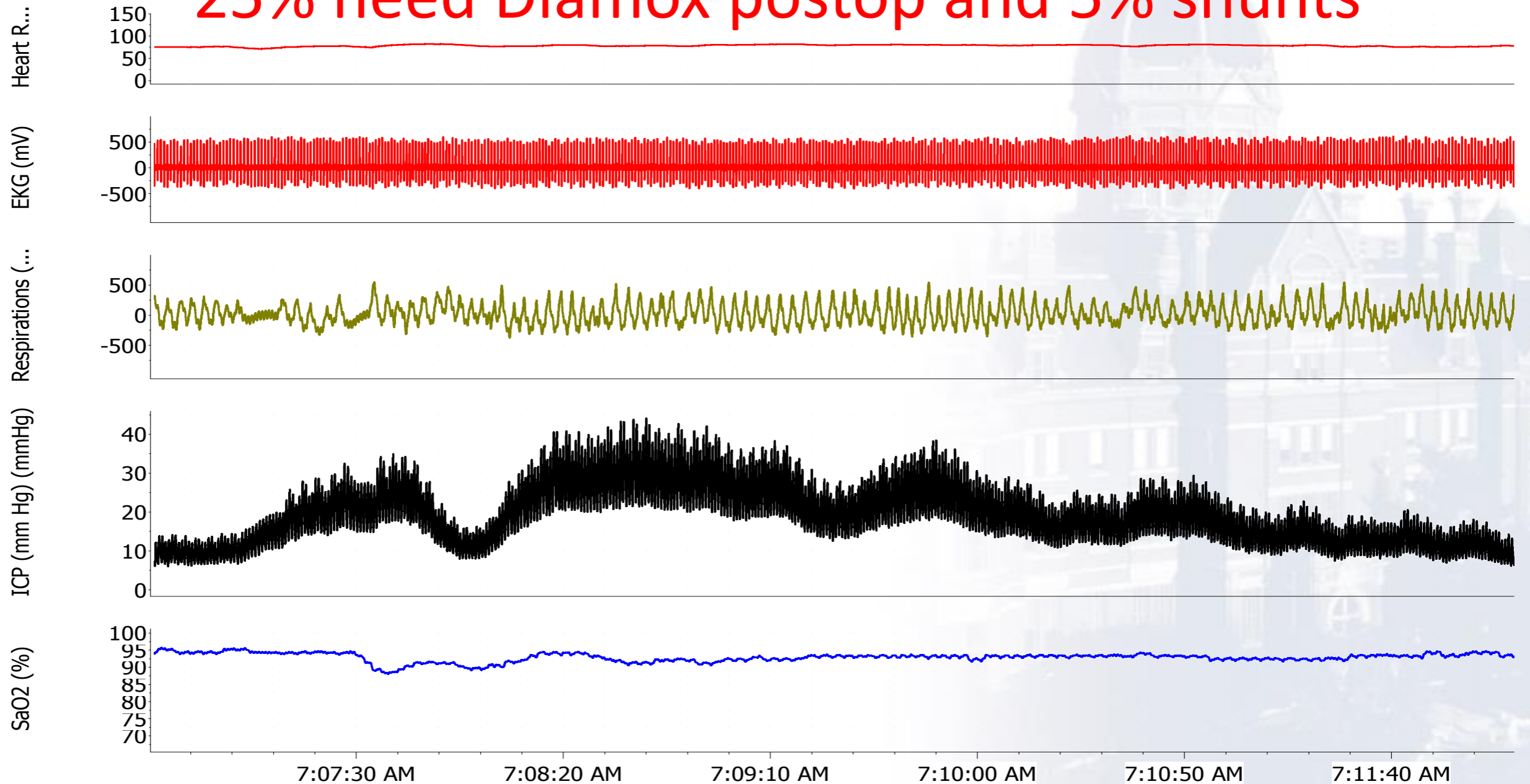
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CSF Otorrhea & Rhinorrhea – post-op

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25% need Diamox postop and 5% shunts



Perioperative continuous cerebrospinal fluid pressure monitoring in patients with spontaneous cerebrospinal fluid leaks: Reh DD, Gallia GL, Ramanathan M, Solomon D,

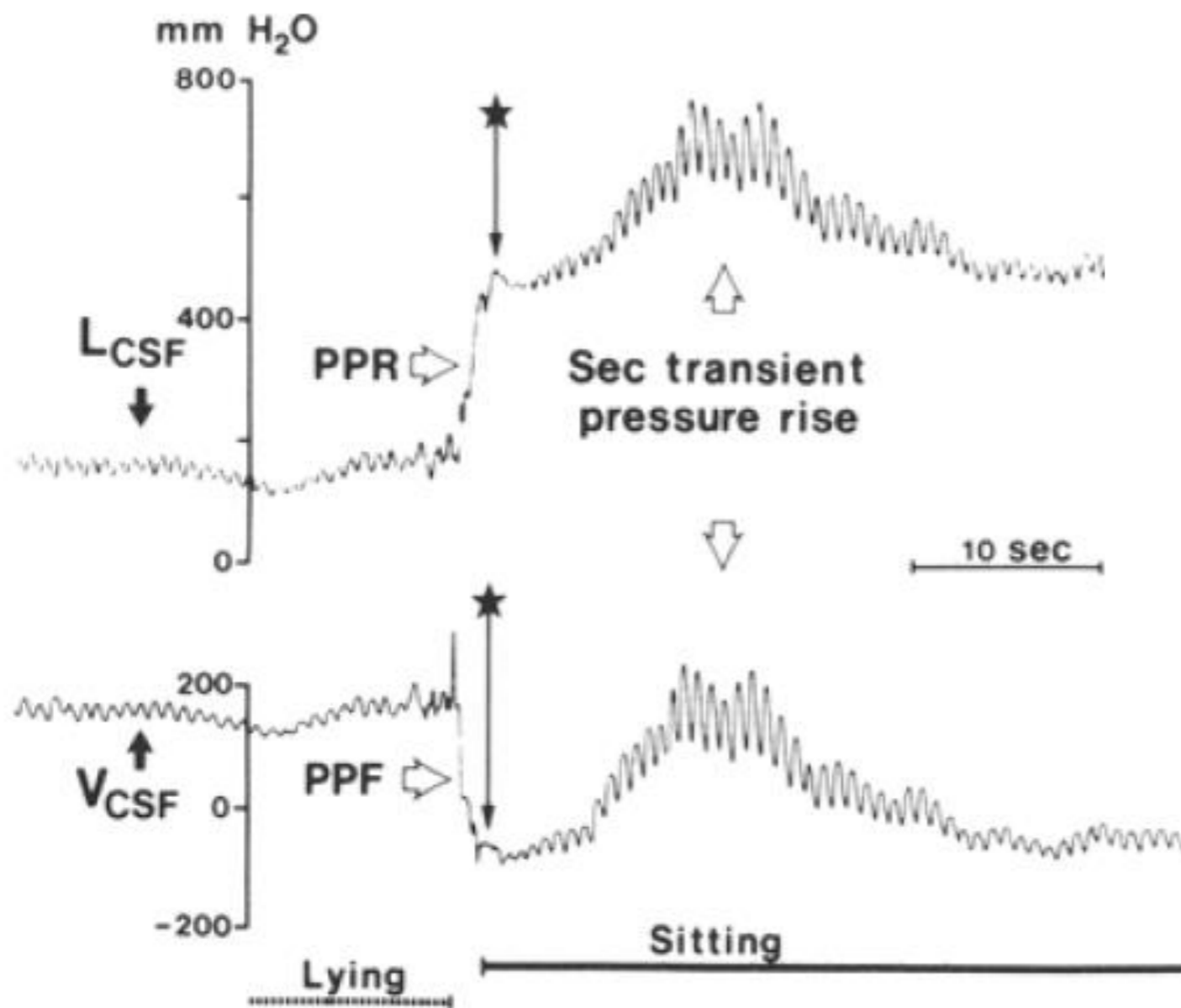
Moghekar A, Ishii M, Lane AP. Am J Rhinol Allergy. 2010 May-Jun;24(3):238-43.

Perioperative ICP management of spontaneous skull based CSF Leaks

- Neuro-ophthalmology assessment
- Lumbar puncture
- Sleep study – mandibular advancement device for OSA, NOT CPAP
- Lumbar continuous ICP Monitoring pre-op and post-op

Perioperative continuous cerebrospinal fluid pressure monitoring in patients with spontaneous cerebrospinal fluid leaks. Xie YJ, Shargorodsky J, Lane AP, Ishii M, Solomon D, Moghekar A, Gallia GL, Reh DD. Int Forum Allergy Rhinol. 2015 Jan;5(1):71-7

What are normal intracranial (not lumbar) pressures when upright ?



Body position and cerebrospinal fluid pressure

Part 1: Clinical studies on the effect of rapid postural changes

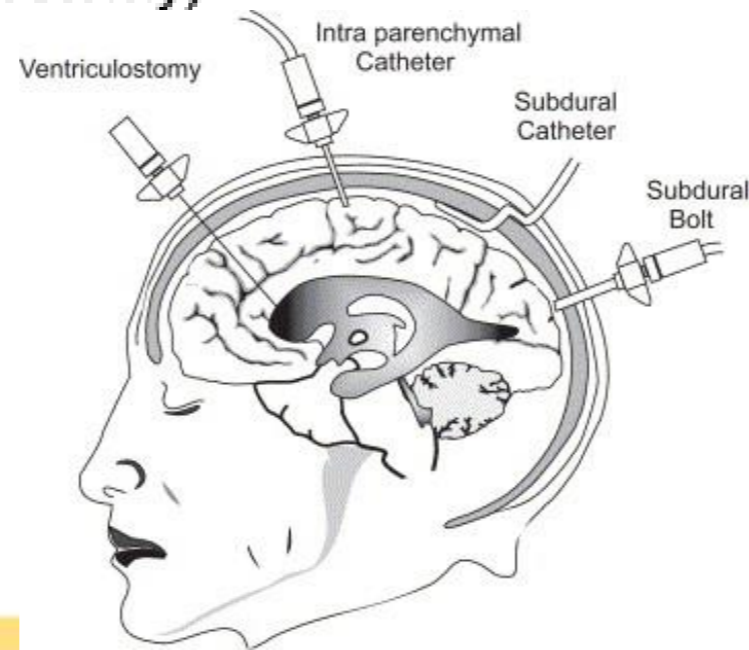
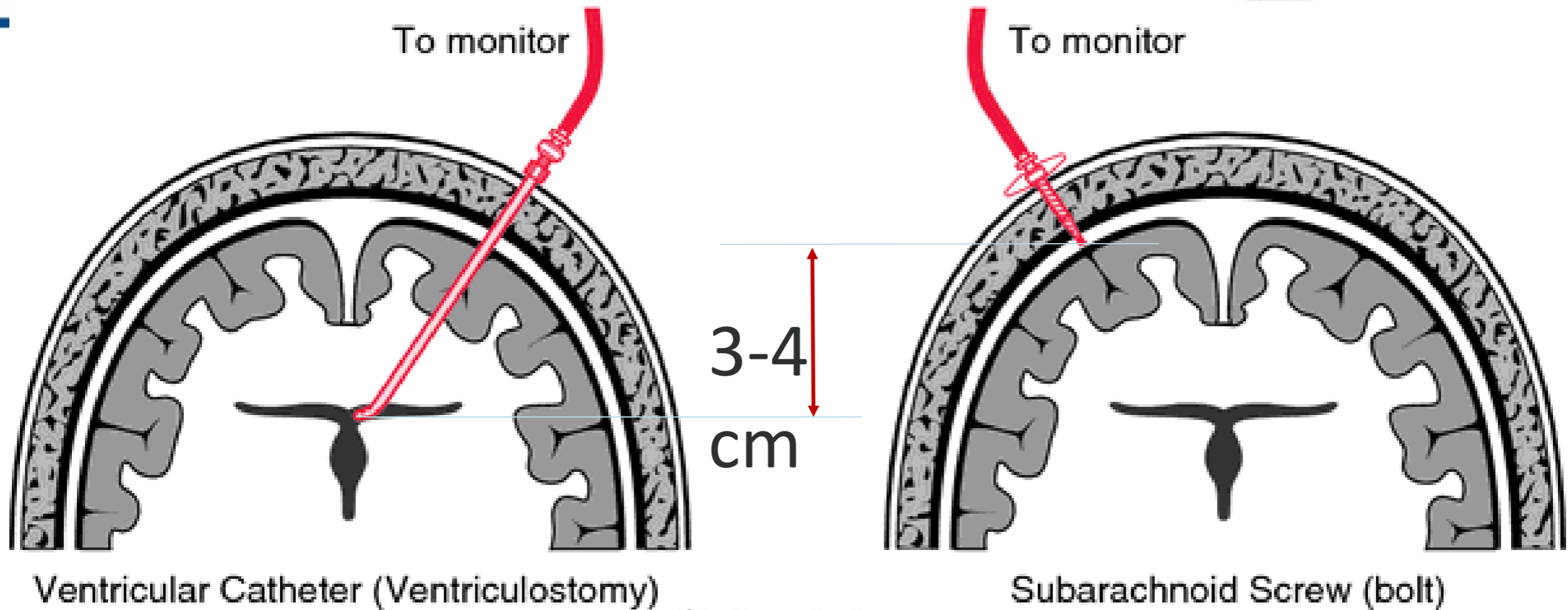
BJØRN MAGNÆS, M.D.

Department of Neurosurgery, Rikshospitalet, Oslo University Hospital, Oslo, Norway

J. Neurosurg. / Volume 44 / June, 1976

11 patients with hydrocephalus, posterior fossa tumors and aqueductal stenosis etc

Location matters



What is normative CSF pressure in the sitting/standing position

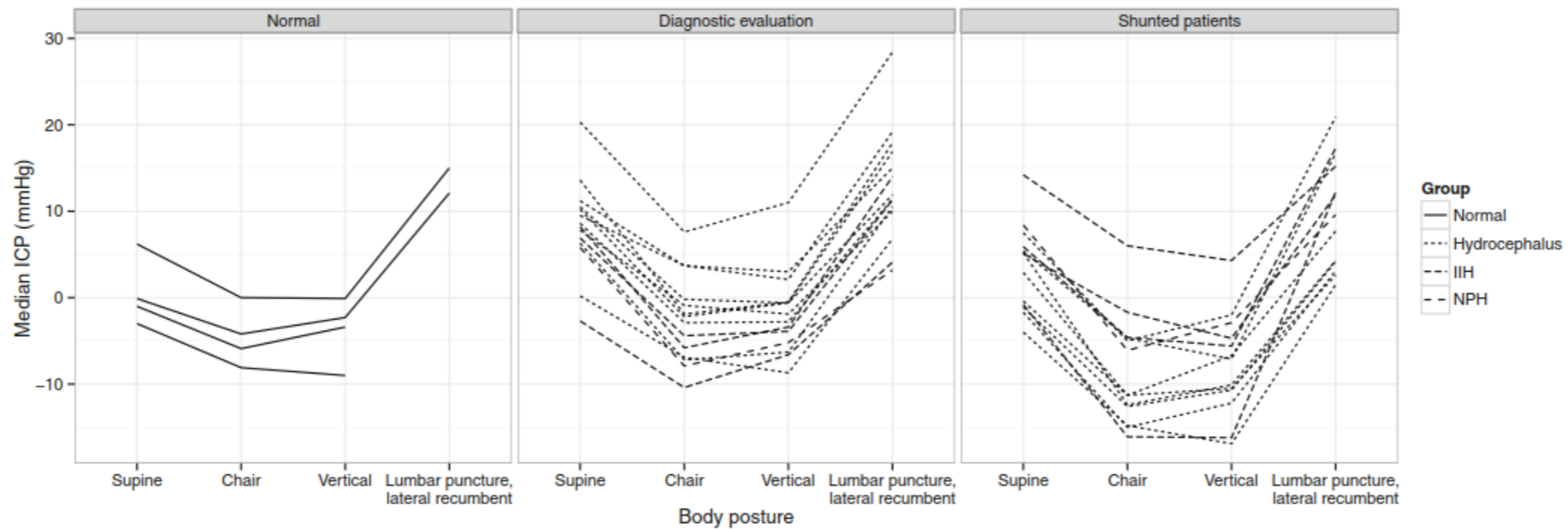
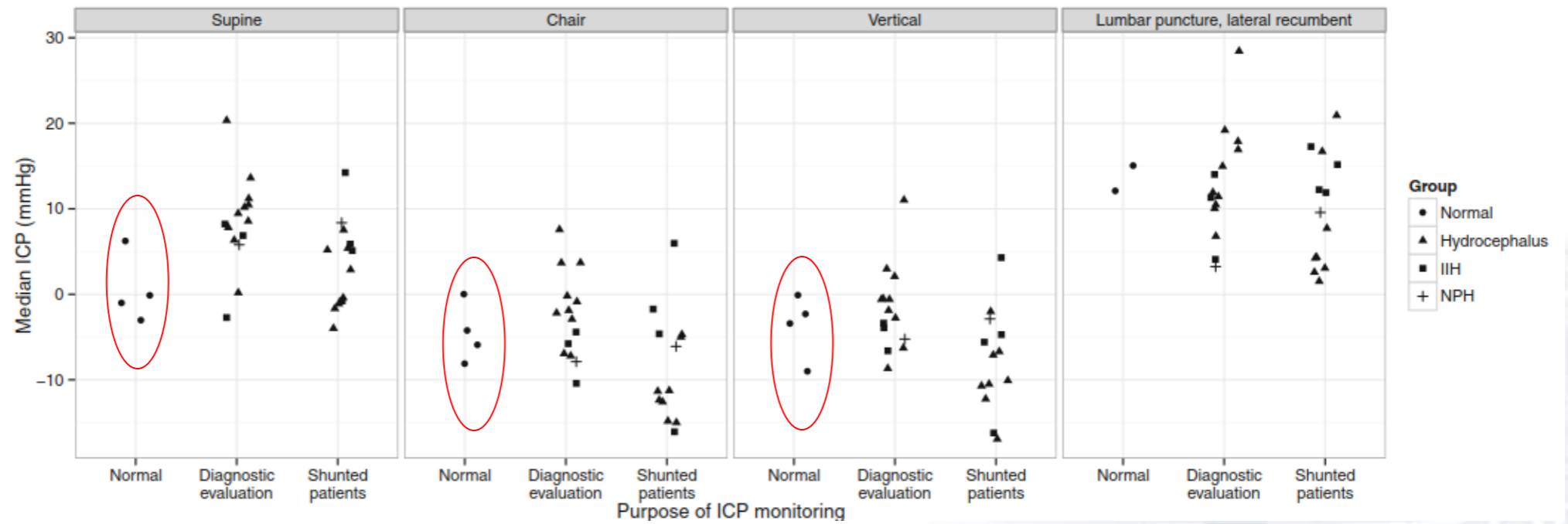
Author	N	Subjects	Reference	Range
Chapman-Cossman	8	patients	Foramen of Monro	-5 to +5 cm H ₂ O
Loman	13	normals	Cisterna magna	-8.5 to +4.5 cm of H ₂ O
Bradley	1	patient	Convexity	-16.5 cm H ₂ O
Fox	18	patients	Foramen of Monro	-14 to +7 cm
Andresen	4	normals	Convexity	-10 to 0 mm Hg
Juhler	4	normals	Convexity	-9 to 0 mm Hg

What is low pressure?

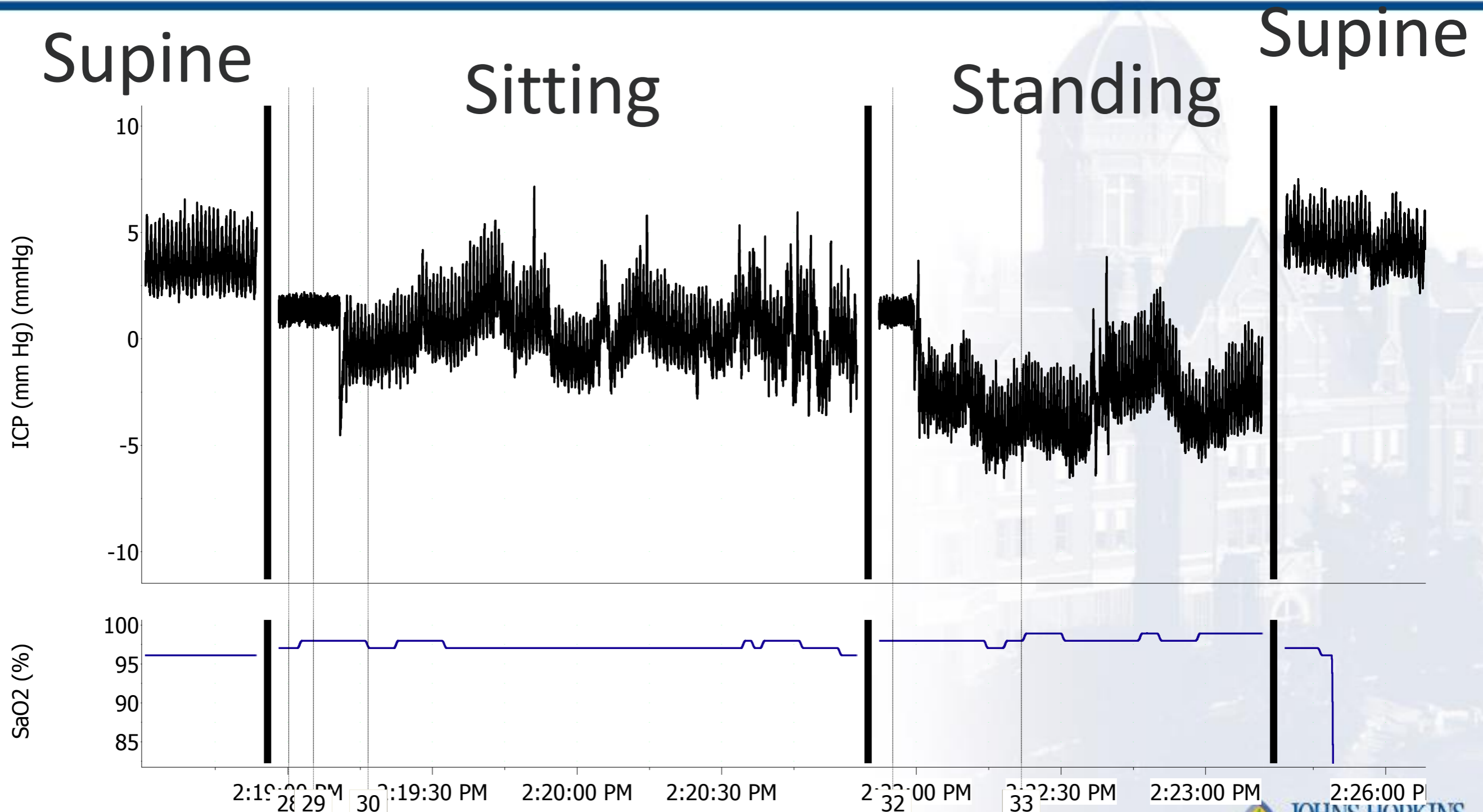
Less than -10 mm Hg when monitored by a parenchymal transducer in the cortex.

Effect of postural changes on ICP in healthy and ill subjects

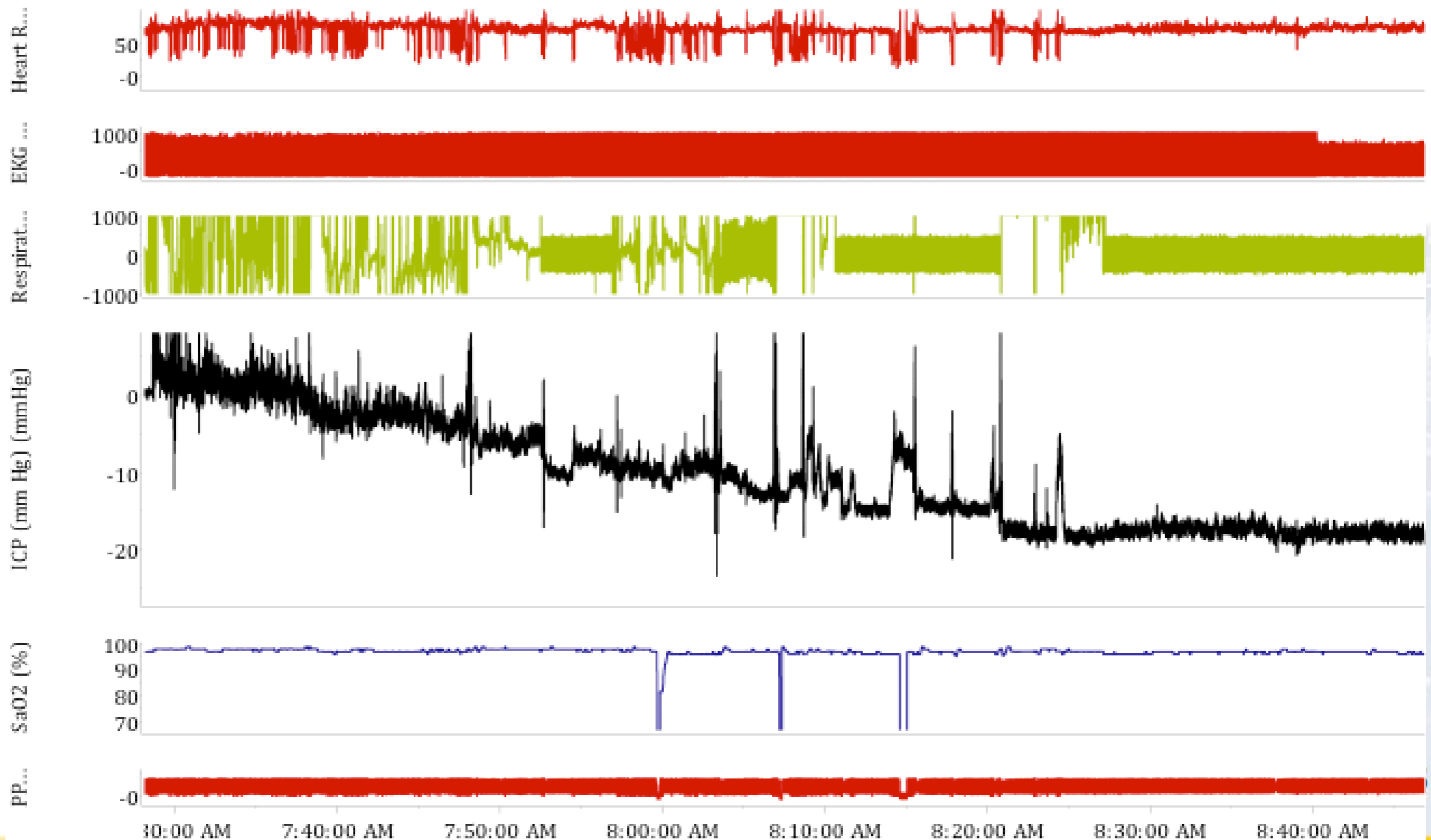
Morten Andresen · Amer Hadi · Lonnie G. Petersen ·
Marianne Juhler



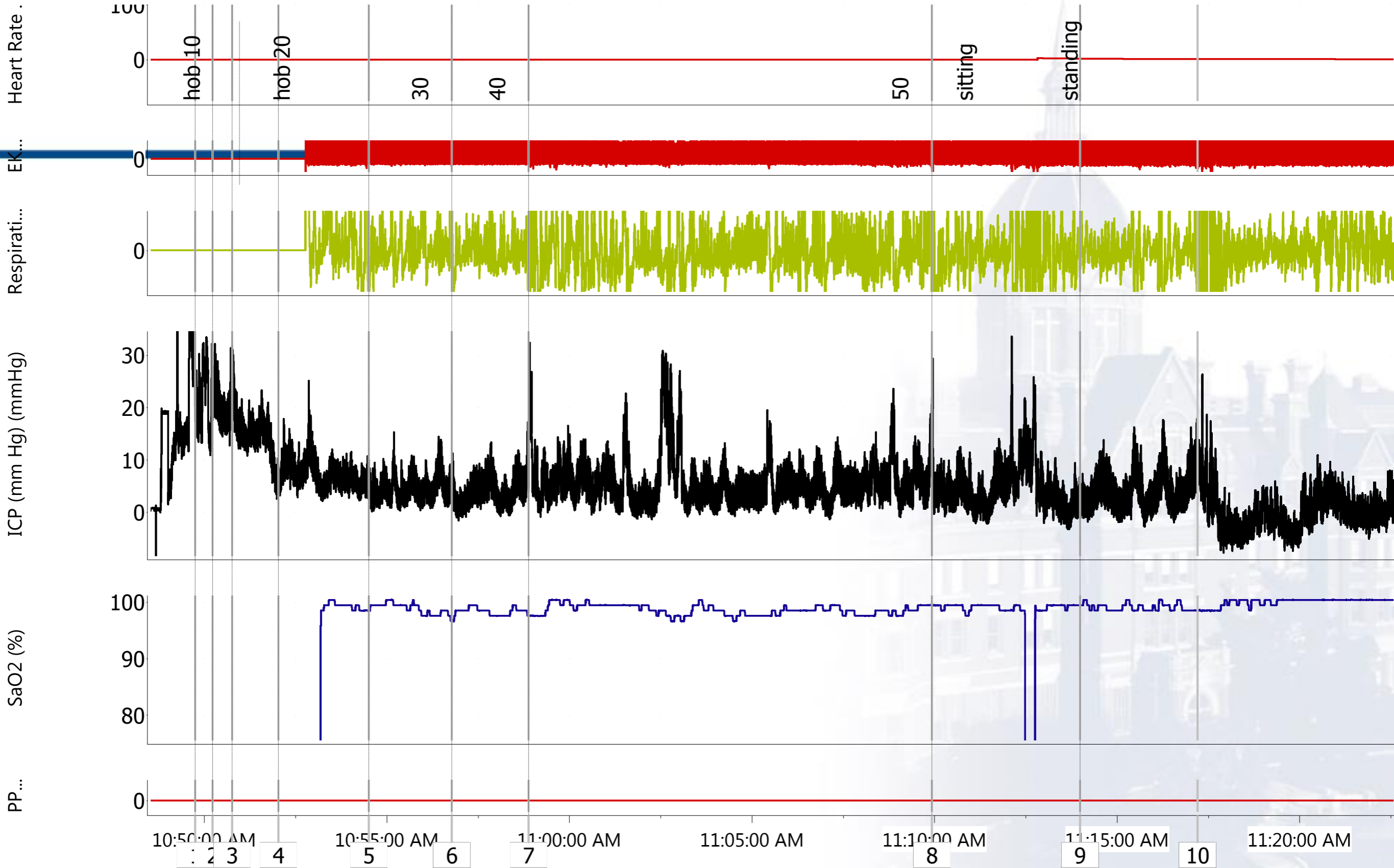
Normal ICP change with position



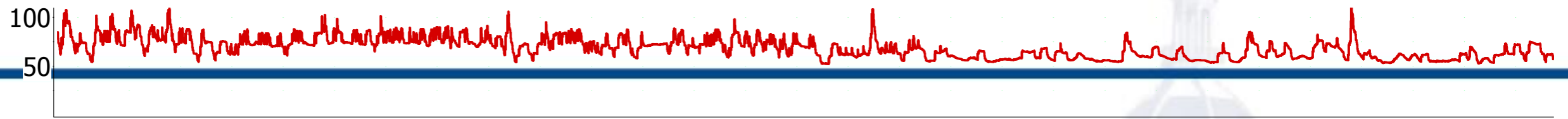
ICP changes with sitting in a EDS patient with no classic MRI brain findings over 60 mins



Severe orthostatic headaches; negative imaging

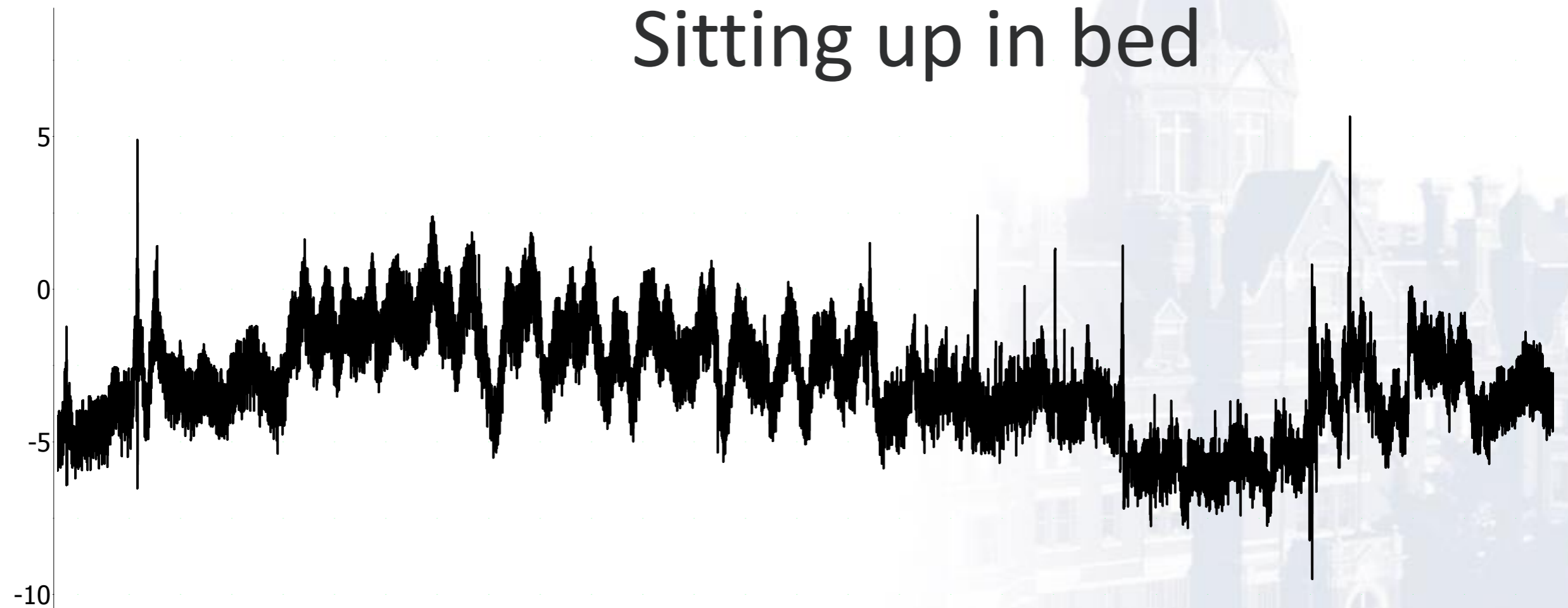


Heart Ra...

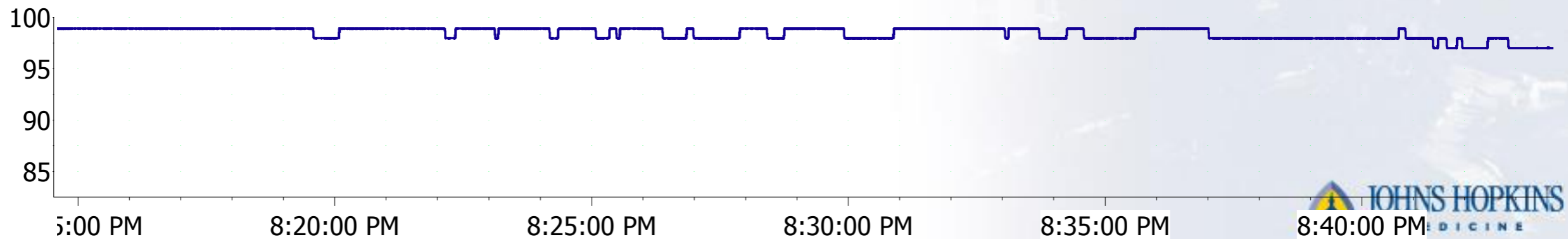


Sitting up in bed

ICP (mm Hg) (mmHg)

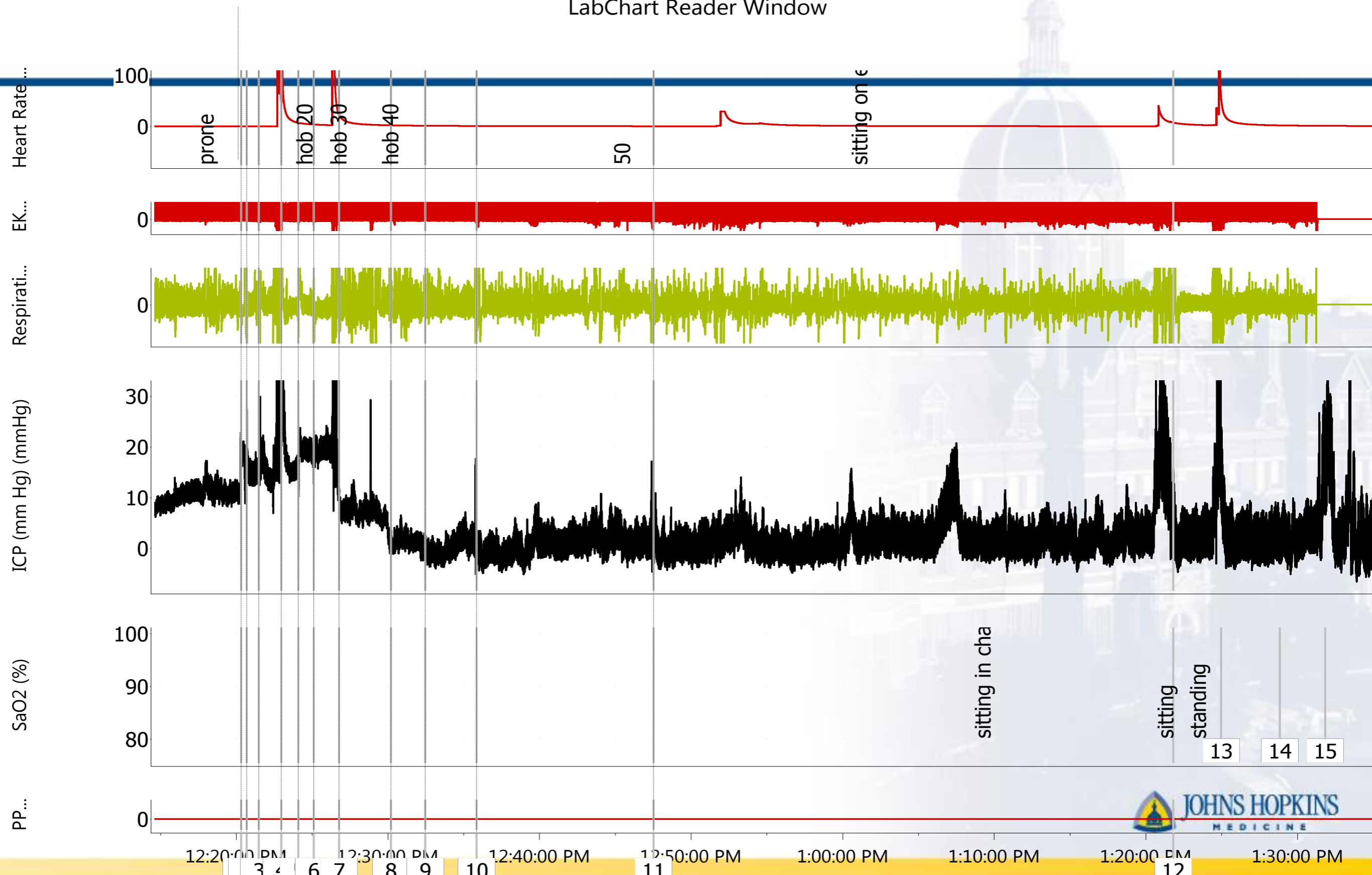


SaO2 (%)



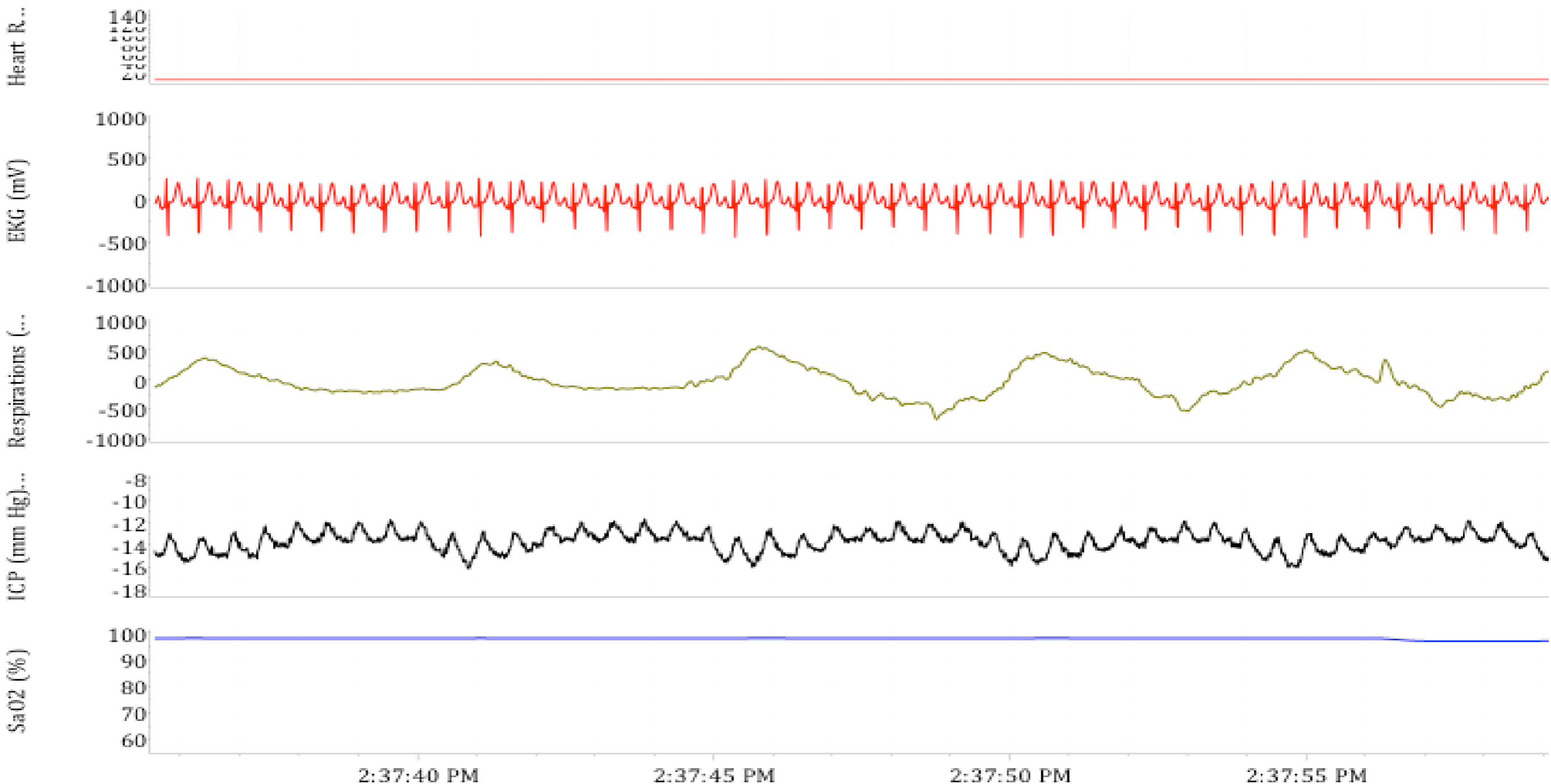
CSF Leak s/p multilevel epidural blood/fibrin patches with persistent orthostatic symptoms

LabChart Reader Window



Multi-level perineural cysts Day 1 baseline monitoring, sitting up

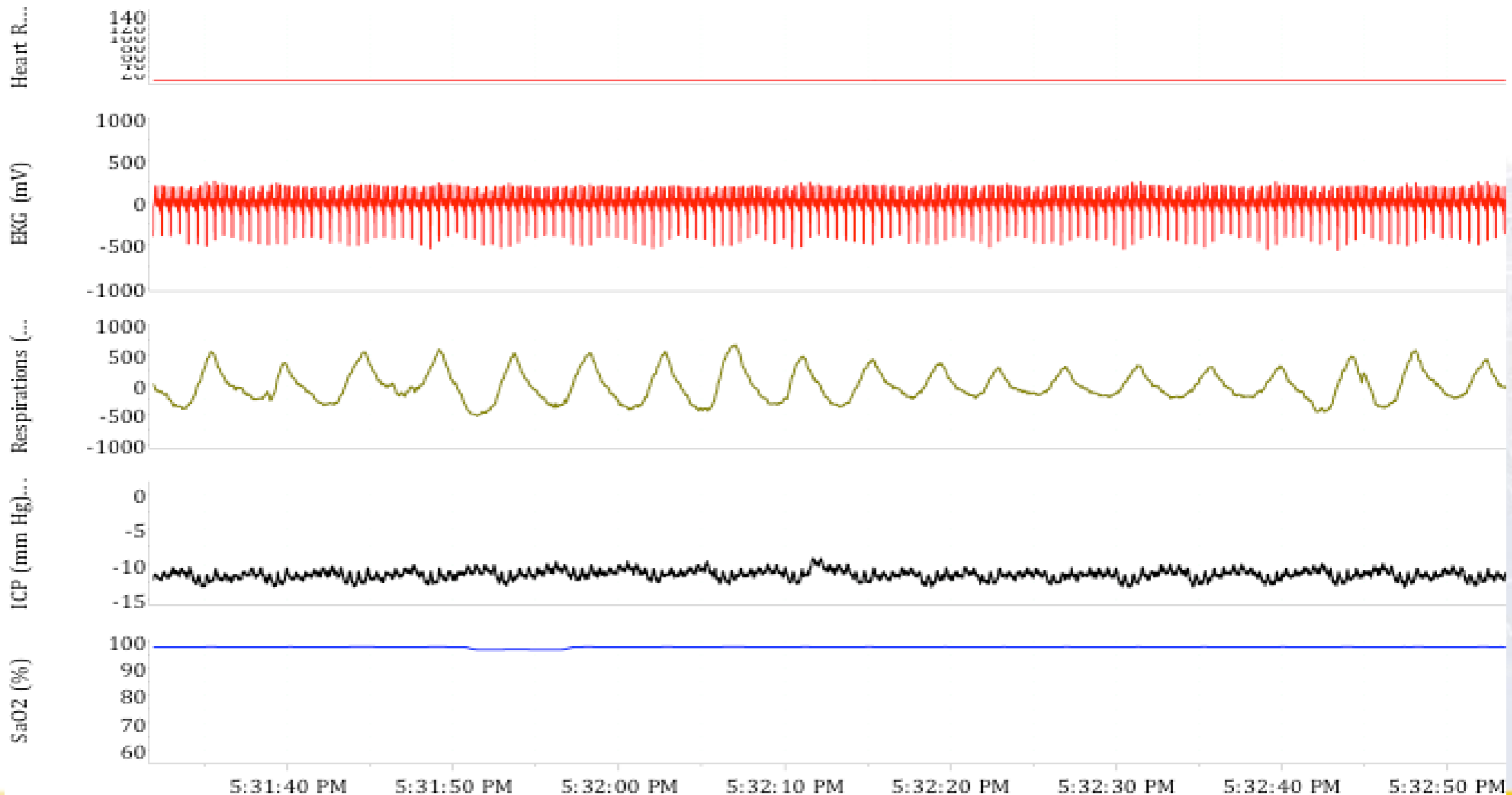
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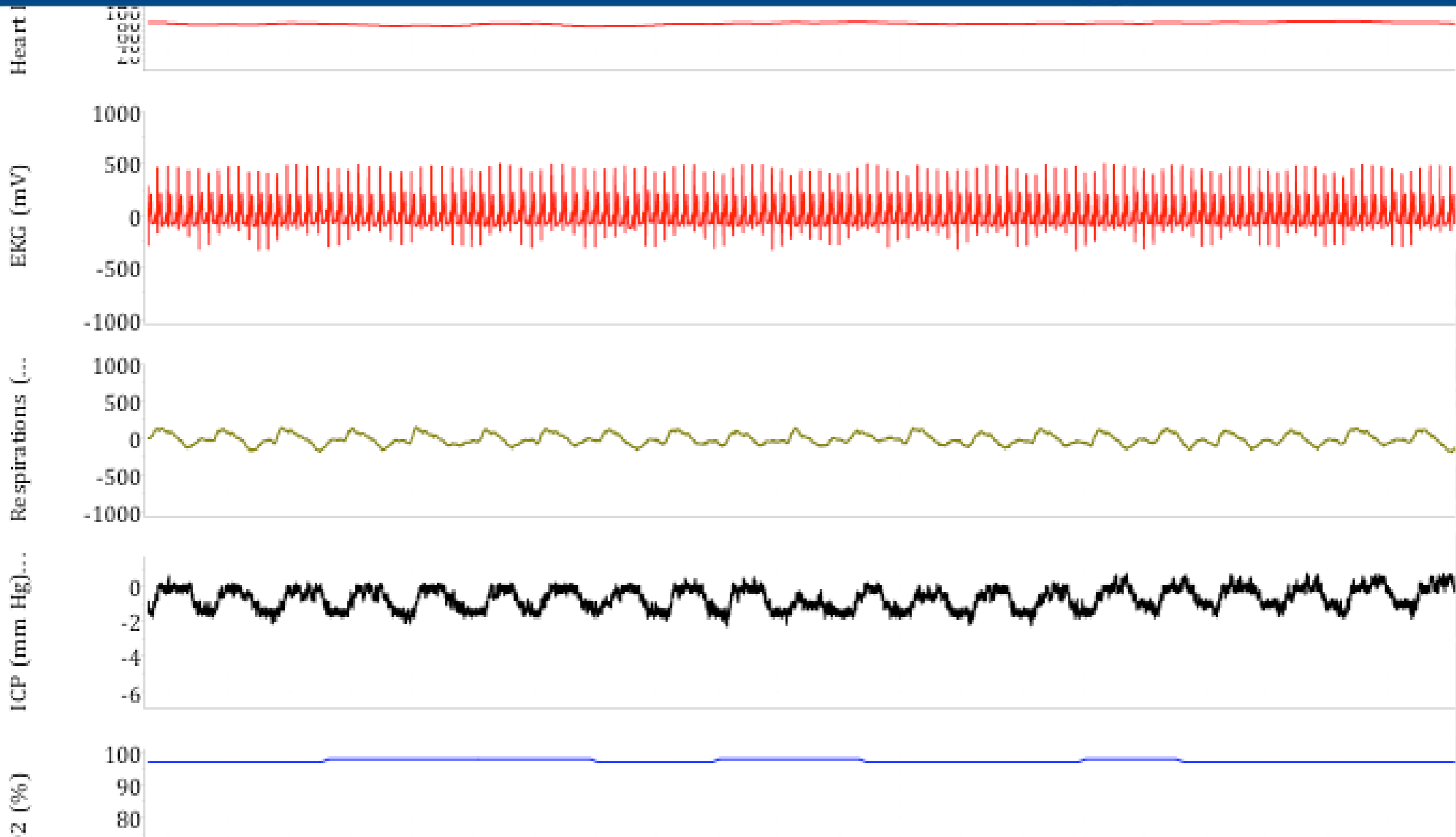
Day 2 after 4 multilevel blood/fibrin patches



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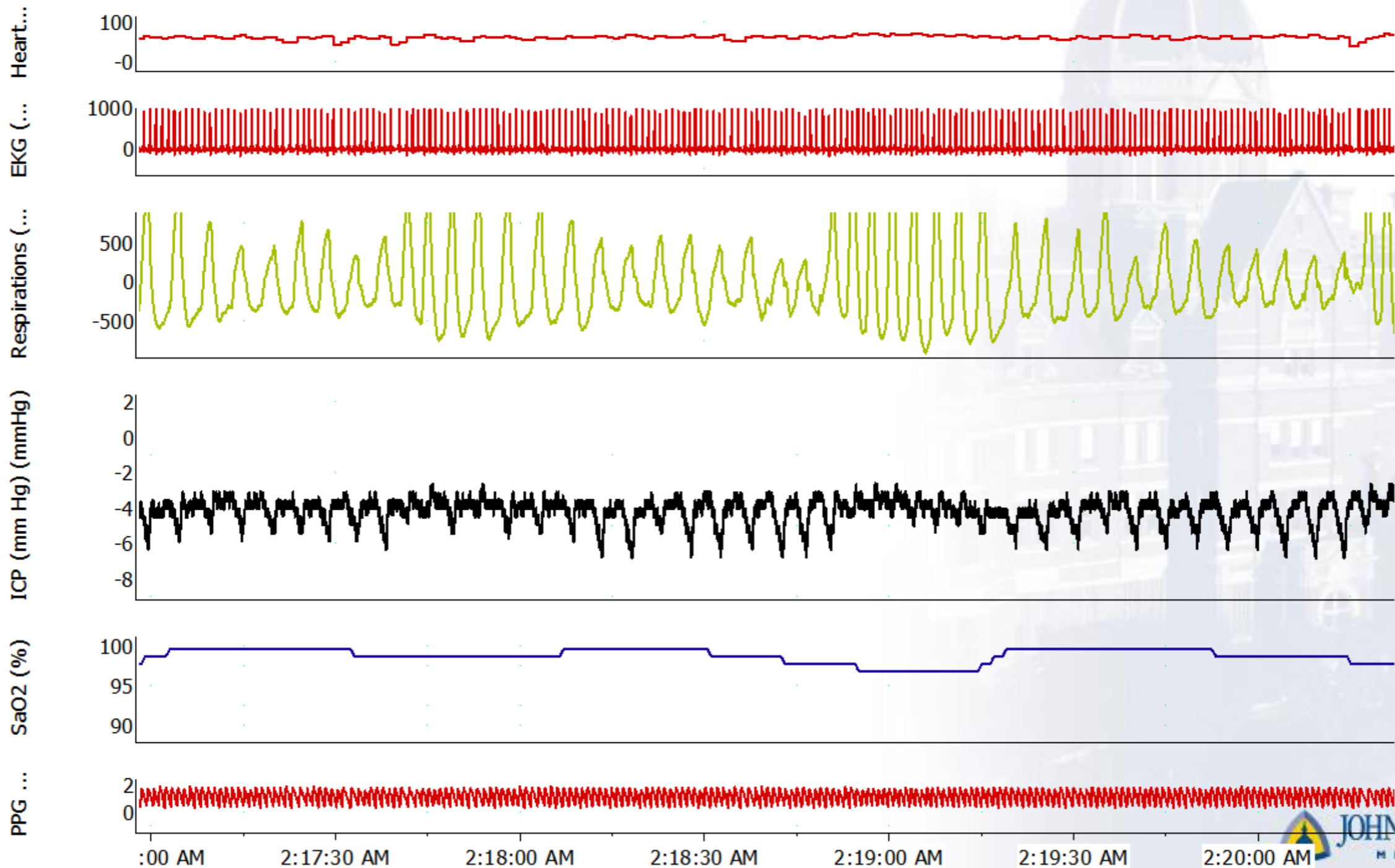


Day 3 after an additional 2 levels were targeted



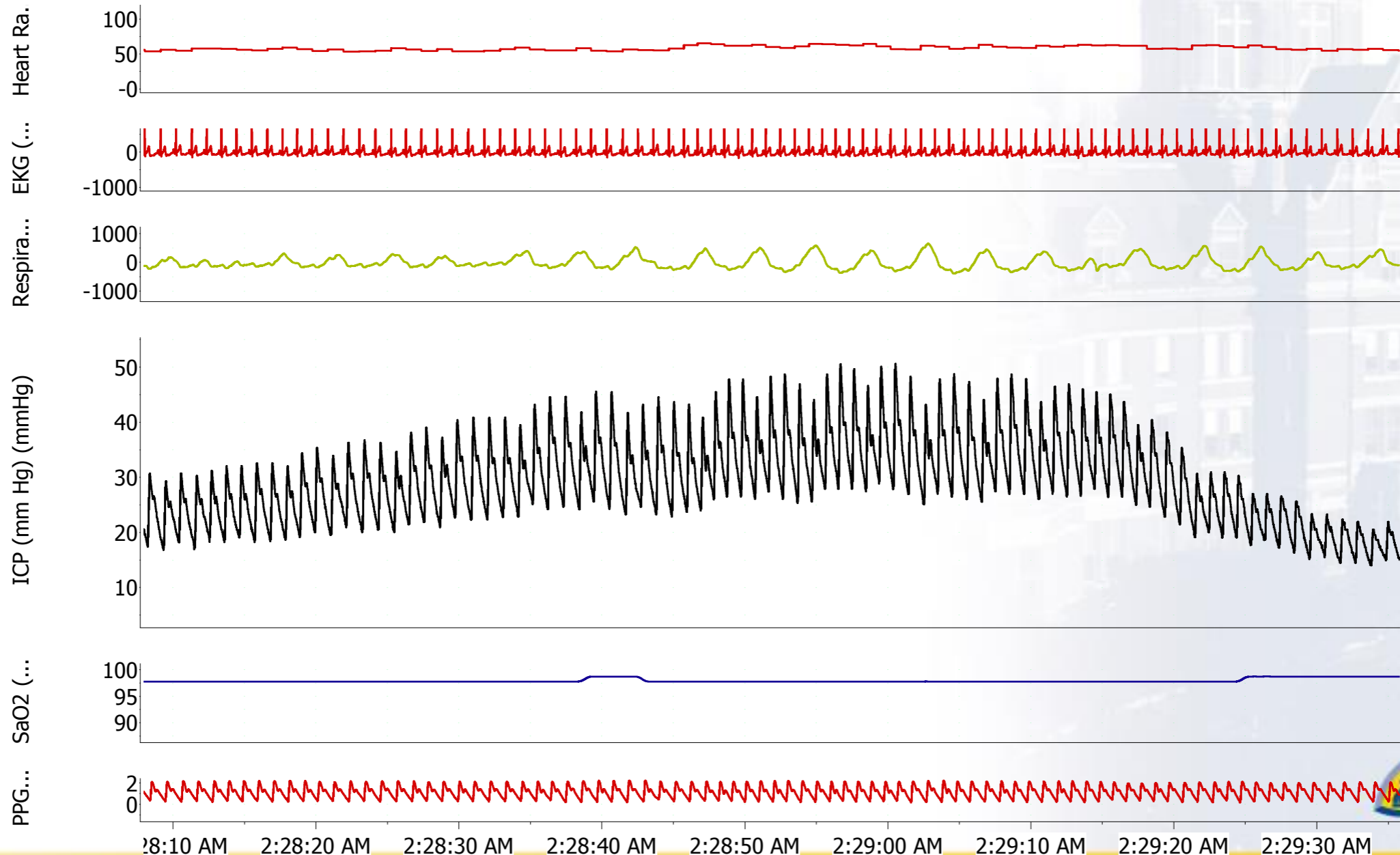
Spinal CSF Leak – baseline Day 1 monitoring - supine

LabChart Window



Day 2 – post patch rebound hypertension - supine

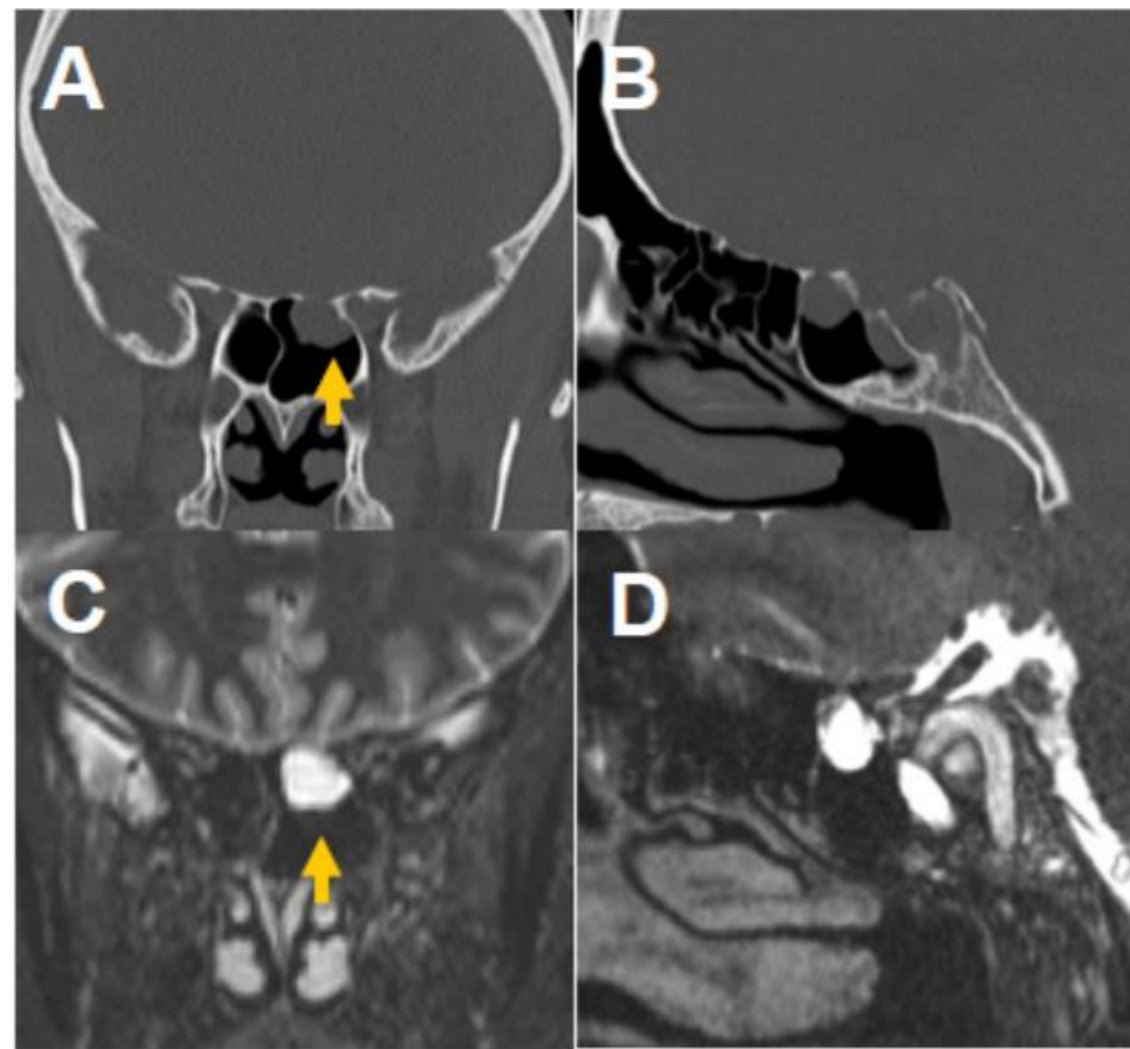
Mean CSFP was greater or equal to 19 mm Hg (about 25 cm water) for 27 mins (8.7% of the recording) and greater or equal to 15 mm Hg (about 20 cm water) for 64 (20.5%). Mean peak CSFP ranged from 9.3 to 42.5, with average mean peak CSF of 16.1. Mean peak CSFP was greater or equal to 25 for 25 minutes (8.0%). Mean waveform amplitude was 5.6, and ranged from 2.9 to 18.5. Mean waveform amplitude was greater than or equal to 5 for 142 minutes (45.5%).



Skull based CSF leak

A 61 year-old male with beta-2 transferrin positive left-sided rhinorrhea

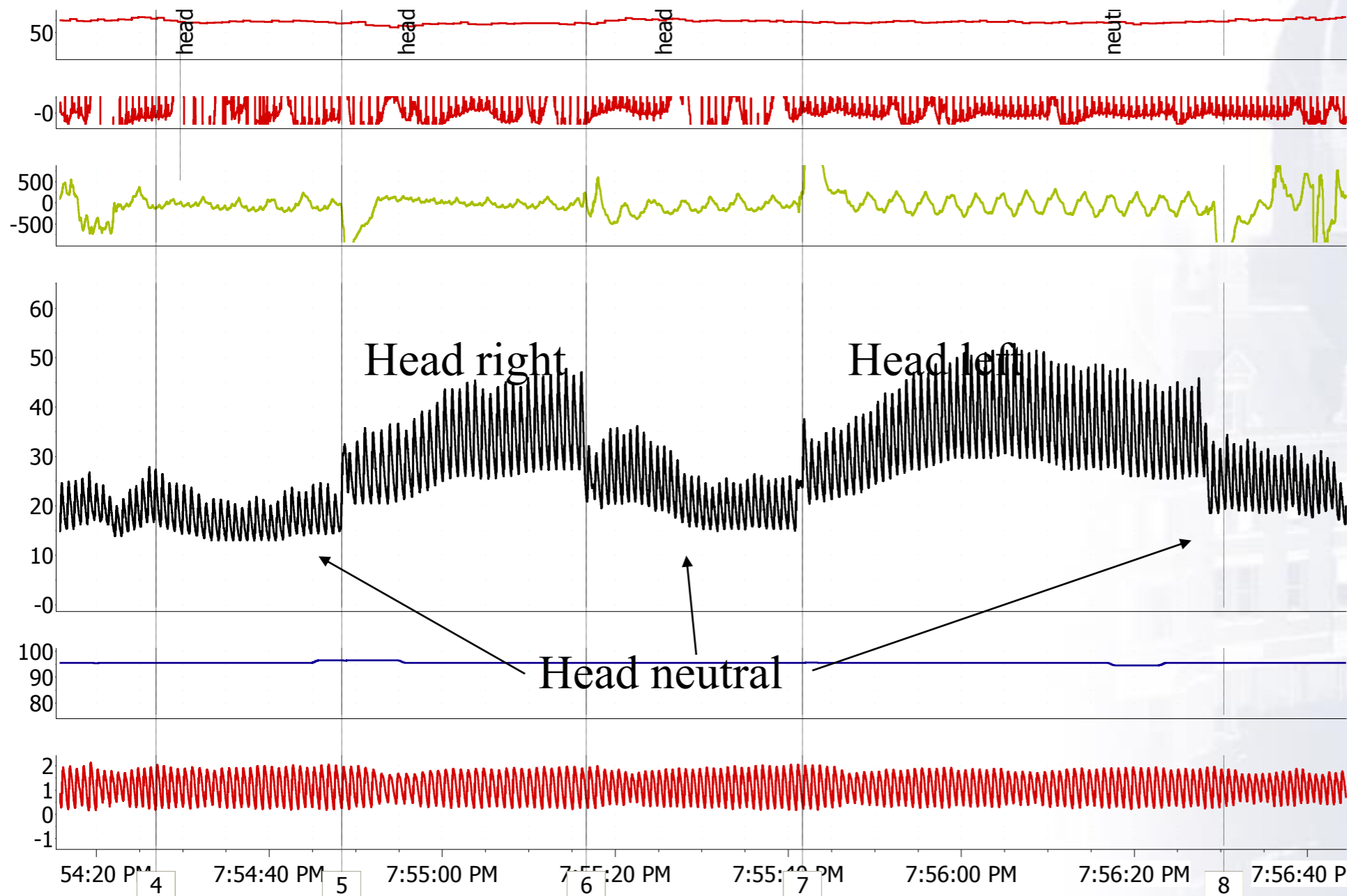
BMI was 26.6, no clinical history of obstructive sleep apnea, meningitis, trauma, or sinonasal/cranial surgery.



- High-resolution CT showed left sided planum sphenoidale defect
- T2-weighted MR demonstrated left sided meningoencephalocele extending into the left sphenoid sinus

- Prior to endoscopic endonasal repair, a lumbar spinal catheter was inserted
- Overnight CSF pressure monitoring revealed CSF pressure greater or equal to 19 mm Hg 11% of the time.
- Mean CSF pulse waveform amplitude was greater than 5 mm Hg for 53.4% of the time.
- Lumbar drainage was performed for 3 days
- Overnight post-operative CSF pressure monitoring showed CSF pressure greater than 19 mm Hg only 5.6% of the time.
- Positional CSF pressure testing was done...

Supine CSF Pressure Recordings

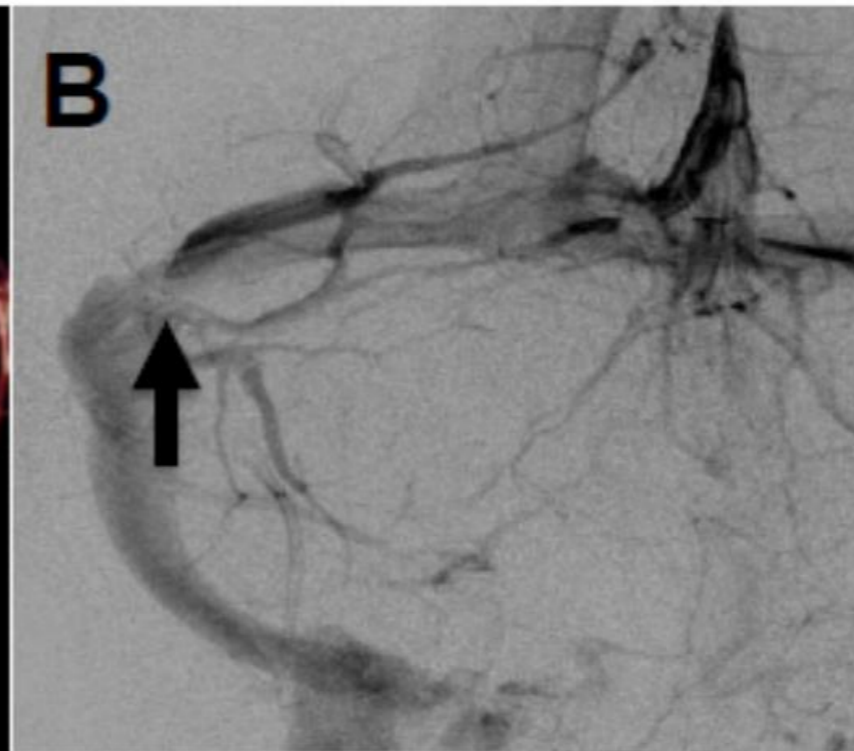


Head right = 32.5 mm Hg
(44.2 cm H₂O)

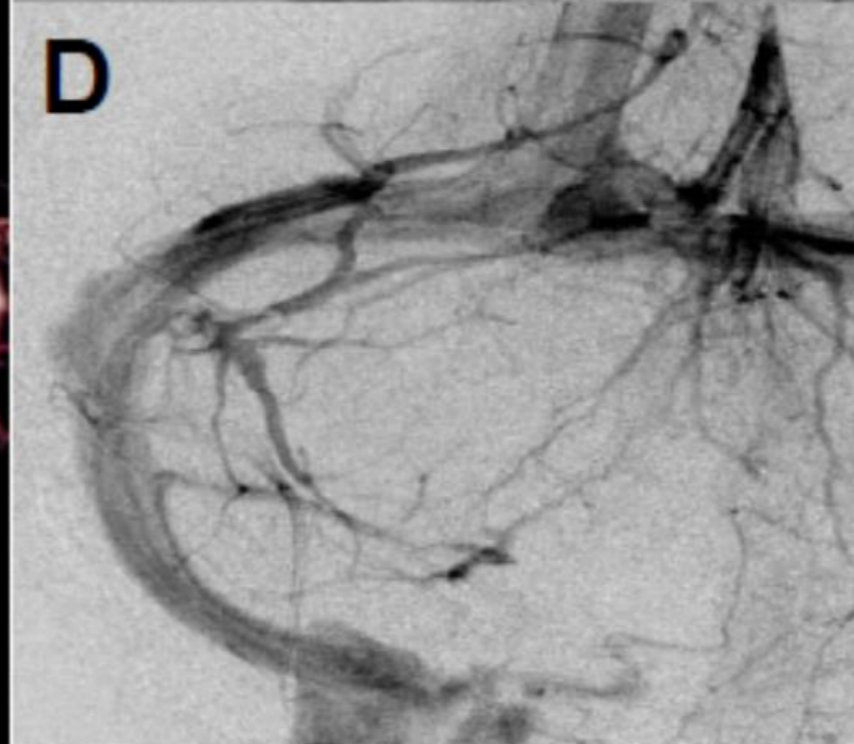
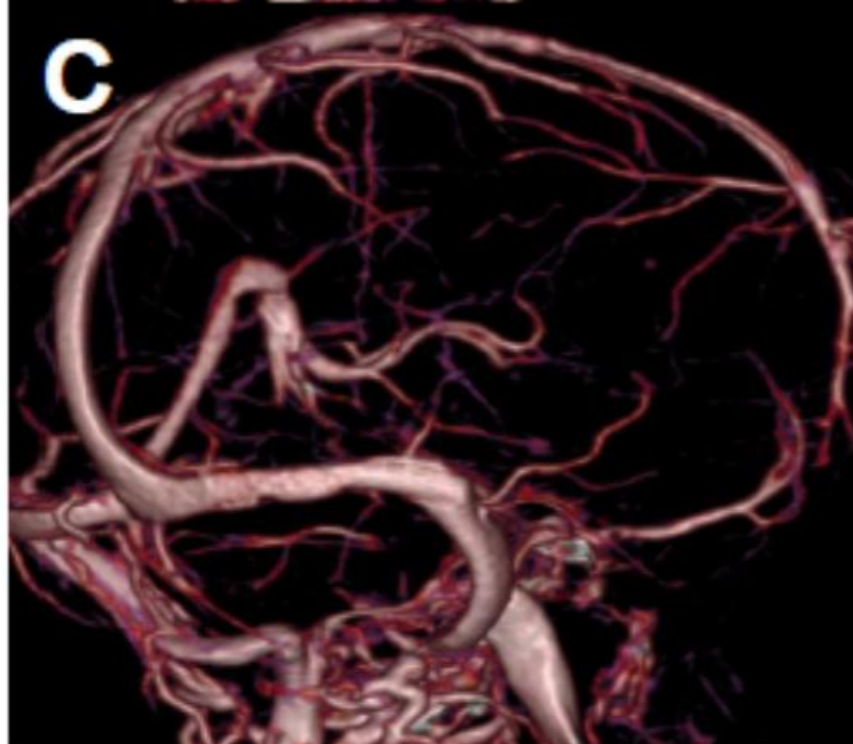
Head left = 36.8 mm Hg
(50 cm H₂O),

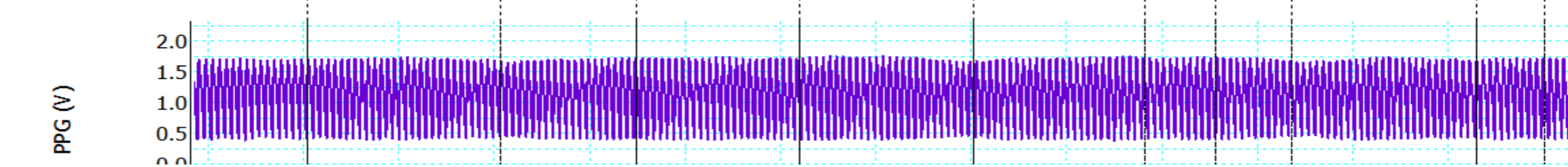
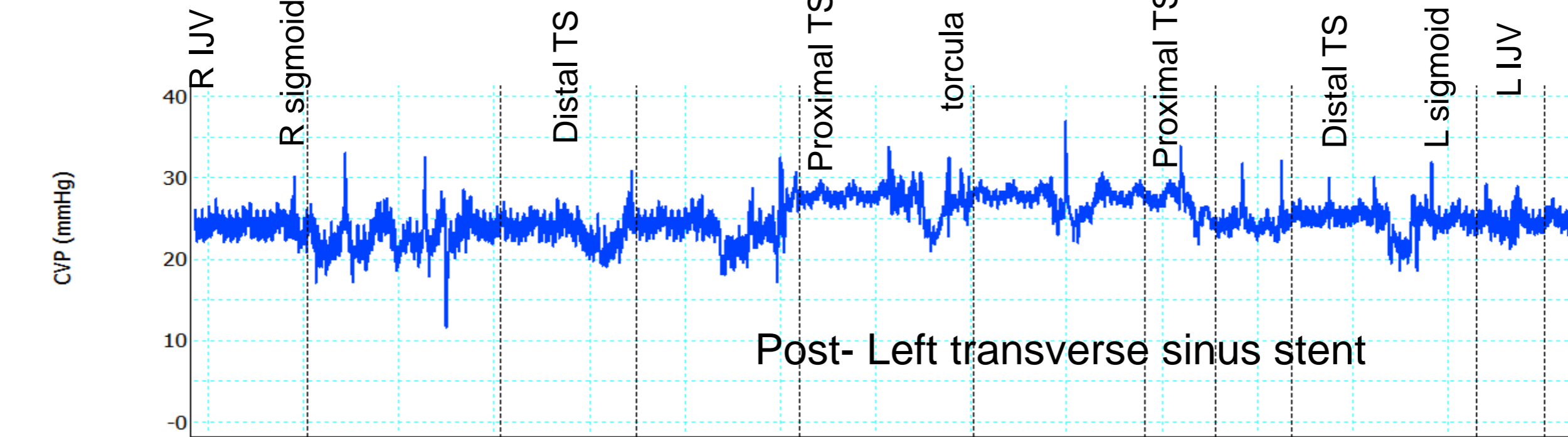
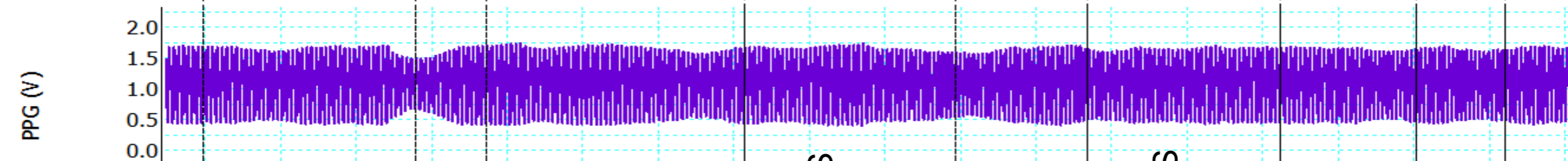
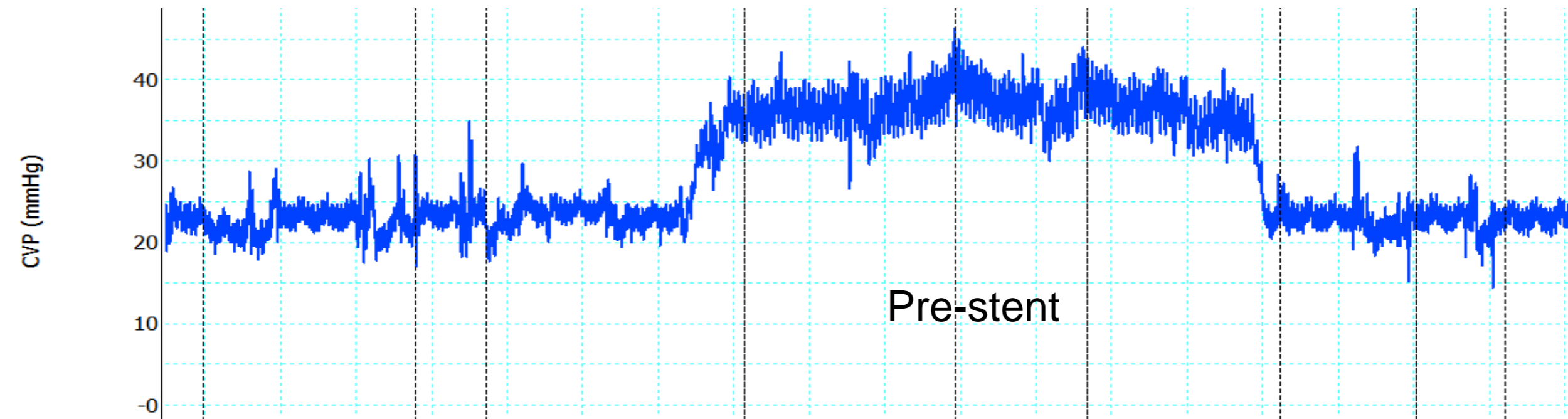
Angiography demonstrates focal transverse venous sinus stenosis

Pre stent



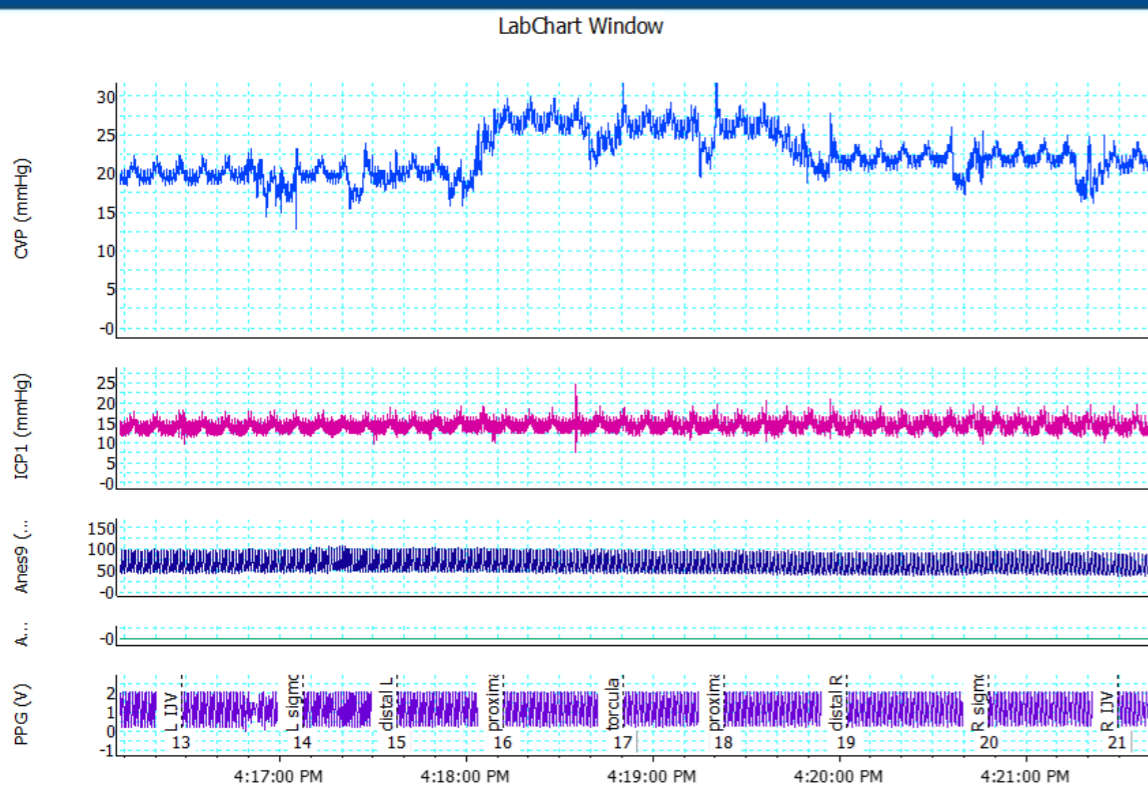
Post stent



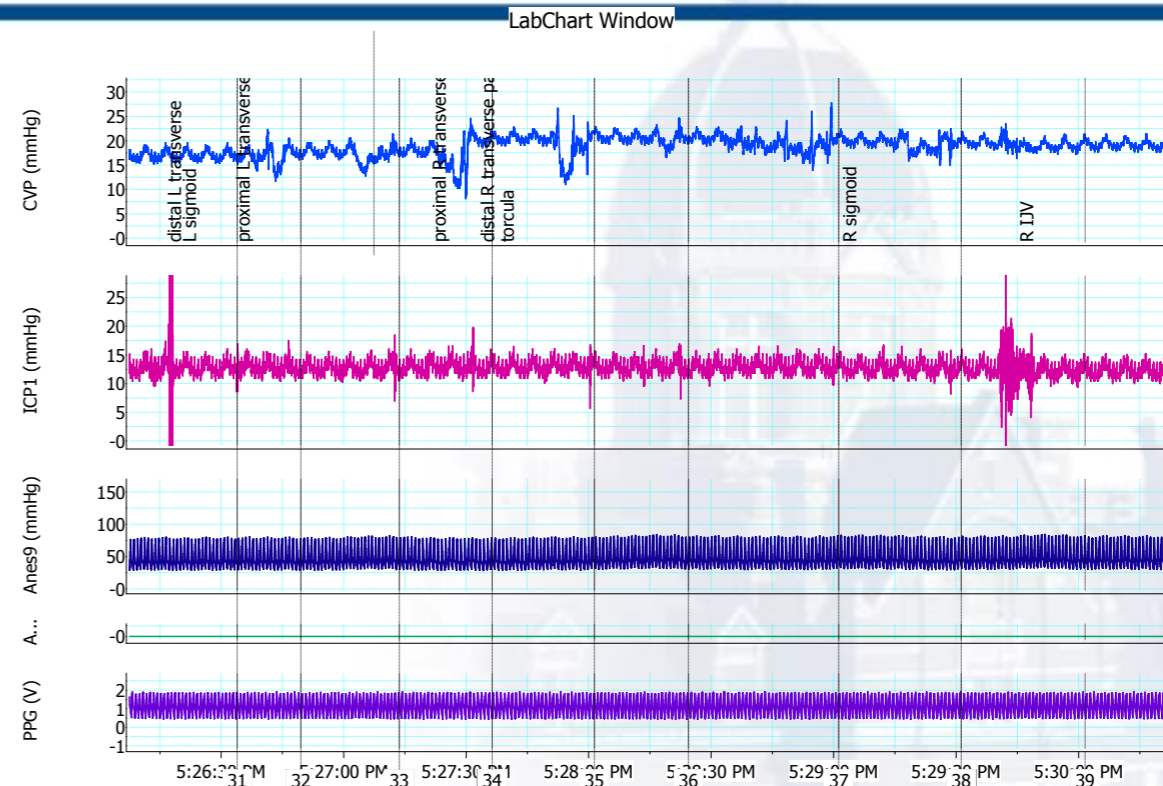


One year following surgical leak repair he underwent a diagnostic angiogram with cerebral venous sinus manometry

Pre stent



Post R transverse sinus stent



Bilateral transverse sinus pressure gradient of 6.7 mm Hg across the areas of stenosis.

A 6 x 40 mm right transverse sinus stent was then deployed in the right transverse sinus. Pressure gradients decreased to 0.4 mm Hg right and 2.3 mm Hg left.

Eight months following stenting, the patient was weaned off acetazolamide and he remains asymptomatic at 30 months follow up.

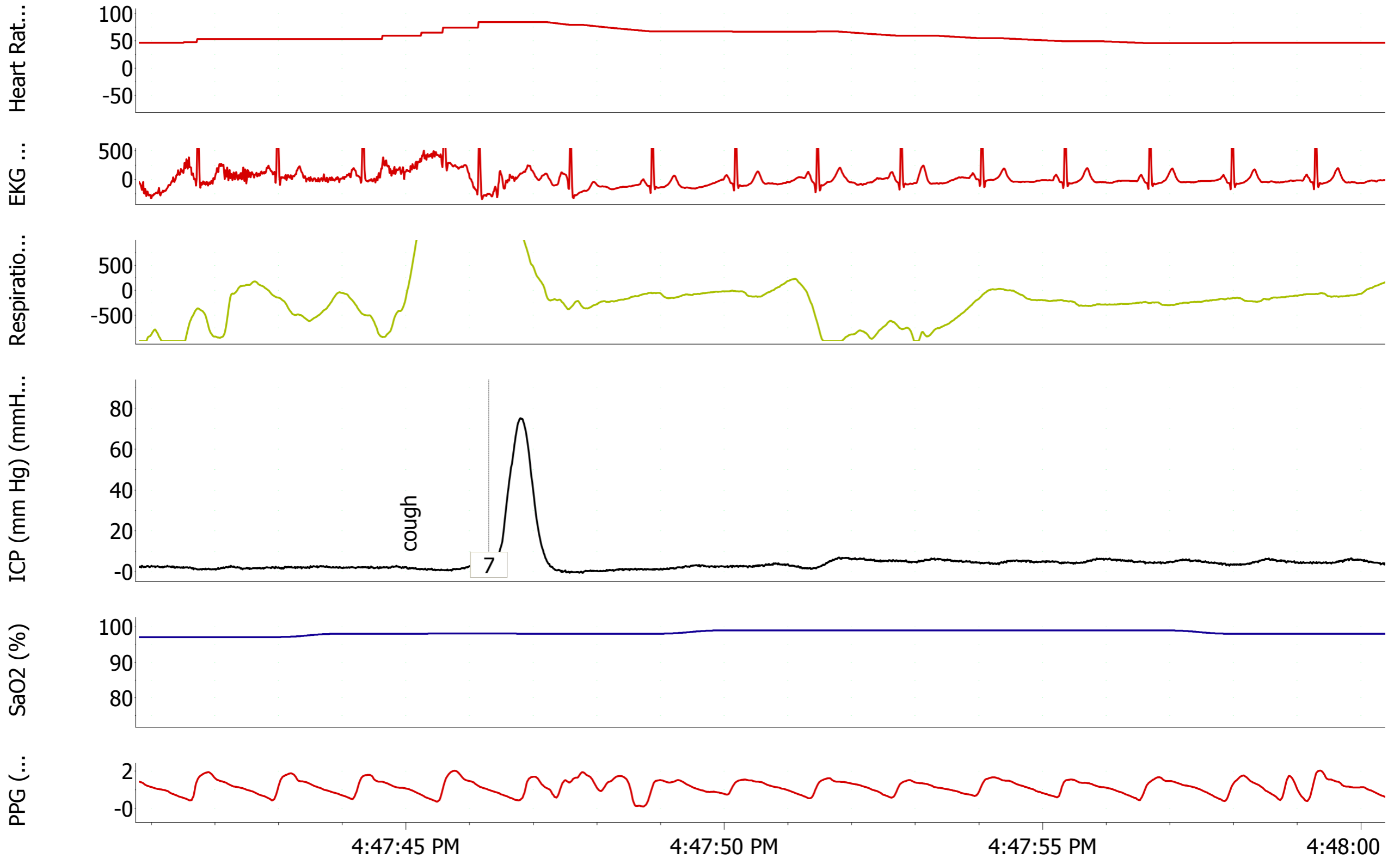
ICP Monitoring in large Tarlov Cysts with no radiographic signs of leak

Age	Diagnoses	Upright pressure (mm Hg)	Orthostatic headache
58	Tarlov cyst.	-13	Yes
49	Sacral dural cyst	-16	Yes
41	Sacral cyst	-14	Yes
49	Marfan syndrome Sacral dorsal ectasias	-25	Yes
25	Tarlov cyst	-10.7	Yes
36	Tarlov cysts	-7	Yes
39	Tethered cord syndrome, Tarlov cyst	-20	Yes
31	Sacral cyst	-12	Yes
66	Large sacral internal meningocele	-5	Yes
42	chronic low back pain, sacral dural cysts, infertility, bicornuate uterus.	-13	Yes
34	Occult spina bifida Meningocele	-4	Yes

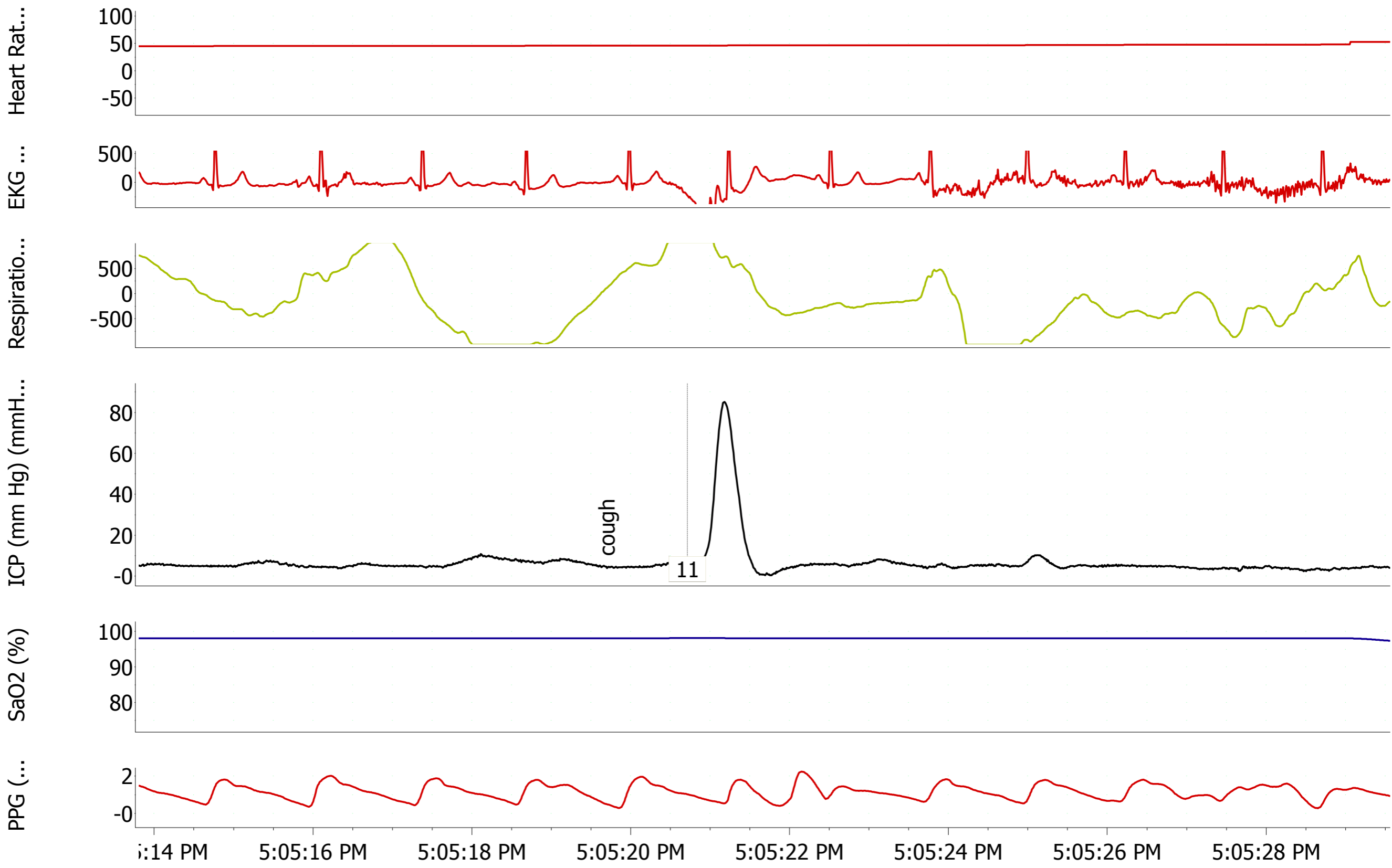
cICP Implications post-treatment –

No straining.....

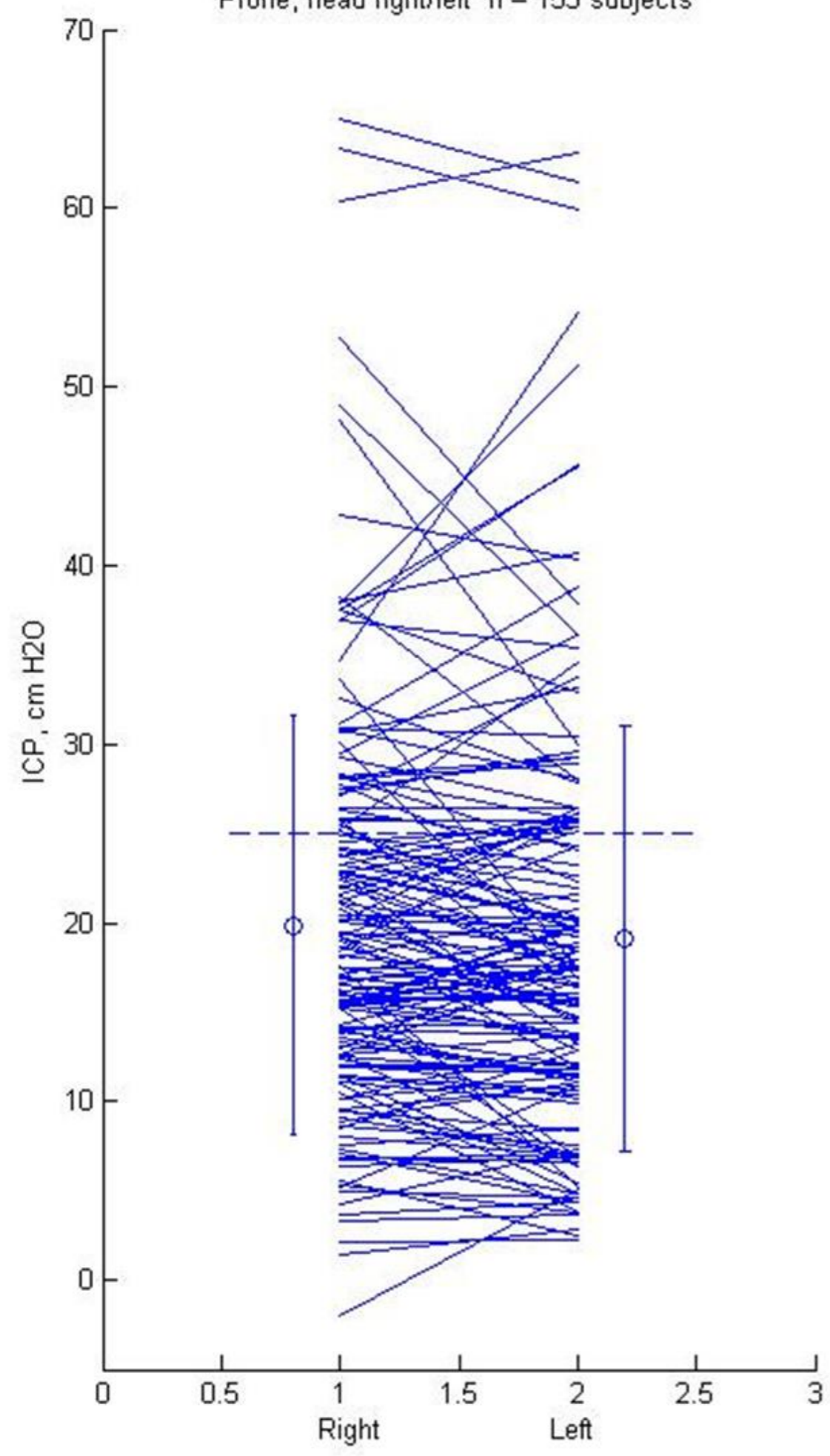
Effects of Coughing



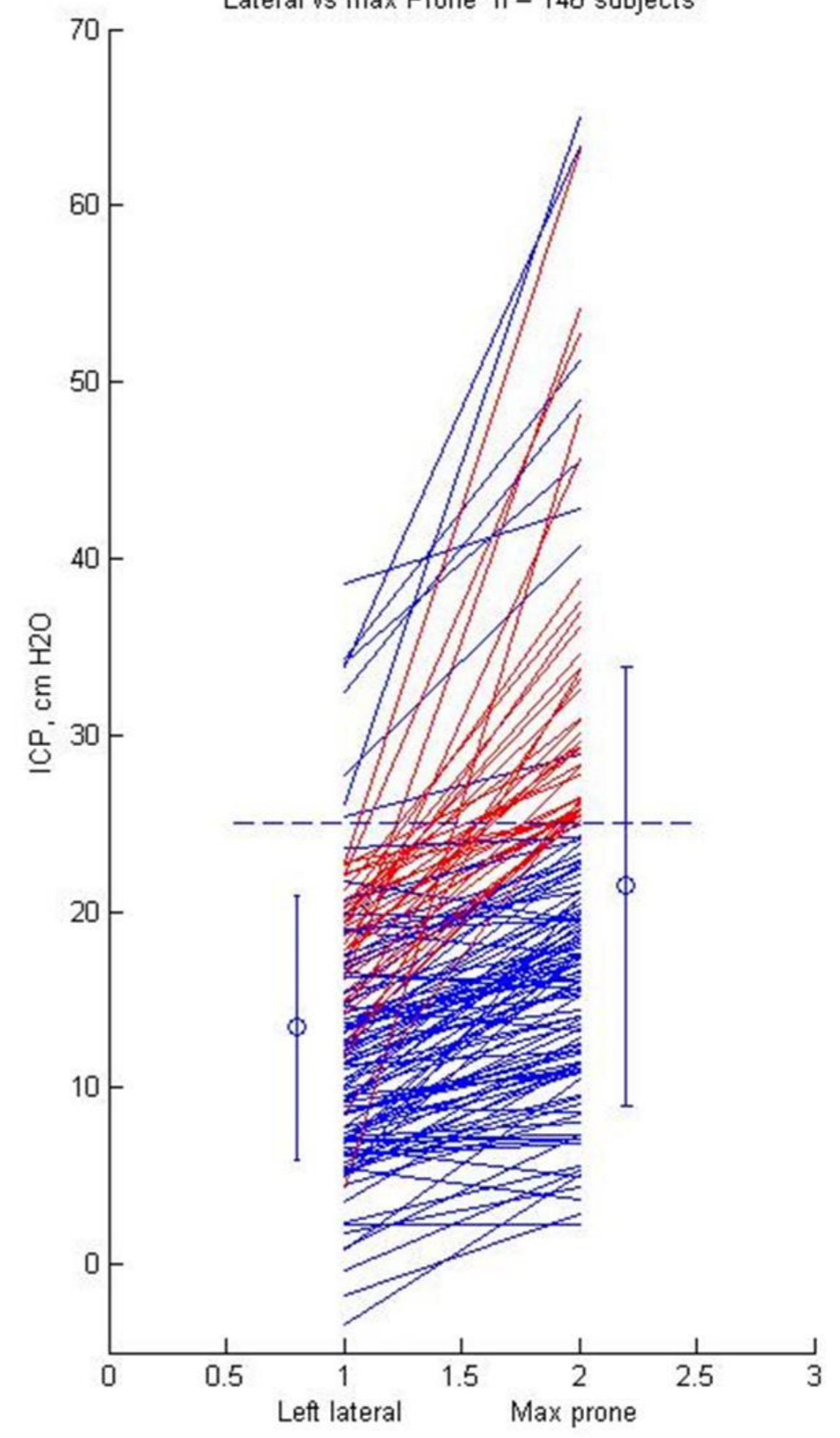
LabChart Window



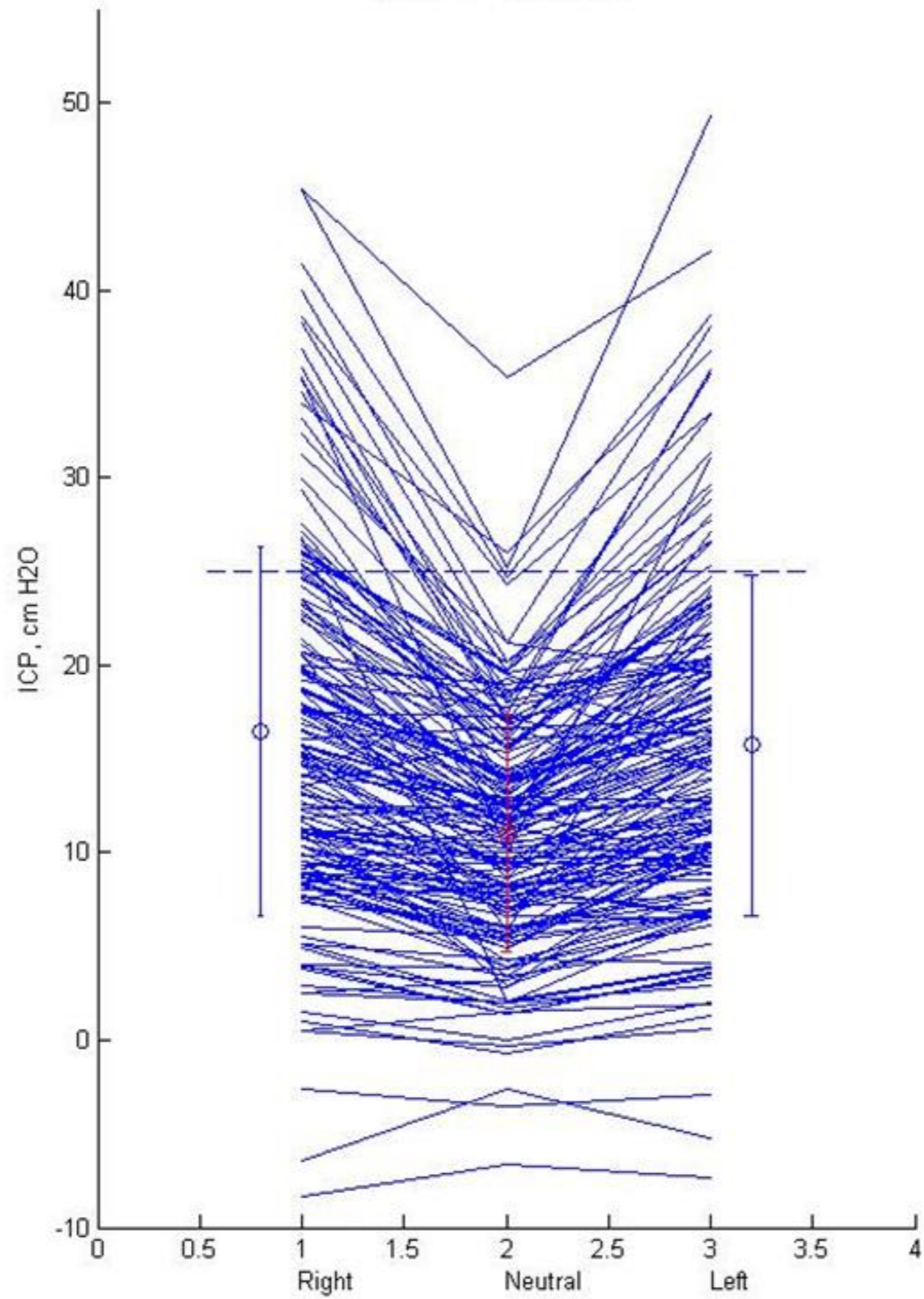
Prone, head right/left n = 155 subjects



Lateral vs max Prone n = 148 subjects



Supine n = 163 subjects



Sleep Apnea related ICP elevations

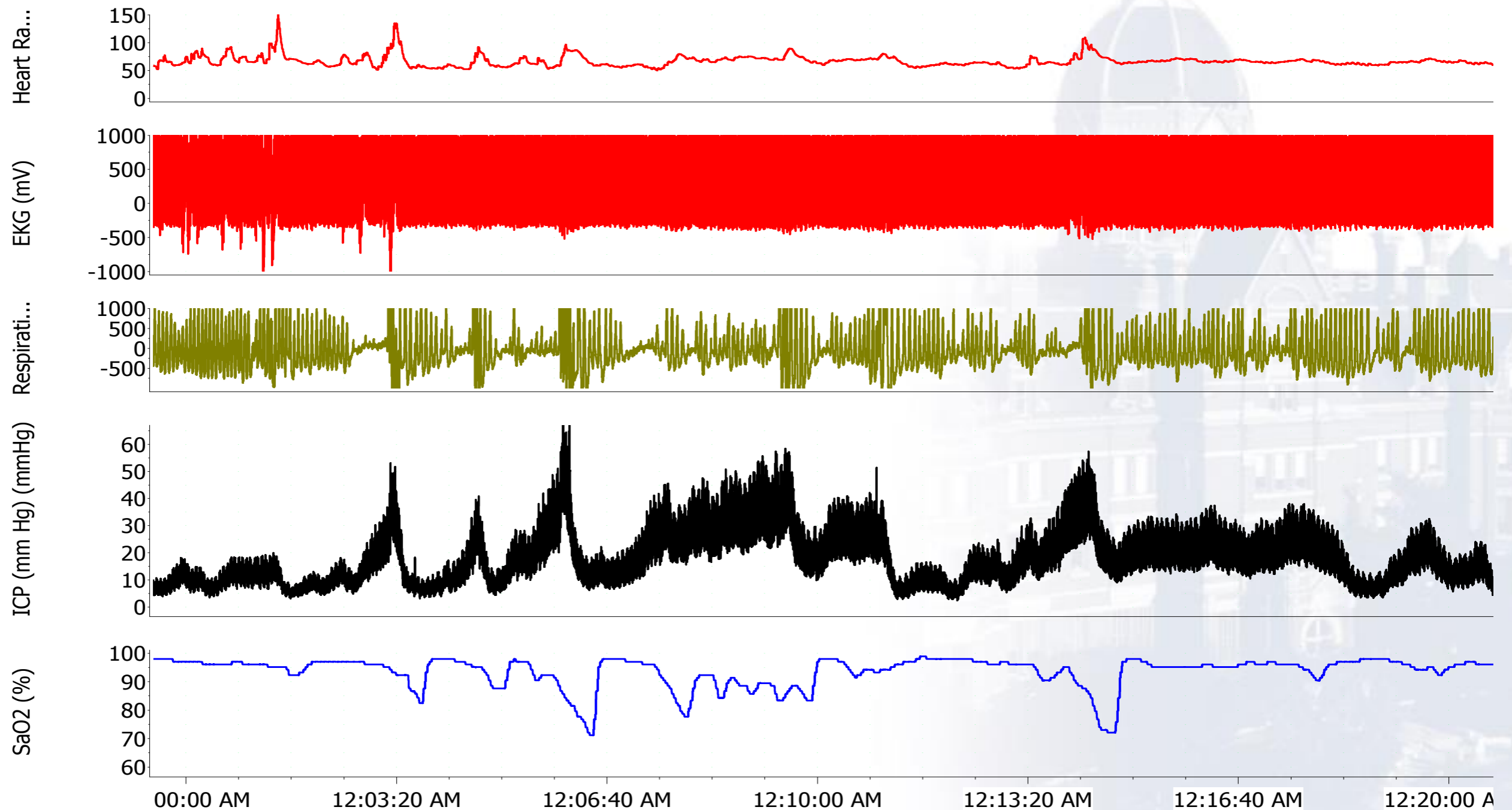


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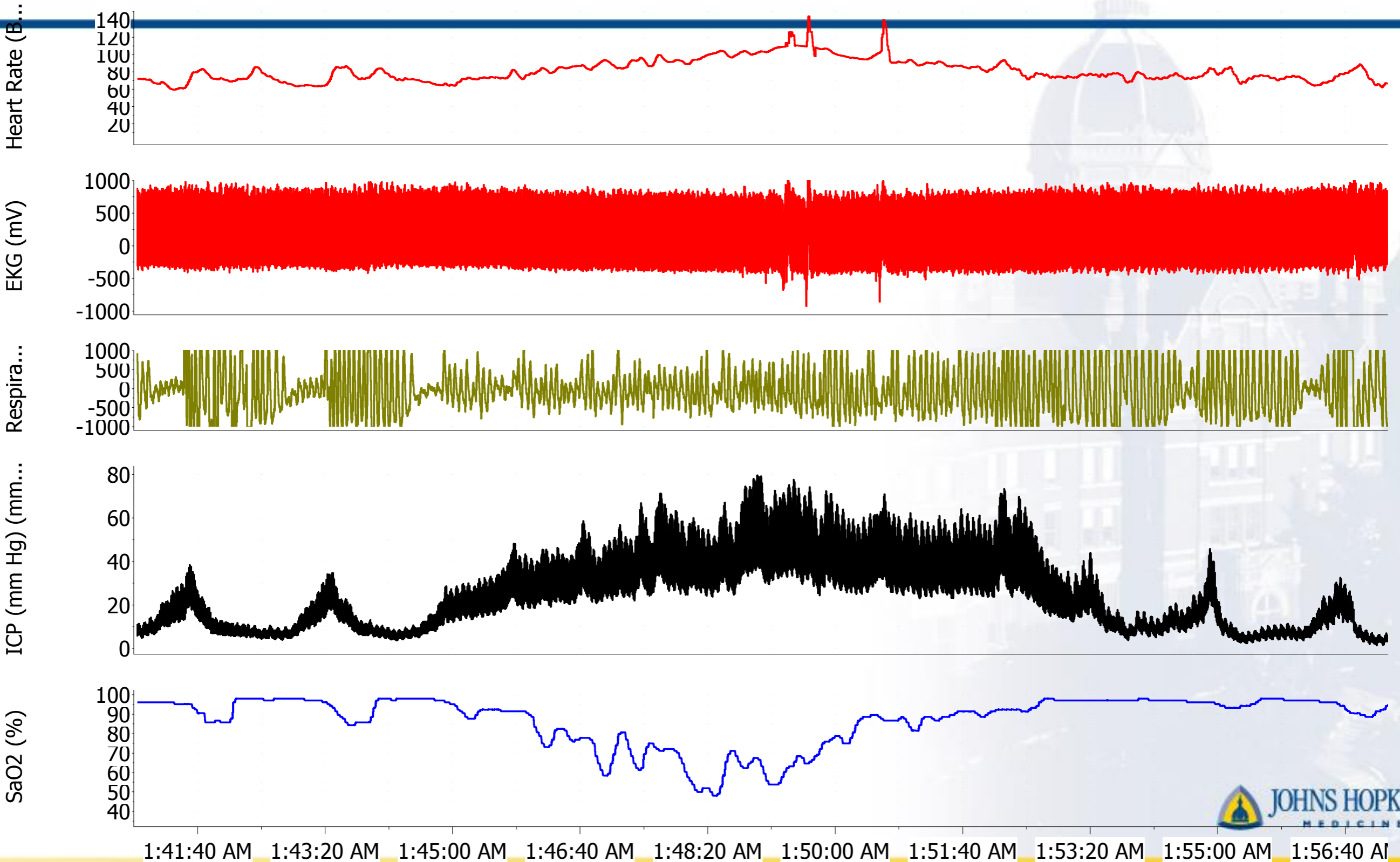
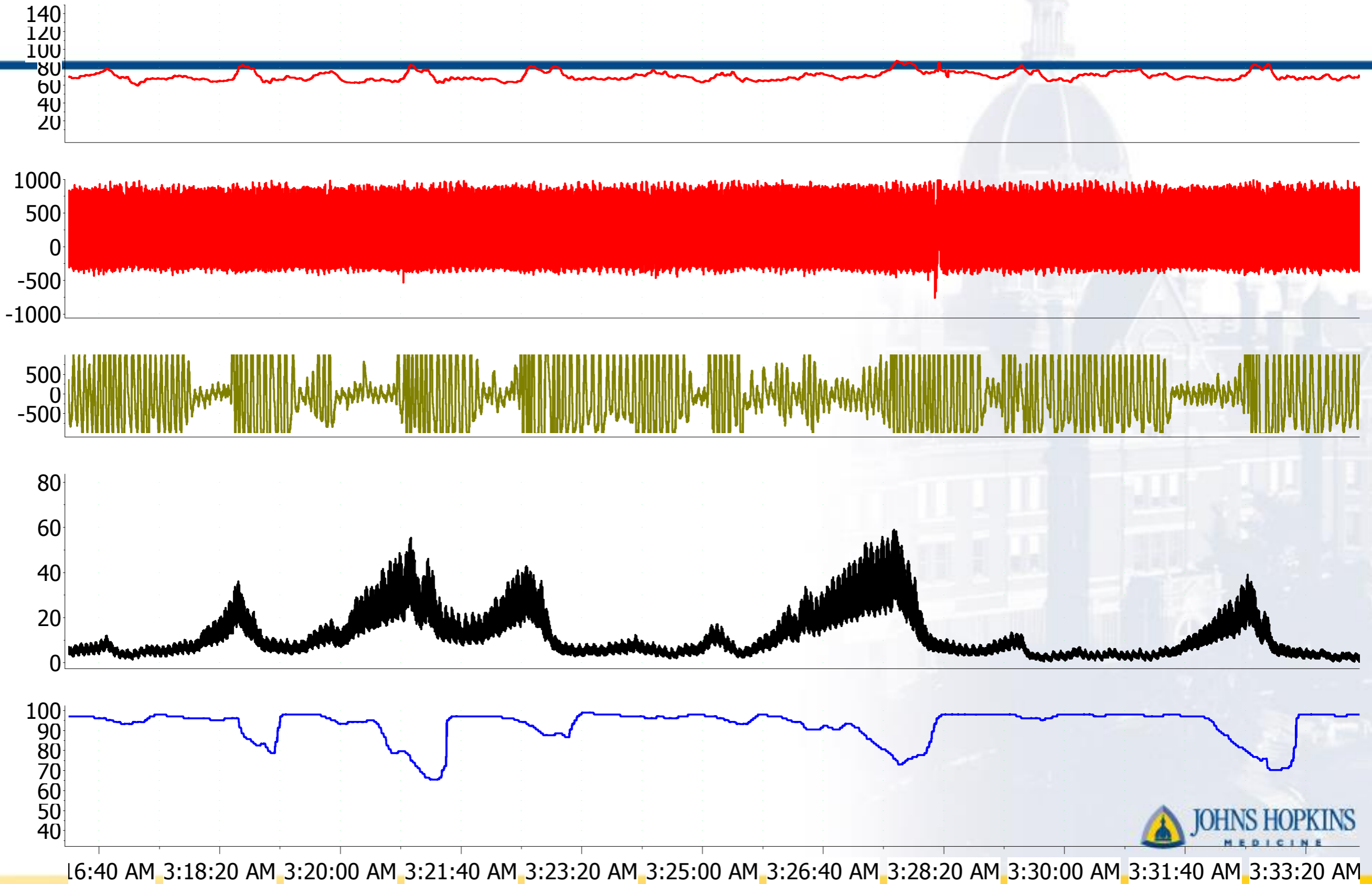


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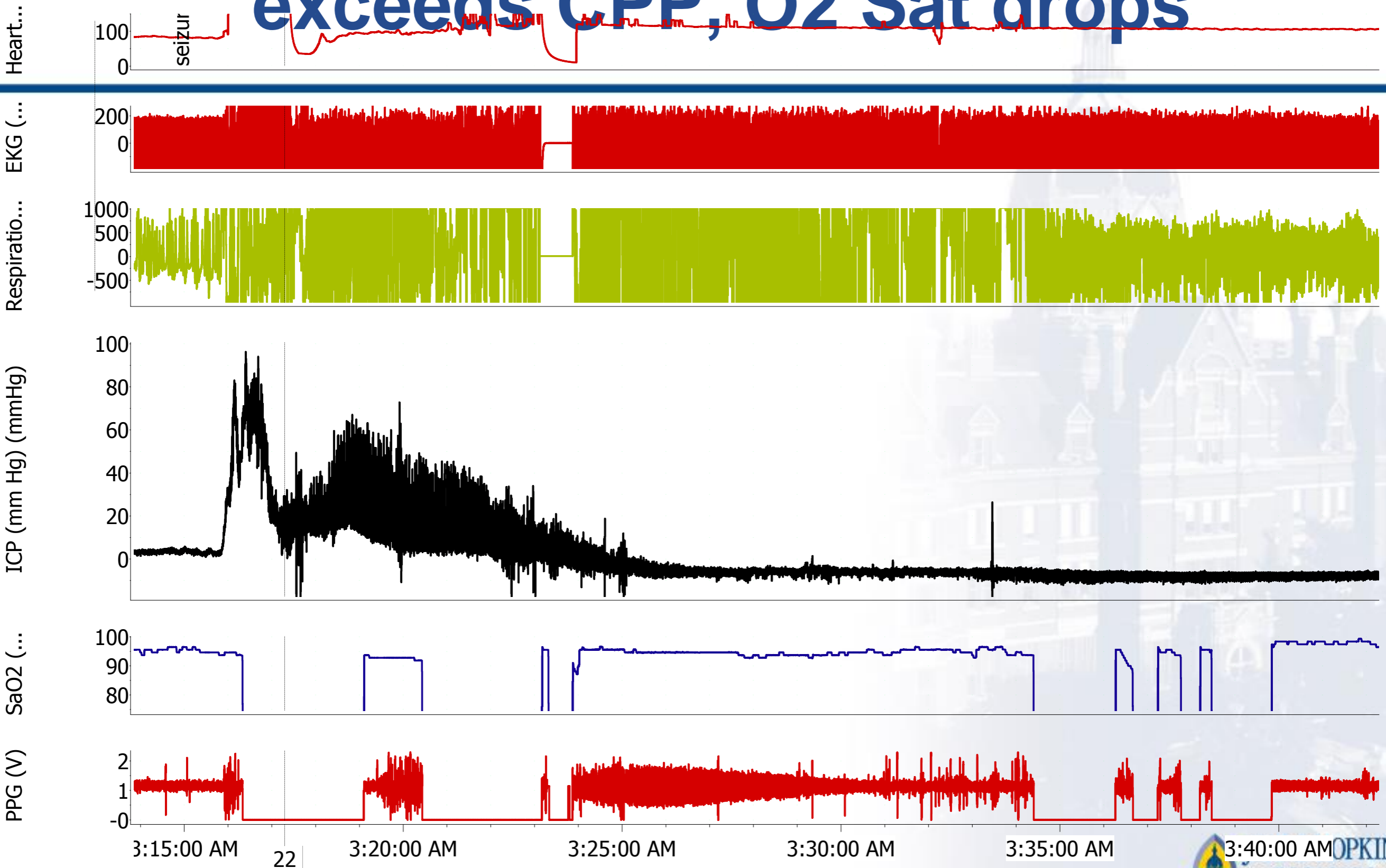
Practical Implications of cICP for SIH post-treatment

- Sleep Apnea
- Body position
- Rebound intracranial hypertension
- Venous Stenosis
- Avoid futile treatment
- Guide appropriate treatment

Complications

- Scalp infection: <1%
- Seizures: <1%

ICP during a GTC Seizure – exceeds CPP, O2 Sat drops



Acknowledgments

Neurology

- Dr. Aruna Rao
- **Dr. David Solomon**

Neurosurgery

- Dr. Mark Luciano

Radiology

- Dr. Ferdinand Hui
- Dr. Majid Khan
- Dr. Ari Blitz

Neuroscience Nurses