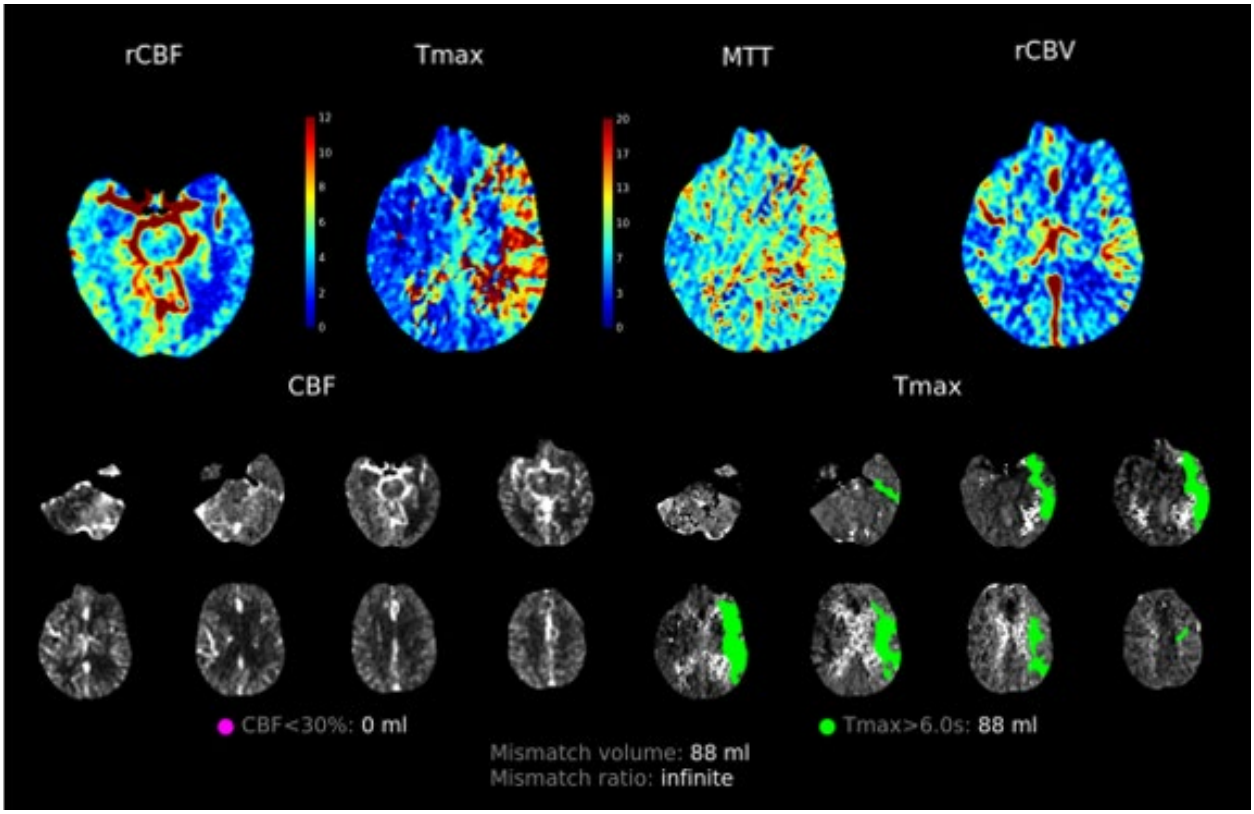
Supplementary figures

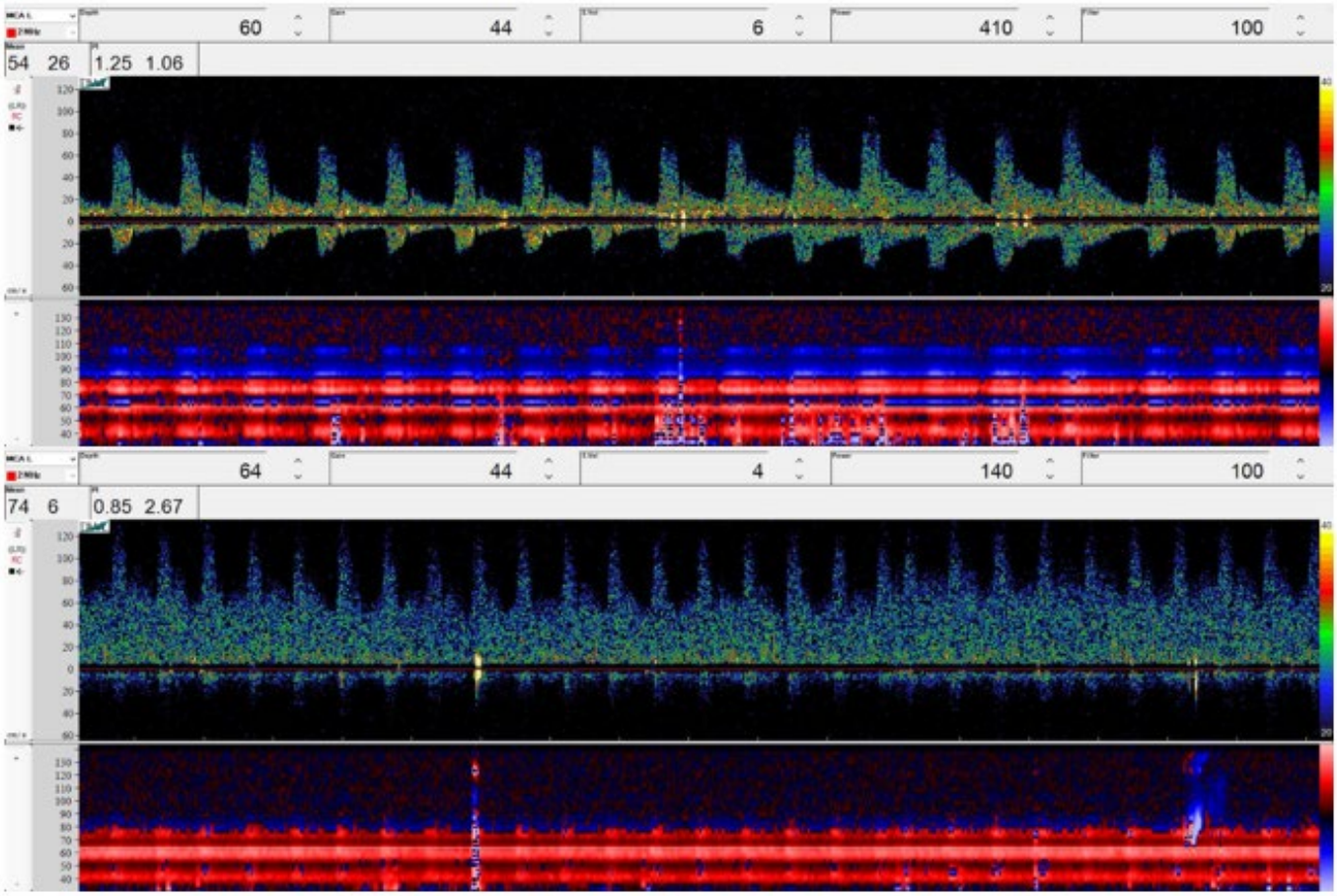
Supplementary Figure 1 shows a practical example of neurological assessments used in a neurocritical care unit. Frequent assessments with this detail can be taxing both for patients as well as nursing staff and can be reserved for patients with high risk of brain injury or deterioration from known neurological or neurosurgical illness. In this patient, these assessments are being performed every 4 hours.

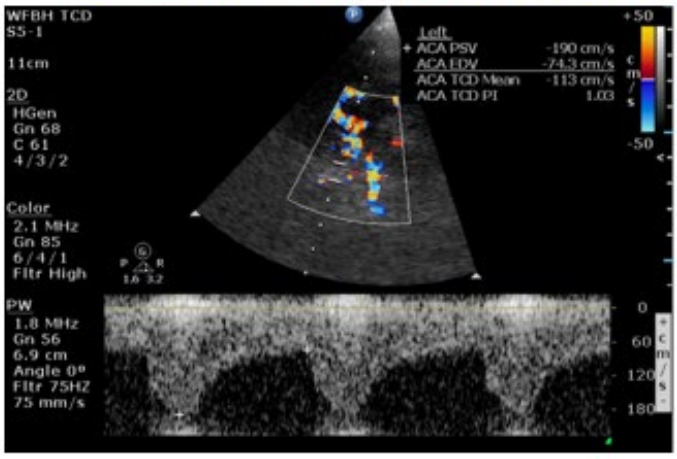
Continuous Infusion of Sedatives																	
Exam on continuous infusion of sedatives?		No				No				No				No			Exam o...
RASS																	
RASS Goal		0				0				0				0	0		RASS G...
RASS Score (With OR Without sedation)		0				0				0				-1	0		RASS S...
CAM-ICU																	
Feature 1: Acute change or fluctuating cours...		No				No				No				No			Feature...
Feature 3: Altered level of consciousness		RASS...				RASS...				RASS...				RASS...	RASS...		Feature...
CAM Delirium Assessment		Negat...				Negat...				Negat...				Negat...			CAM De...
Glasgow Coma Scale																	
Eye Opening		4				4				4				3	4		Eye Op...
Best Verbal Response		5				5				5				5	5		Best Ver...
Best Motor Response		6				6				6				6	6		Best Mo...
Glasgow Coma Scale Score		15				15				15				14	15		Glasgo...
Cranial Nerves																	
R Pupil Size (mm)		3				3								3			R Pupil...
L Pupil Size (mm)		3				3								3			L Pupil...
R Pupil Reaction		Brisk				Brisk								Brisk			R Pupil...
L Pupil Reaction		Brisk				Brisk								Brisk			L Pupil...
R EOM		Yes				Yes								Yes			R EOM
L EOM		Yes				Yes								Yes			L EOM
Facial Strength Smile/Grimace		Strong				Strong								Strong			Facial S...
Gag		Strong				Strong											Gag
Cough		Strong				Strong								Strong			Cough
Involuntary Movement		No				No								No			Involunt...
Neuro Additional Assessments		No				No											Neuro A...
Neuro																	
Level of Consciousness		Alert				Arous...				Alert				Alert			Level of...
Orientation Level		Orien...				Orien...				Orien...				Orien...			Orientati...
Cognition		Follo...				Follo...				Follo...				Follo...			Cognition
Speech		Clear				Clear				Clear				Clear			Speech
Motor - Follow Commands																	**Motor ...**
R Shoulder Abduction		5				5				5				5			R Shoulder
L Shoulder Abduction		5				5				4				4			L Shoulder
R Elbow Extension		5				5				5				5			R Elbow Ex
L Elbow Extension		5				5				4				4			L Elbow Ex
R Hand Grip		Strong				Strong				Strong				Strong			R Hand Gri
L Hand Grip		Strong				Strong				Strong				Strong			L Hand Grip
R Hip Flexion		5				5				5				5			R Hip Flexi
L Hip Flexion		5				5				5				5			L Hip Flexio
R Knee Extension		5				5				5				5			R Knee Ext
L Knee Extension		5				5				5				5			L Knee Ext
R Foot Dorsiflexion		5				5				5				5			R Foot Dor
L Foot Dorsiflexion		5				5				5				5			L Foot Dors
Respiratory																	**Respira**

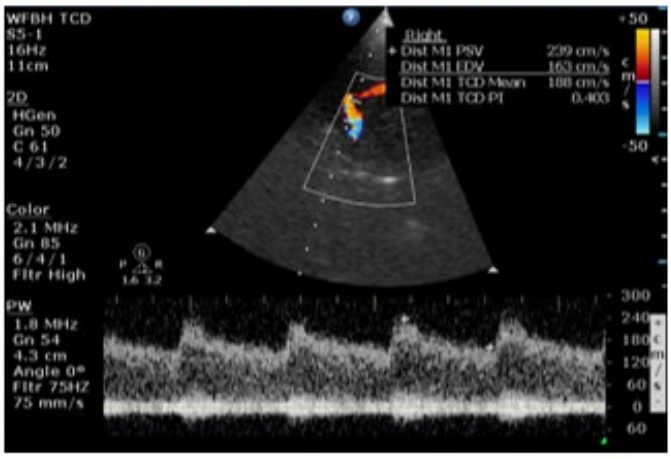
Supplementary Figure 2 upper panel shows classical representation of perfusion deficits with risk of ischemia without associated infarction in a patient with clinical exam consistent with left middle cerebral artery (MCA) ischemia. Lower panel shows automated artificial intelligence algorithm with image analysis to calculate T-max, the time of circulation of contrast to left MCA and CBF proportion <30% denoting no significant infarction. (Viz.Ai Inc; iSchemaView RapidAI™, Frost Radar™; Briefcase, Aidoc Medical; Brainomix, Oxford, England)



Supplementary Figure 3 shows changes in middle cerebral artery velocity in a patient during hyperventilatory phase of Cheyne-Stokes breathing with high resistance waveforms (pulsatility index 1.25) and normal middle cerebral artery velocities(54 cm/s). During the apneic phase retention of CO2 leads to decreased cerebral vascular resistance and relative hyperemia(mean flow velocity 74 cm/s and pulsatility index 0.85). Bottom panel shows high velocities in a patient with subarachnoid hemorrhage: Anterior cerebral artery 113 cm/s, middle cerebral artery(MCA) 180 cm/s concerning for sonographic vasospasm. Low pulsatility index 0.4 in MCA raises the concern for concomitant hyperemia in ischemic brain.


60
44
6
410
100
54 26
1.25 1.06
64
44
4
140
100
74 6
0.85 2.67


WFBH TCD
S5-1
11cm
2D
HGen
Gn 68
C 61
4/3/2
Color
2.1 MHz
Gn 85
6/4/1
Fltr High
PW
1.8 MHz
Gn 56
6.9 cm
Angle 0°
Fltr 75HZ
75 mm/s
Left
ACA PSV -190 cm/s
ACA EDV -74.3 cm/s
ACA TCD Mean -113 cm/s
ACA TCD PI 1.03
+50
-50
0
60
120
180


WFBH TCD
S5-1
16Hz
11cm
2D
HGen
Gn 50
C 61
4/3/2
Color
2.1 MHz
Gn 85
6/4/1
Fltr High
PW
1.8 MHz
Gn 54
4.3 cm
Angle 0°
Fltr 75HZ
75 mm/s
Right
Dist M1 PSV 239 cm/s
Dist M1 EDV 163 cm/s
Dist M1 TCD Mean 188 cm/s
Dist M1 TCD PI 0.403
+50
-50
300
240
180
120
60
0
60

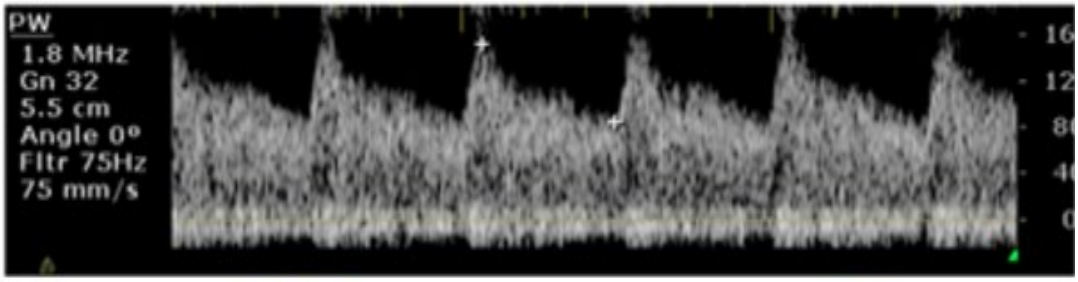
Supplementary Figure 4. Multimodality monitoring based on routine ICU monitoring panels available in most ICUs (Phillips, Intellivue MX850). Tracing of a patient with hemorrhagic stroke who underwent placement of an external ventricular drainage (EVD) catheter due to poor exam and intraventricular hemorrhage with improvement in exam after EVD. Upper panel shows telemetry tracings and heart rate 106 beat per minute (green), invasive blood pressure measured via arterial line 146/78 mmHg (red), invasive Intracranial pressure (ICP) monitoring 7 mmHg (pink), pulse oximetry reading through a fibreoptic sensor placed on finger 97% (aqua) and spirometry tracings for respiratory monitoring 28 (white). Bottom panel shows the patients' monitor tracing few hours. The tracing now show similar ICPs 7mmHg but with non-compliant ICP waveforms with increasing systemic blood pressures requiring escalation of antihypertensive infusion and change in respiratory pattern to sighing. The patient had no clinical change in exam. The patient suffered an ICP crisis few hours after this pattern followed by clinical deterioration with confirmed progression of cerebral edema on neuroimaging requiring evacuation of hemorrhage. Assessing change in compliance in this case heightened alert on assessing neurological exam frequently leading to earlier surgical evacuation.


106
106
96
2.84
146/78
(103)
(7)
99.7
97
468
28
-8
75
512
182/90
(7)
100
11

Supplementary Figure 5 shows pathophysiological mechanisms in two etiologies causing Intracranial pressure (ICP) crisis. Upper panel shows increase in cerebral perfusion driving ICPs also called hyperemic intracranial hypertension demonstrated by concomitant hyperemic waveform seen on transcranial Doppler. Such phenomenon can be seen in disturbed autoregulation. Lower panel shows increase in cerebral edema impairing perfusion as manifest by oscillating waveforms seen on transcranial Doppler's also called oligemic intracranial hypertension. [34]

Perfusion driven ICP crisis

Hyperemic intracranial hypertension

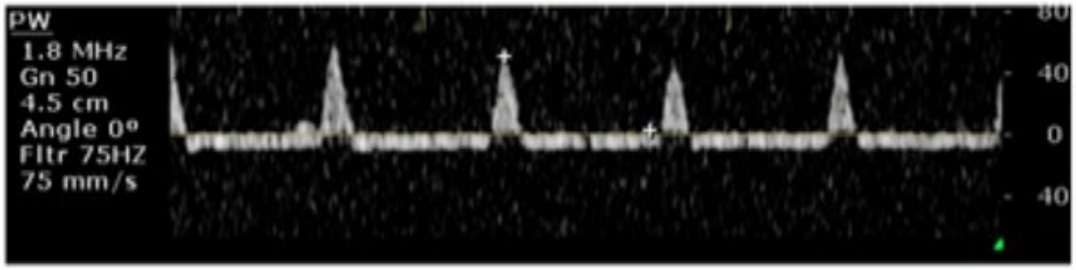


CSF Blood Brain

CSF Blood Brain

Perfusion limiting ICP crisis

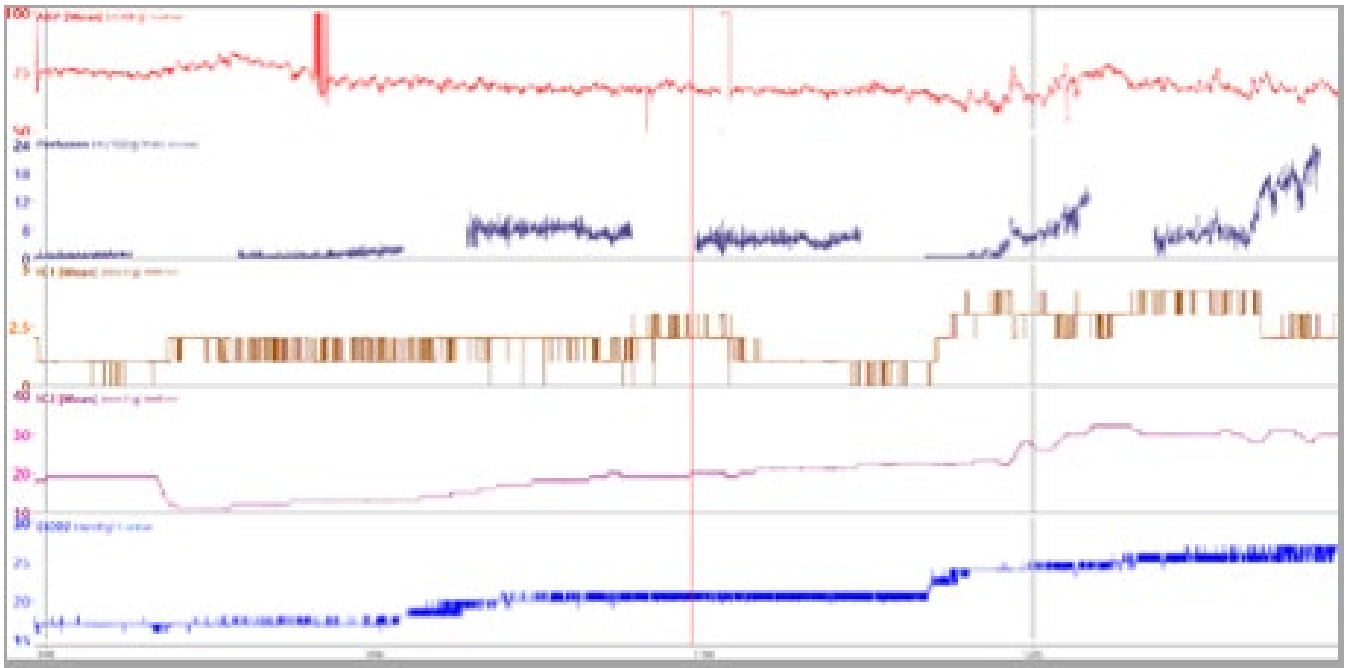
Oligemic intracranial hypertension

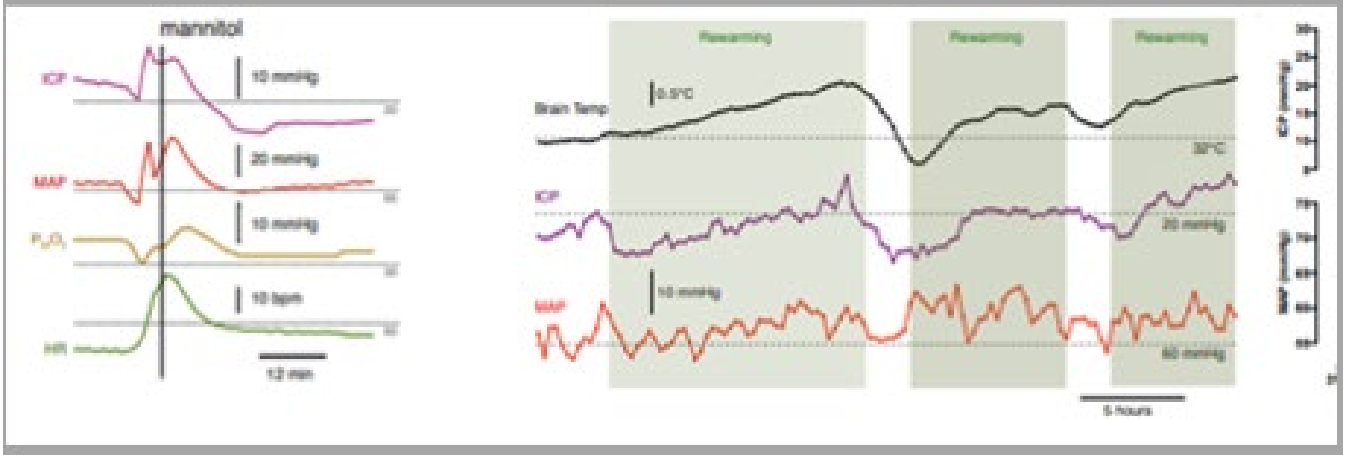


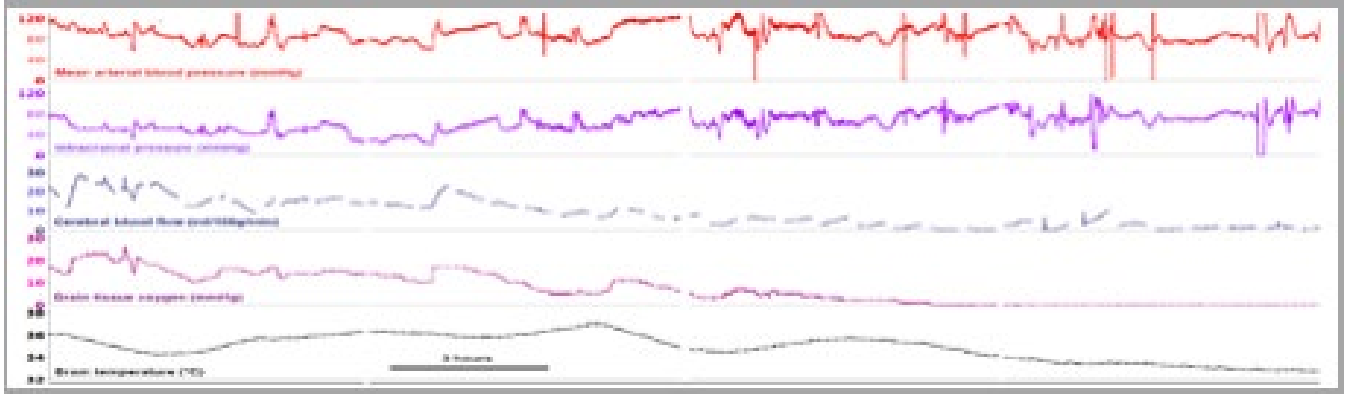
CSF Blood Brain

CSF Blood Brain

Supplementary Figure 6. Upper panel shows a multimodality platform in a patient with an inadvertent reduction in ventilatory rate caused by sedation corresponding increase in an end-tidal CO2. This led to an increase in cerebral perfusion measured by invasive thermal diffusion monitor, eventually leading to increase in intracranial pressure (ICP). Middle panel shows a patient undergoing therapeutic temperature modulation with multimodality monitoring with ICP crisis during rewarming that responded to osmotic therapy but recurred during subsequent rewarming warranting prolonged & slower rewarming phase. Lower panel shows a patient showing physiological progression of cerebral circulatory arrest. (Image courtesy Ramani Balu, MD)




mannitol
ICP
10 mmHg
MAP
20 mmHg
P_{tO_2}
10 mmHg
HR
10 bpm
12 min
Rewarming
Rewarming
Rewarming
Brain Temp
0.5°C
32°C
ICP
20 mmHg
10 mmHg
MAP
60 mmHg
5 hours



Supplementary Figure 7 upper panel shows unprocessed electroencephalography (EEG) in a post cardiac arrest patient undergoing rewarming after therapeutic temperature modulation consistent with a diagnosis of generalized nonconvulsive status epilepticus. Lower panel shows quantitative EEG analysis in a patient with electrographic seizures emanating from right cerebral hemisphere (even numbered leads Fp4, C4, P4 & O2). Such analysis uses fast Fourier transformation spectrogram's to allow bedside detection of electrographic seizures synthesized from raw EEG waveforms facilitating more efficient & selective review of source EEG and event review.


P14 Trends, AR OS

Supplementary Figure 8. Left figure shows electronic medical record nursing flowsheet with trends in ICP and patient systemic pressure tabulated over couple of hours that show a linear relationship between the systemic blood pressure and ICP showing disturbed autoregulation. Right panel provides similar monitoring tracings in addition to serial representation of an index of autoregulation PRx, a moving correlation coefficient between the MAP and ICP. This panel showing the dynamic nature of PRx based on other physiological parameters.