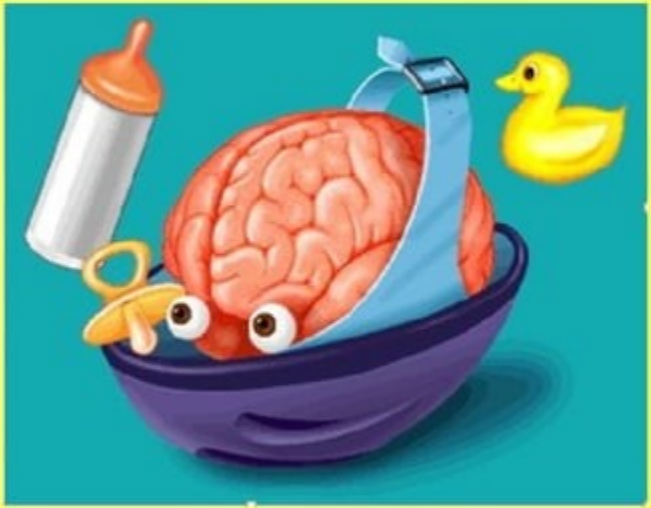
Advances in Neuro-Anesthesia Monitoring

Something in the market?

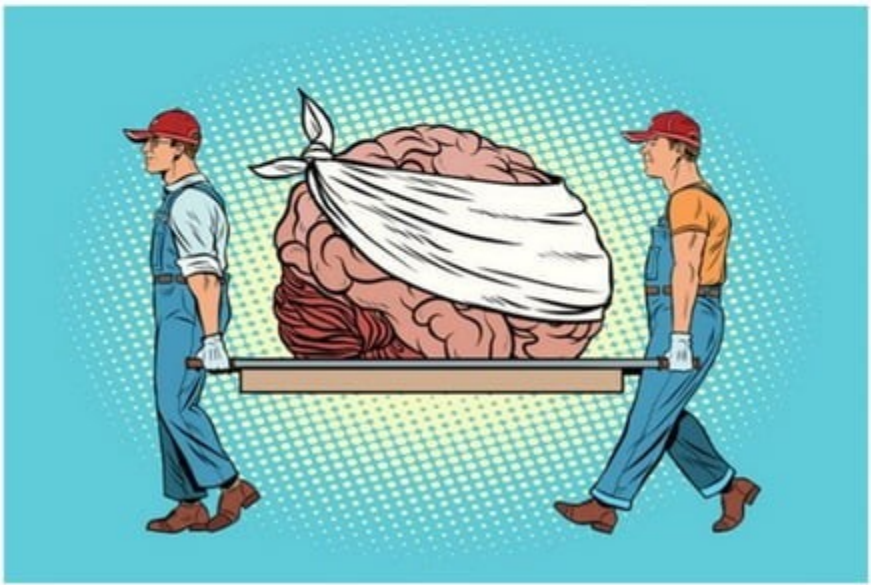


Wesam Farid Mousa

Proffessor of Anesthesia & Surgical ICU

Tanta University, Egypt

The anaesthetized brain is vulnerable to ischemic insults, which could result in neuropsychological disturbances, stroke and even death.

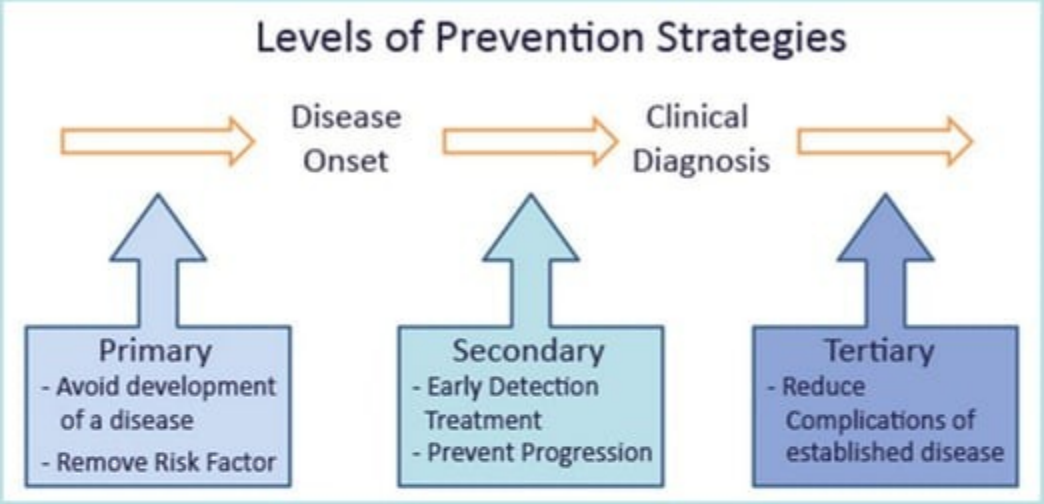


The anesthesiologist plays a pivotal role in instituting neuro protective strategies



He has to rely on neuromonitoring to prevent intraoperative neurological insult.




Levels of Prevention Strategies
Disease Onset
Clinical Diagnosis
Primary
- Avoid development of a disease
- Remove Risk Factor
Secondary
- Early Detection Treatment
- Prevent Progression
Tertiary
- Reduce Complications of established disease



Secondary prevention include
early detection of neuro-ischemia

SO

Secondary prevention needs efficient
monitoring tests and tools.

The brain can be monitored in terms of:-

- Function
- ICP & CBF
- Brain oxygenation

The brain can be monitored in terms of:-

- Function
- **ICP & CBF**
- Brain oxygenation

Monitoring of function:-

1)Wake up test

2) Electroencephalogram EEG

Raw EEG Bispectral index Entropy

3) Evoked Potentials:

SEP: SSEP Visual Auditory

MEP: Transcranial magnetic / Transcranial electric

Wake-up test

Lightening anesthesia during the procedure and observing the patient's ability to move to command.

It was first described in 1973.

Disadvantages:

- Evaluates gross functional integrity of motor pathway
- Provides information at the time of the wake-up only
- Does not assess sensory pathways


Middle
RISK
Low
High

Monitoring of function:-

1)Wake up test

2) Electroencephalogram EEG

Raw EEG Bispectral index Entropy

3) Evoked Potentials:

SEP: SSEP Visual Auditory

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Electroencephalography

EEG

"Recording brain's spontaneous electrical activity over a period of time from multiple electrodes placed on the scalp"



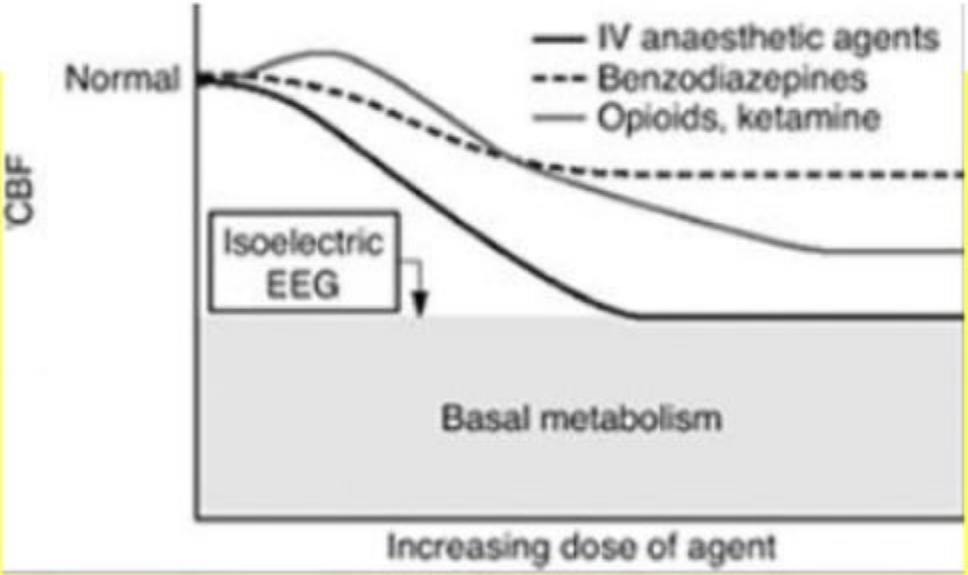


Intraoperatively, EEG can be used to :

Indirectly measures blood flow

Measures anesthetic effects

Detect cerebral ischemia

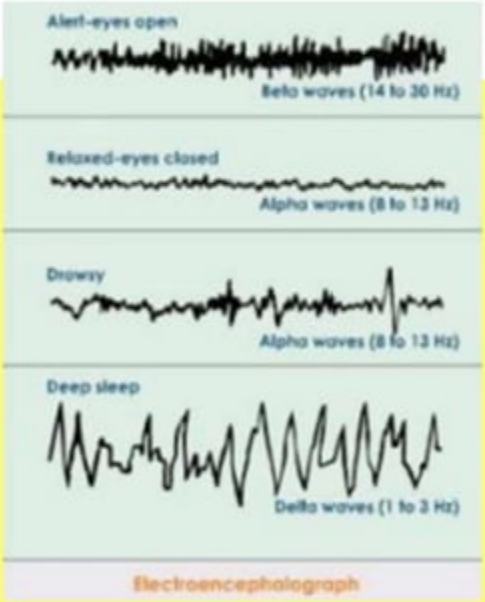


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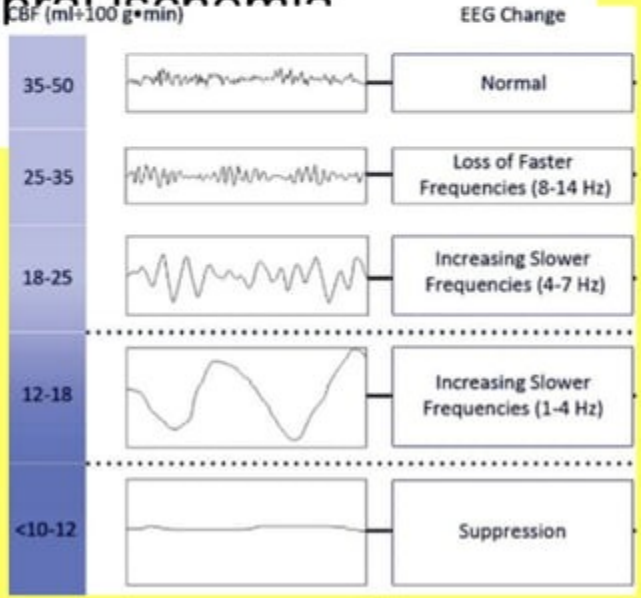
Detect cerebral ischemia

EEG criteria for ischemic changes e.g. in CEA:

Attenuation of 8-15 Hertz activity to minimal or nil

and/or

Two-fold or more increase of delta activity at one Hertz or less



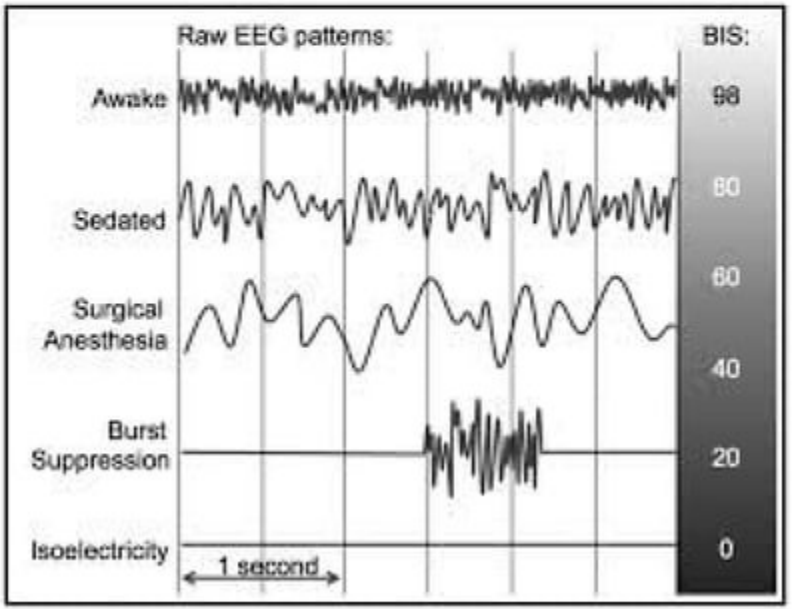
Limitation:

*Expert encephalographer is required

*Affected by Artefacts, Anesthesia, Hypoxemia Hypotension Hypothermia Hyper-Hyporcarbia

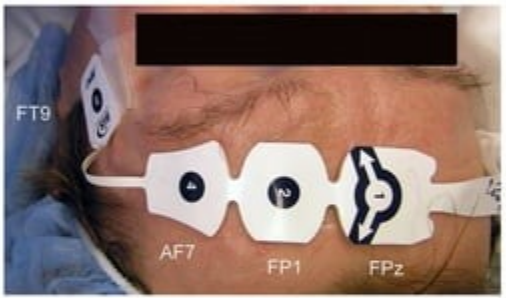


"raw EEG" was converted to a "processed" one that needs less experience to interpret



Bispectral Index (BIS), Entropy

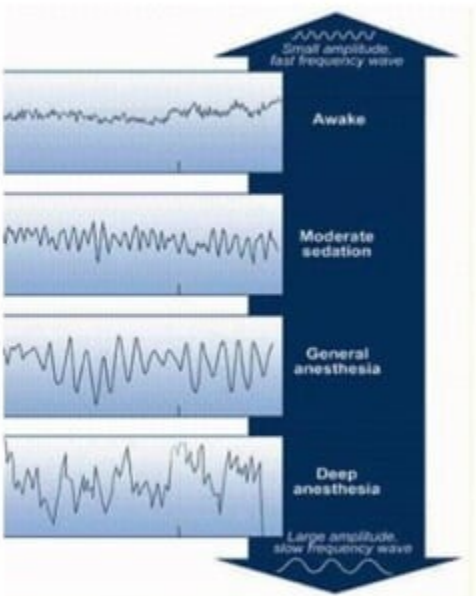
These monitors provide a number derived from EEG, which indicates level for general anesthesia

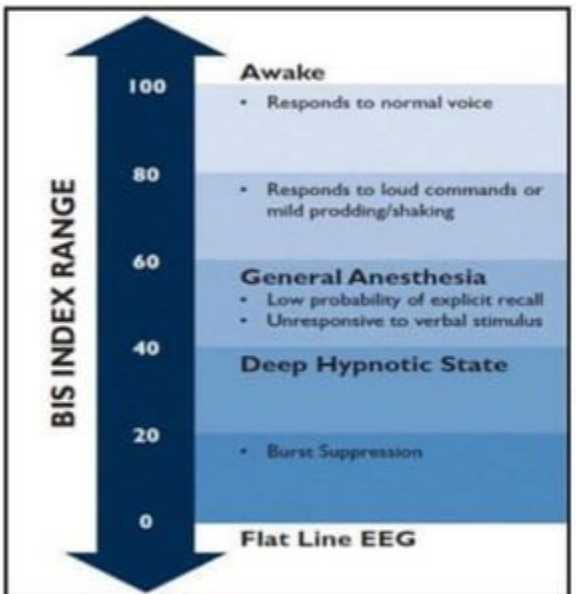






BIS

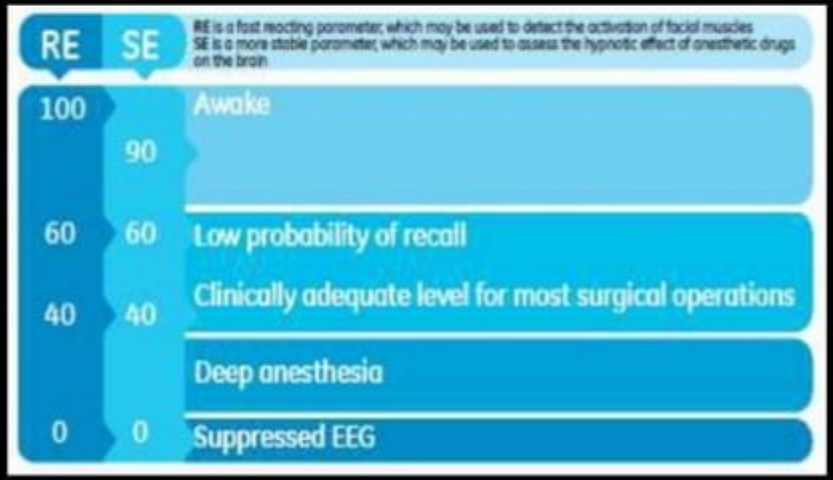

Small amplitude, fast frequency wave
Awake
Moderate sedation
General anesthesia
Deep anesthesia
Large amplitude, slow frequency wave


BIS INDEX RANGE
100
80
60
40
20
0
Awake
Responds to normal voice
Responds to loud commands or mild prodding/shaking
General Anesthesia
Low probability of explicit recall
Unresponsive to verbal stimulus
Deep Hypnotic State
Burst Suppression
Flat Line EEG

Entropy

RE Fast matching parameter used to detect activation of facial muscles

SE Used to assess the hypnotic effects of anesthestic drugs on the brain



During awake state and induction there is a difference between the two entropies indicating muscle activity on the face



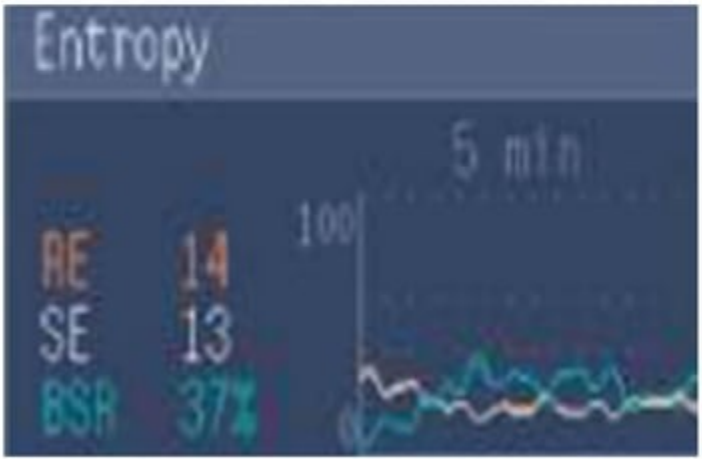
Decrease in the entropy measurement may enable the anesthetist to observe the moment when patient loses responsiveness



Both entropies stabilize during the operation. Sudden peaks in RE during surgeryare caused by activation of FEMG

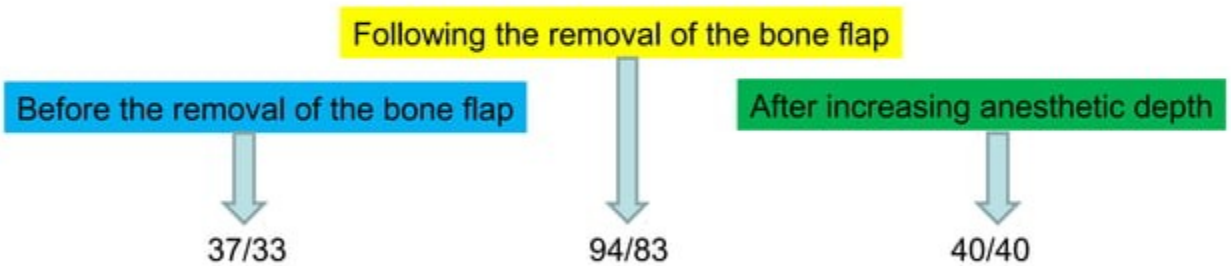


Burst suppression can be selected on the screen to indicate the silent periods in the EEG



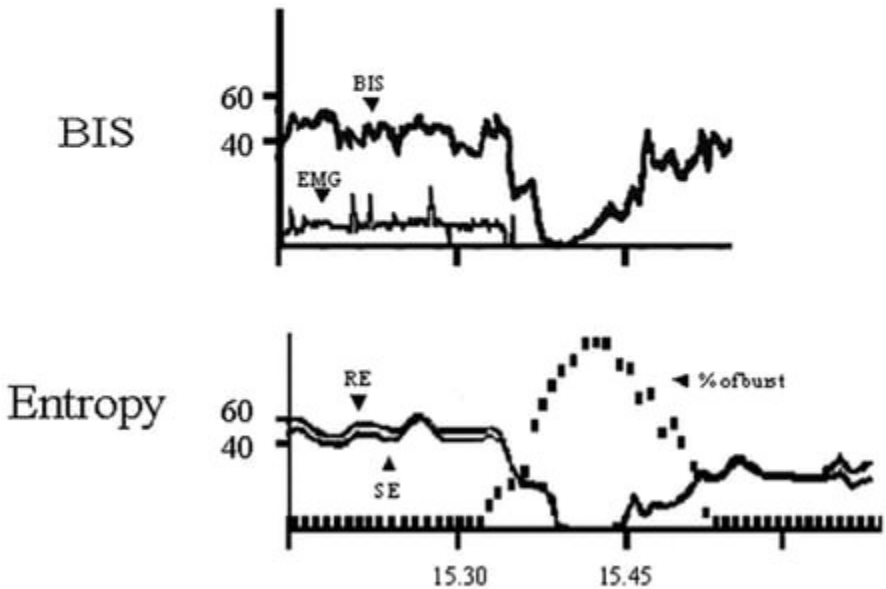
BIS and Entropy can be used as an indirect indicators of increased CBF and ICP

In patients with raised ICP, where anesthesia is titrated according to BIS or entropy values, they suddenly increases after cranial decompression, reflecting decrease in CPP.



(RE) / (SE)

Detection of Gas Embolism by BIS & Entropy



Monitoring of function:-

1)Wake up test

2) Electroencephalogram EEG

Raw EEG Bispectral index Entropy

3) Evoked Potentials:

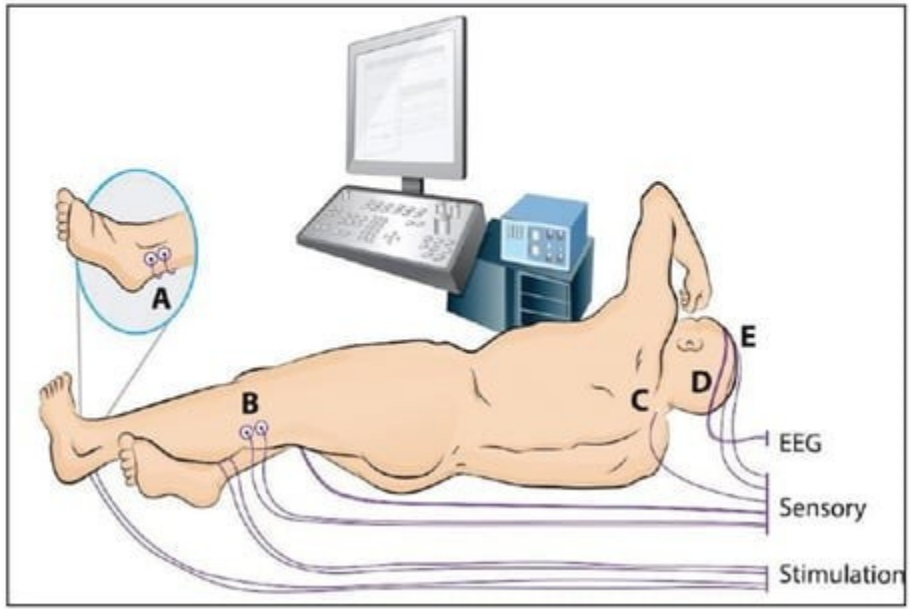
SEP: SSEP Visual Auditory

MEP: Transcranial magnetic / Transcranial electric

Somatosensory evoked potentials

SSEPs

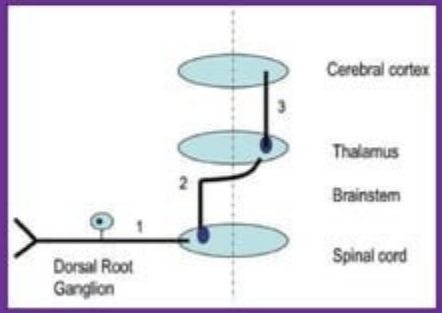
Electrical activity of the brain that results from the stimulation of touch

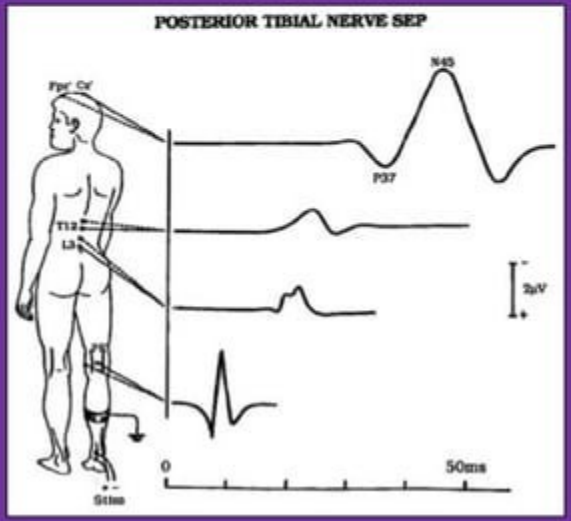


In the 1970's, SSEPs were used to avoid paralysis in scoliosis surgeries and became the standard of care for a wide variety of spinal and other surgeries.

SSEPs provide monitoring to the dorsal columns of spinal cord.

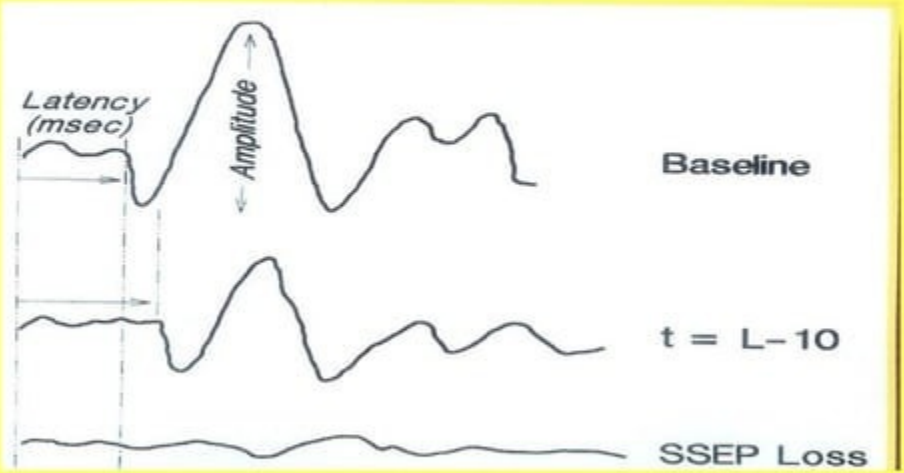
The stimulus applied to the peripheral N (tibial or ulnar)
Recording electrodes placed: scalp or exposed dura
Responses are recorded intermittently during surgery





SSEPs

A reduction in the amplitude by 50% and an increase in the latency by 10% are considered significant.



- Latency – time from stimulus to onset of SER
- Amplitude – voltage of recorded response

Indications

Scoliosis correction

Spinal cord decompression

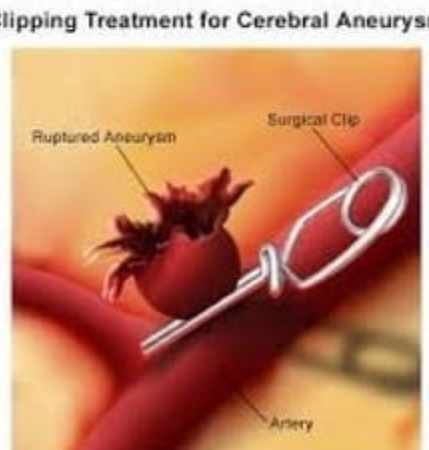
Brachial plexus exploration

Resection of spinal cord tumor

Resection of intracranial lesions

SSEP help to recognize any deterioration in CBF and indicate intermittent reperfusion during:

clipping of intracranial aneurysms, carotid endarterectomy and thoracic aortic aneurysm repair,



Limitations of SSEPs

Motor ventral corticospinal tracts are away from the sensory dorsomedial tracts

So:

It is possible to have normal SSEPs recordings throughout surgery, but to face a paraplegic patient postoperatively.



During the 1990s, "motor evoked potentials", were recorded from peripheral nerves, following direct electrical stimulation of the spinal cord.

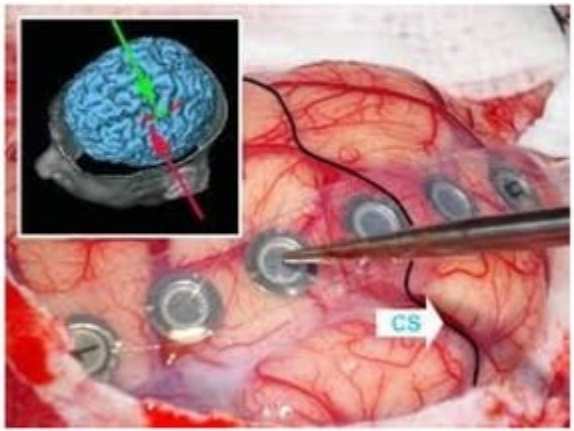
Motor evoked potentials

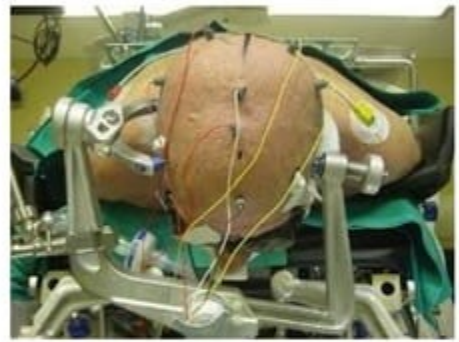
MEP

Central stimulation

Direct: exposed motor cortex

Transcranial: either magnetic or electrical





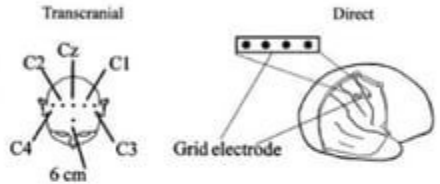


Peripheral responses

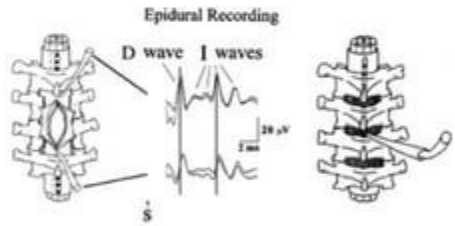
Myogenic: from muscles

Neurogenic: from peripheral nerves or spinal cord

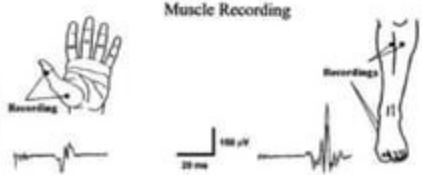
Motor cortex stimulated by electrical or magnetic means



Neurogenic responses: peripheral N or spinal cord



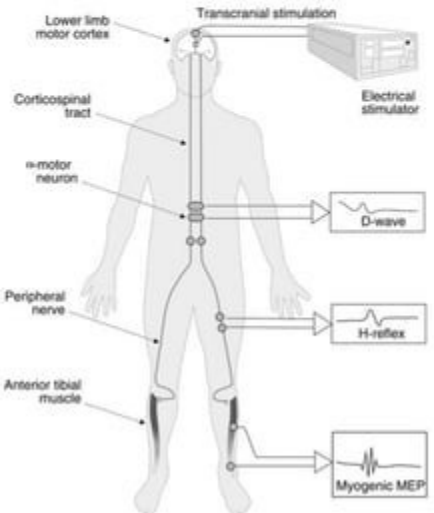
Myogenic responses



Transcranial magnetic stimulation is generally unsuitable intraoperatively because it is sensitive to anesthesia

Electrical stimulation is painful for clinical use in awake patient

Thus, electrical stimulation being the choice for intraoperative monitoring, and magnetic for clinical applications.



The primary problem that has slowed widespread application of the intraoperative SSEPs and MEPs is anesthetic induced depression



Anaesthesia Considerations for MEP

- Nitrous Oxide up to 50%
- Propofol: 75-300 mcg/kg/min (TIVA)
  - -propofol is also recommended for induction at 2.0 mg/kg
- Narcotics: Fentanyl: 1-3 mcg/kg/hr
  - Alfentanil: 10-20 mcg/kg/hr
  - Sufentanil: 0.1-0.3 mcg/kg/hr
- NMB: None

Multimodal monitoring has become the gold standard of care and is the preferred method for detection and reduction of intraoperative neurological injury.



Visual Evoked Potential (VEP)

Flash stimulation of light changes occipital EEG

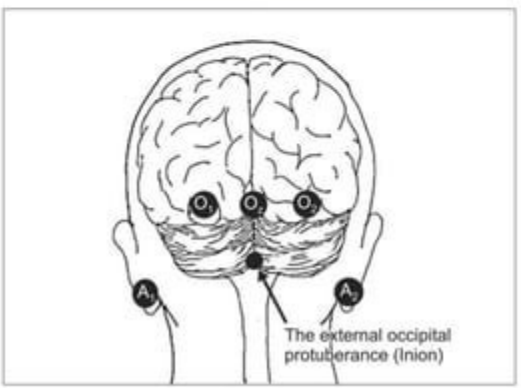


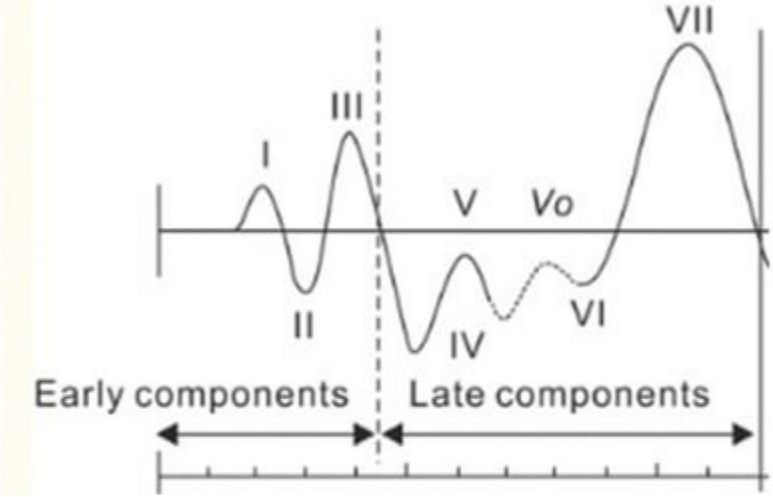
Flash stimulation pad



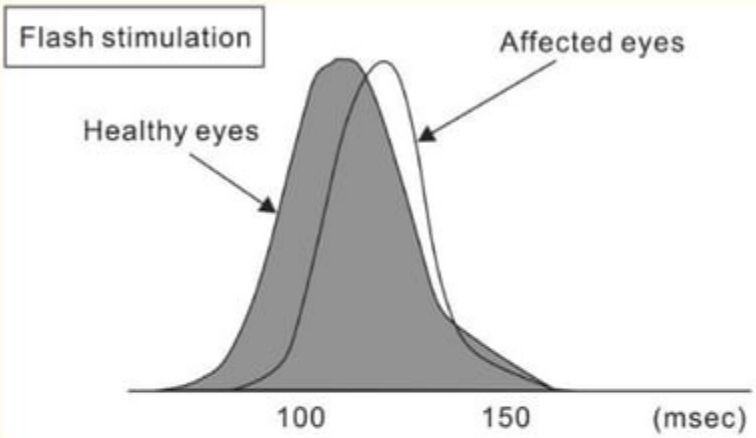
LSF-101 II flash stimulation device
(Unique Medical Co., Ltd., Tokyo, Japan)





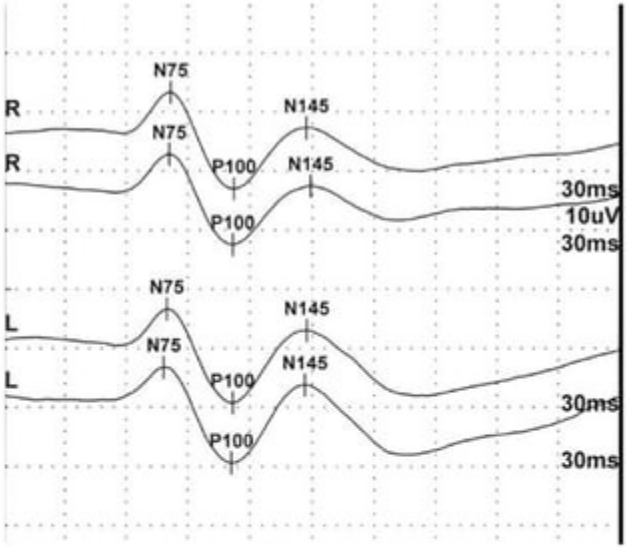


VEP waveform induced by flash stimulation



Comparison of the average latency of major positive vertices of VEP induced by flash stimulation

Upward is negative



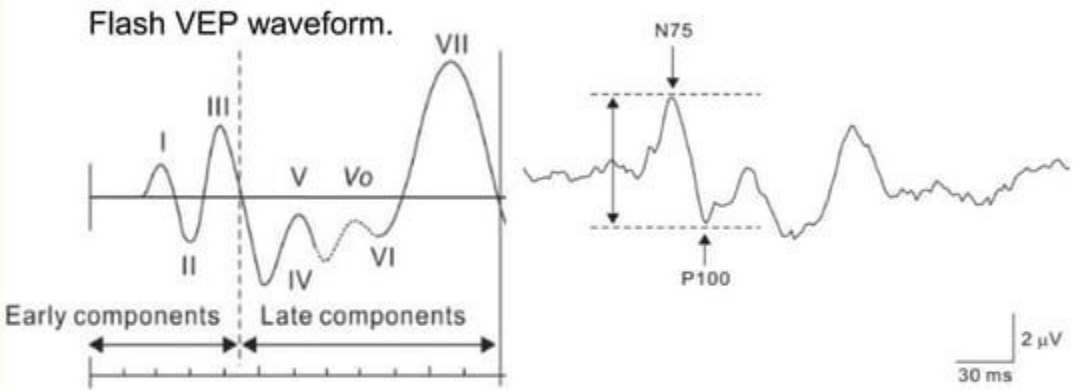
VEP nomenclature is determined by using capital letters stating whether the peak is positive (P) or negative (N) followed by a number which indicates the average peak latency for that particular wave. For example, P100 is a wave with a positive peak at approximately 100 ms following stimulus onset. The average amplitude for VEP waves usually falls between 5 and 20 microvolts.

kja Korean Journal of Anesthesiology http://kja.org

Korean J Anesthesiol. 2017 Apr; 70(2): 127–135.
Published online 2017 Mar 6. doi: 10.4097/kjae.2017.70.2.127
PMCID: PMC5370309
PMID: 28367282

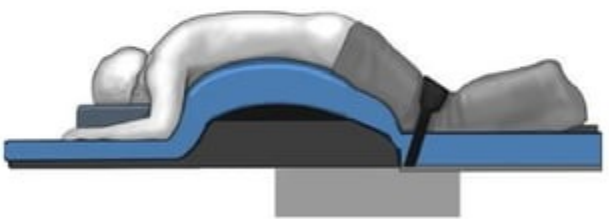
Intraoperative monitoring of flash visual evoked potential under general anesthesia

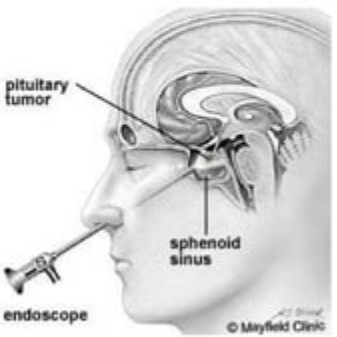
Hironobu Hayashi and Masahiko Kawaguchi



A significant decrease in flash VEP is defined as a decrease in peak-to-peak distance between N75 and P100 by at least 50% from the reference amplitude.

Beneficial in procedures that could cause postoperative visual impairment, such as prone position, transsphenoidal surgery

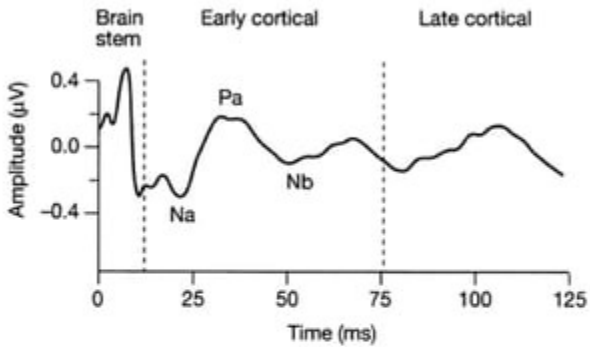




Auditory Evoked Potential (AEP)

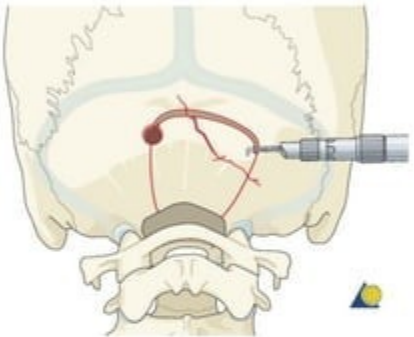
Repetitive clicks delivered to the ear reflects the VIII nerve & brainstem "well-being"

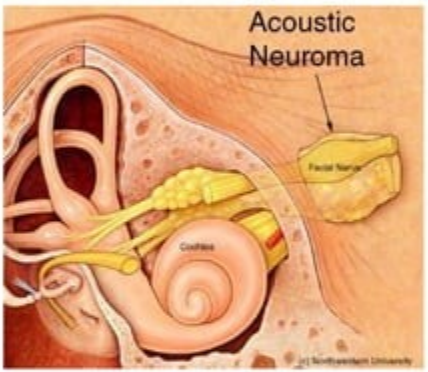


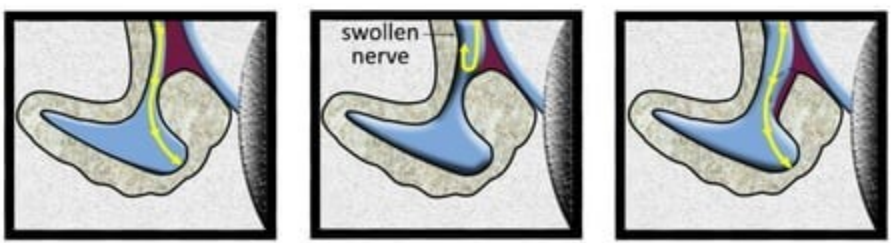


Typical AEP record with its subcortical and cortical components

Beneficial in Procedures near auditory pathway and posterior fossa, decompression of CN VII, resection of acoustic neuroma







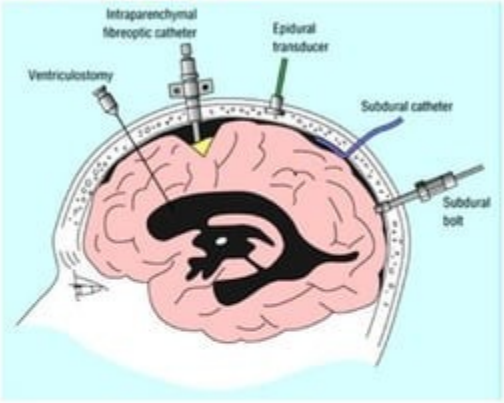
The brain can be monitored in terms of:-

- Function
- **CBF & ICP**
- Brain oxygenation

Monitoring of ICP:-

Invasive
1. Intraventricular catheter
2. Subdural catheter
3. Epidural sensor
4. Subdural screw (blot)
5. Intraparynchymal sensor

Non-invasive
1. Non-contrast CT scan
2. MRI
3. TCD
4. Tympanic membrane displacement
5. Optic nerve sheath diameter

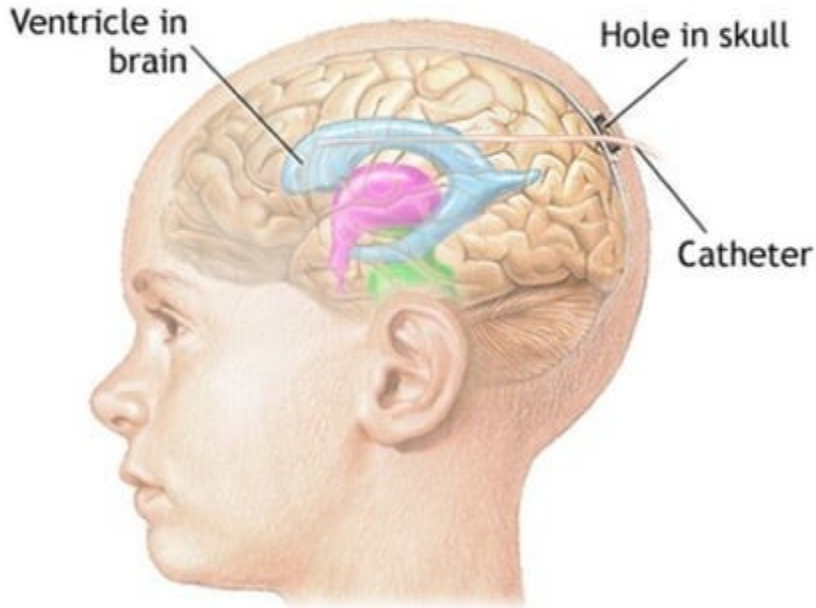


INTRAVENTRICULAR CATHETER

-Most accurate monitoring method

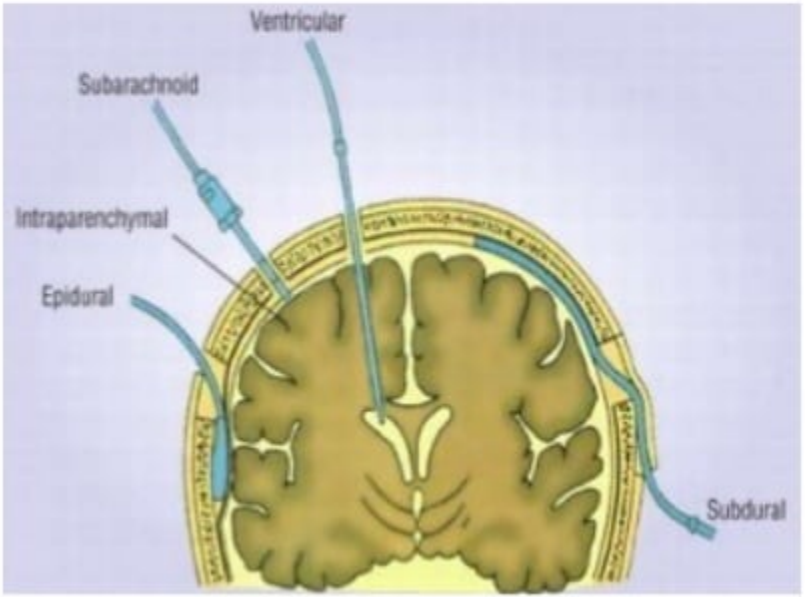
-A hole is drilled through the skull. The catheter is inserted through the brain into the lateral ventricle

-Can also be used to drain fluid out



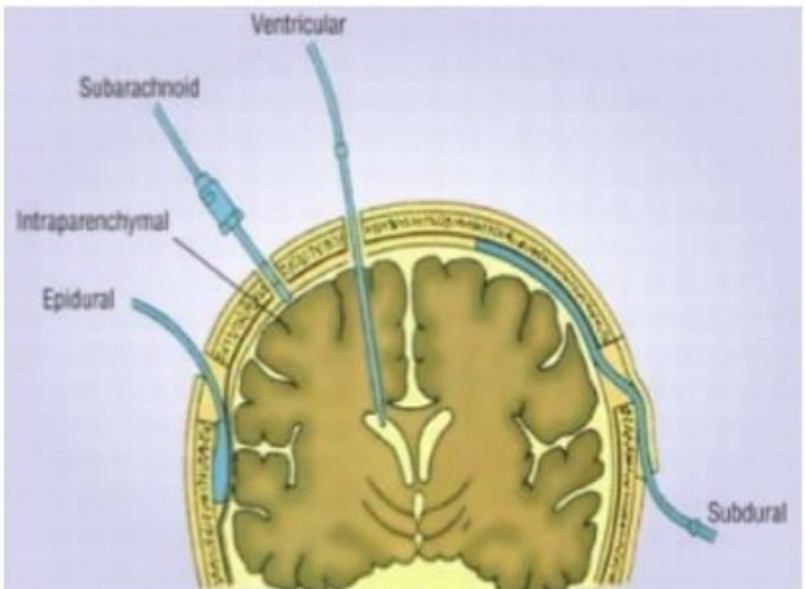
Subdural Catheter

- Inserted through a hole drilled in the skull
- No parynchymal injury
- An epidural sensor is inserted between the skull and dura



Epidural Sensor

- Inserted through a hole drilled in the skull
- An epidural sensor is inserted between the skull and dura
- Allows recording not drainage

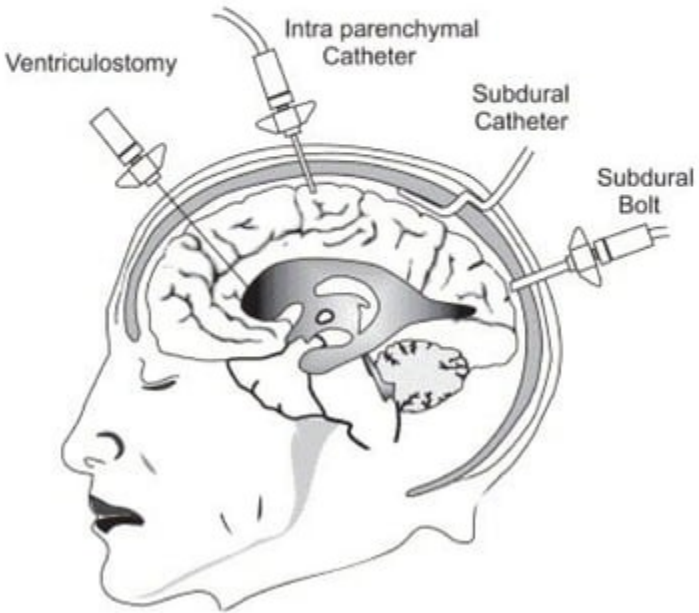


Subdural Screw (BOLT)

Inserted through a hole drilled in the skull

It is placed through the dura.

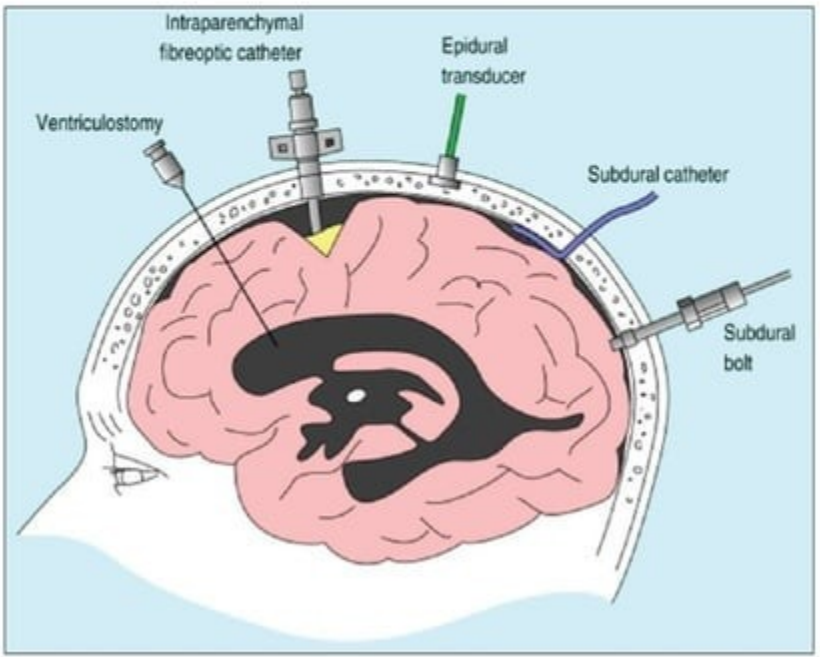
Allows recording not drainage



Intraparynchymal fiberoptic device

It has no chance of catheter occlusion or leakage

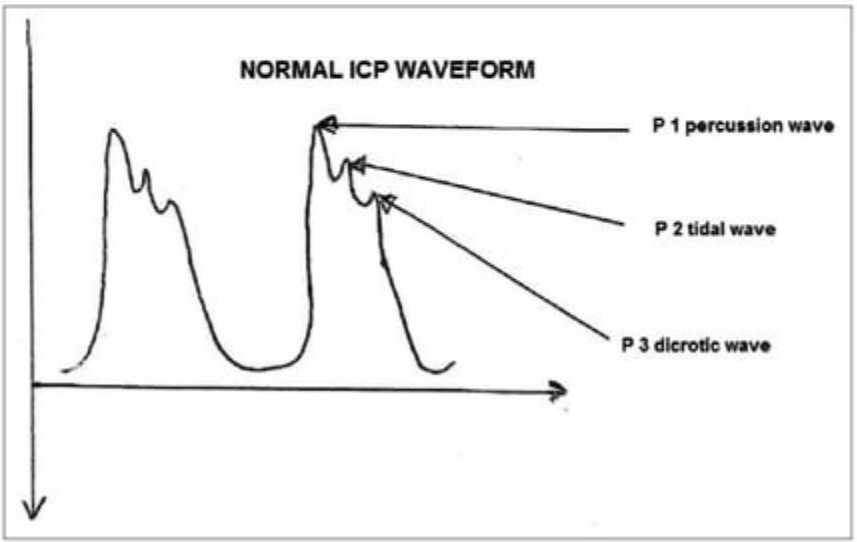
Neurological injury is minimal because of small probe diameter
Allows recording not drainage

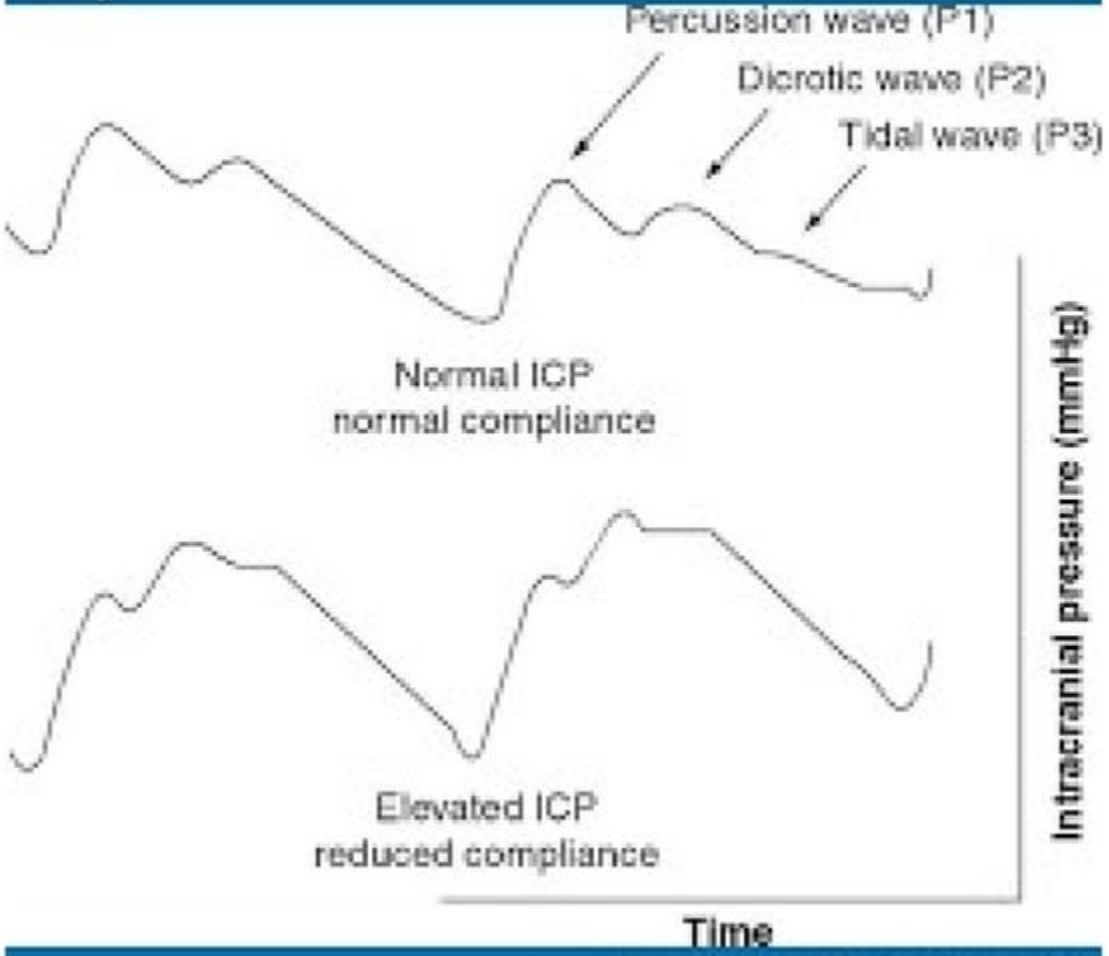


ICP waveforms

ICP shows a pulsatile recording with slow respiratory component superimposed on a biphasic recording synchronous with cardiac cycle

P1 (correlating with the arterial pulse);
P2 (relating to the cerebral compliance);
P3 (corresponding to aortic valve closure)




Percussion wave (P1)
Dicrotic wave (P2)
Tidal wave (P3)
Normal ICP
normal compliance
Elevated ICP
reduced compliance
Intracranial pressure (mmHg)
Time

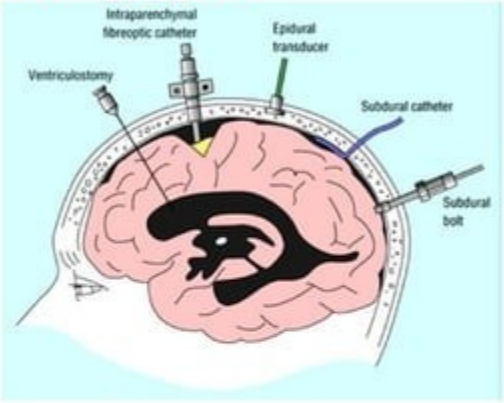
Monitoring of ICP:-

Invasive

1. Intraventricular catheter
2. Subdural catheter
3. Epidural sensor
4. Subdural screw (blot)
5. Intraparynchymal sensor

Non-invasive

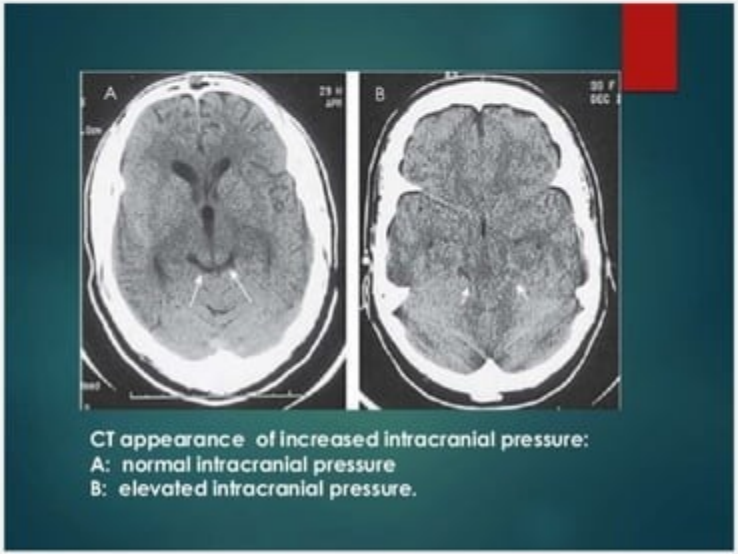
1. Non-contrast CT scan
2. MRI
3. TCD
4. Tympanic membrane displacement
5. Optic nerve sheath diameter



Non-contrast CT scan

fast cost-effective - Gross evaluation - Difficult to repeat

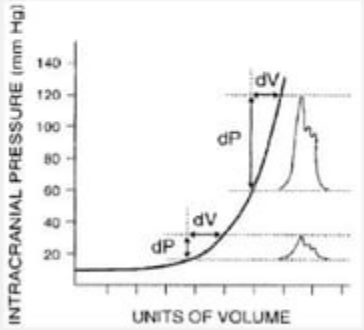
Findings suggestive of a high ICP include cerebral oedema, midline shift, effacement of basal cisterns, loss of grey-white differentiation, and loss of normal gyri and sulci pattern



CT appearance of increased intracranial pressure:
A: normal intracranial pressure
B: elevated intracranial pressure.

Dynamic MRI

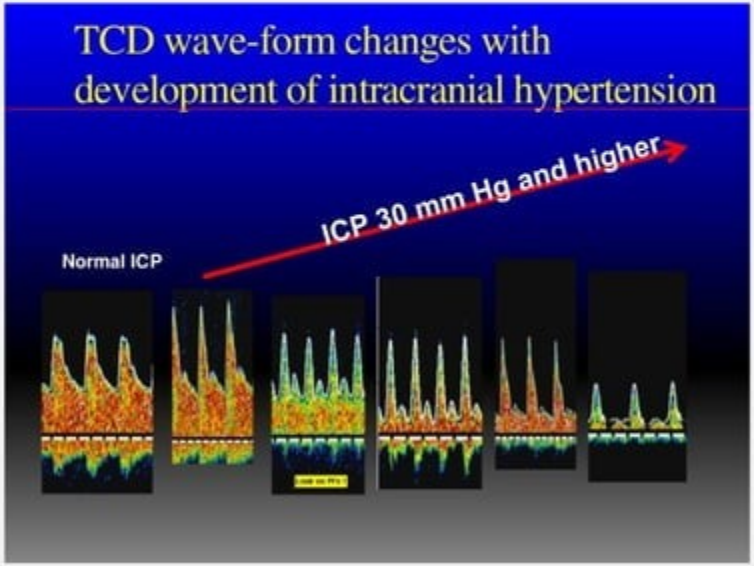
- This method utilizes the fluctuations in intracranial volume occur with each heartbeat.
- A mean ICP value is then derived from the linear relationship between ICP and elastance (a change in pressure due to a small change in volume).
- The MRI study provides a single time point measurement

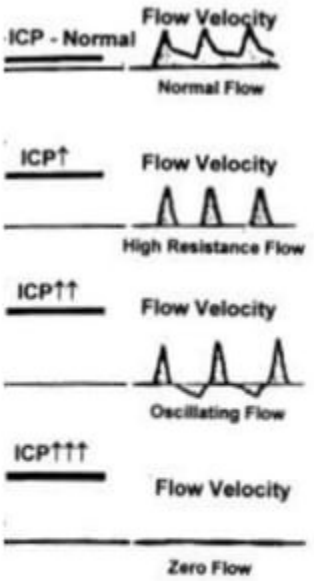


The change in pressure dP due to change in unit volume dV (=Elastance) increases linearlywith increased ICP

TCD

- Elevated ICP can be estimated from TCD as it impedes CBF and consequently decreases the blood flow velocity
- Requires training and inter-observer variations may be seen



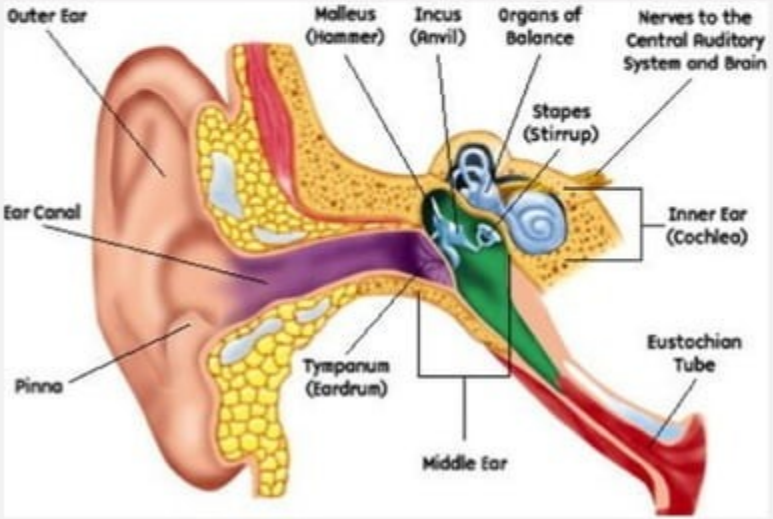


Changes in TCD flow velocity waveform associated with a progressive increase in ICP

Tympanic membrane displacement (TMD)

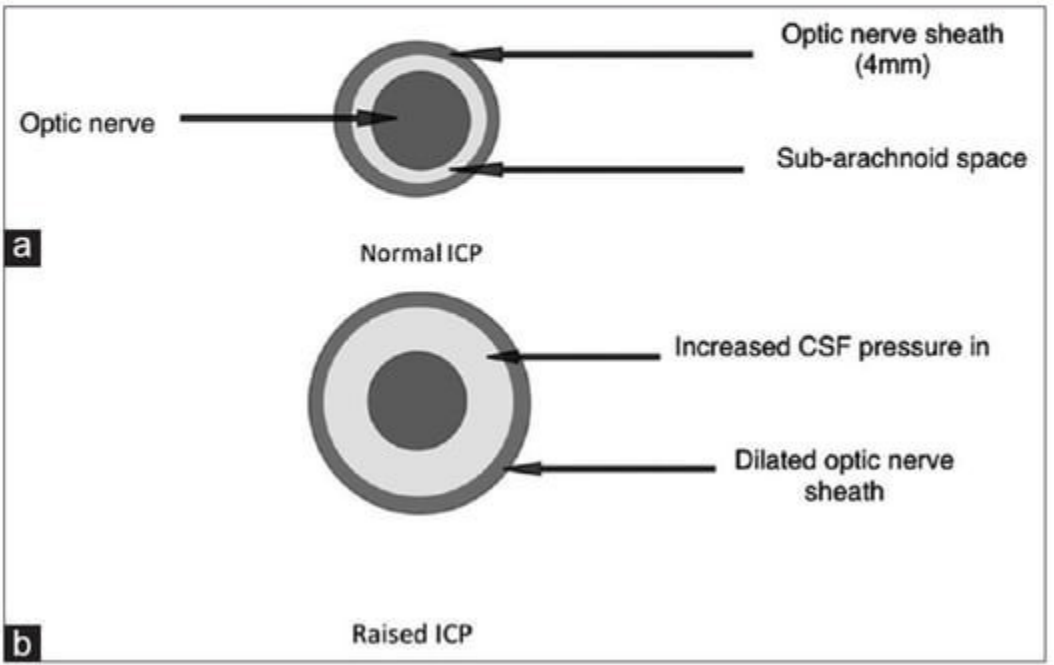
Increase in ICP is directly transmitted to the footplate of the stapes and thereby affecting the response to a sound and hence **audiogram**

Inaccurate of ± 15 mm Hg, which is not sufficient for a reliable assessment of ICP



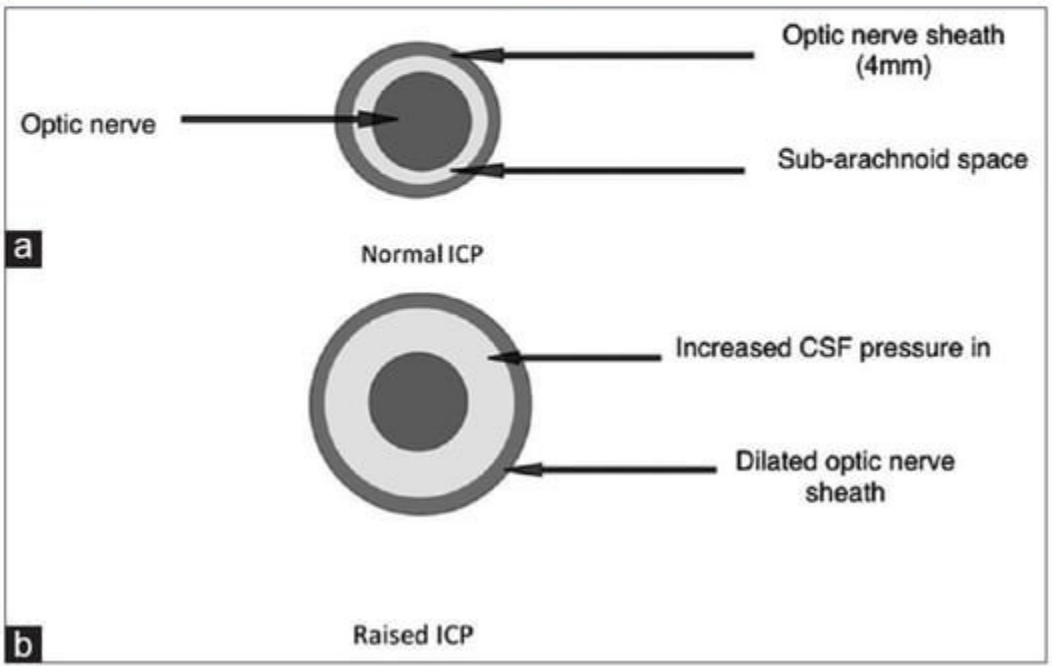
Optic nerve sheath diameter (ONSD)

Optic nerve is a part of CNS and the space between the optic nerve and its sheath is a continuation of the subarachnoid space, filled with CSF, whose pressure is equal to the ICP



Optic nerve sheath diameter

In increased ICP, the ONSD increases, and the blood flow through the central retinal vein that courses through the sheath gets impeded (causing papilloedema).



Optic nerve sheath diameter

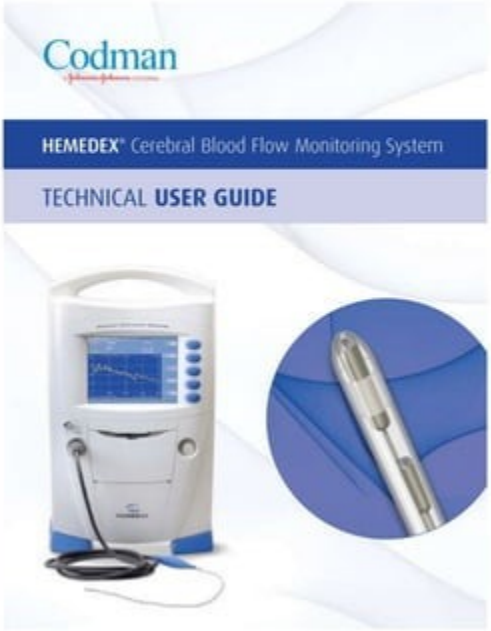
Can be conveniently measured by transocular sonography

>5 mm corresponding to an ICP of 20 mm Hg or higher.



Monitoring of CBF

Transcranial doppler sonography
Thermal diffusion cerebral blood flow monitoring





Transcranial doppler sonography (TCD)

Measure flow velocity in MCA, and thus CBF

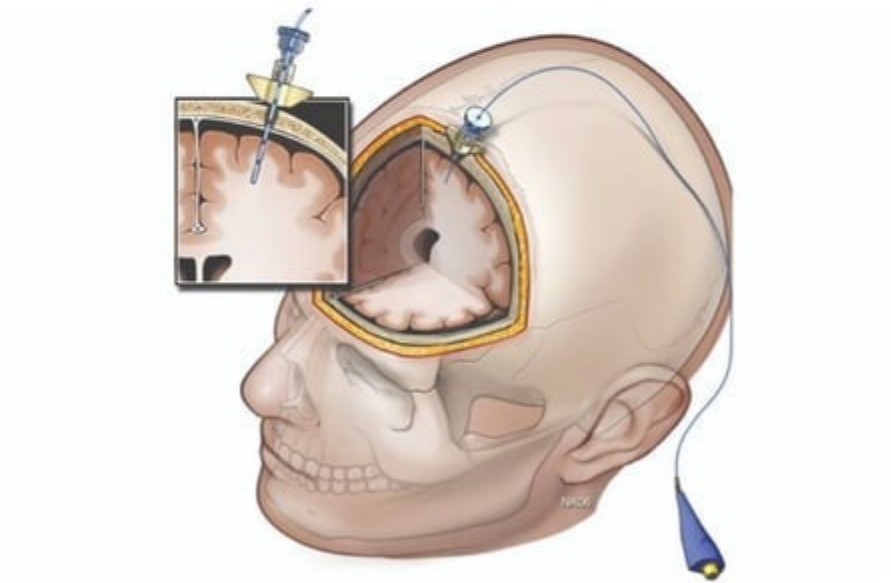
Sensitive method to detect cerebral emboli

Doubtful efficacy in detecting cerebral ischemia



Thermal diffusion cerebral blood flow monitoring

The rate at which heat dissipates in a tissue depends on the tissue's thermal conductive properties and the blood flow in that area.



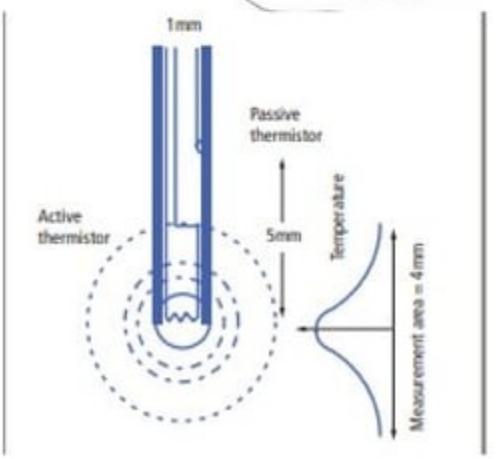
Flexible catheter with two thermistors (proximal & distal)

Distal thermistor is heated to 2°C above tissue temp.

Power dissipated by the heated thermistor provides a direct measure of the tissue's ability to transport heat.

The proximal thermosensor is located outside the thermal field allowing continuous monitoring of tissue temperature





The brain can be monitored in terms of:-

- Function
- CBF & ICP
- **Brain oxygenation**

Monitoring of cerebral oxygenation

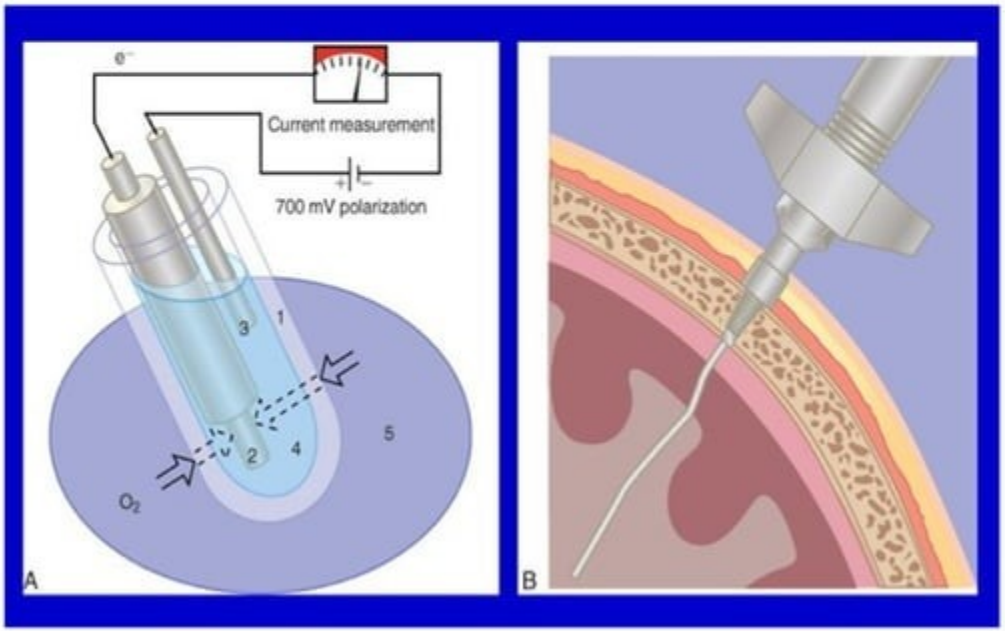
- Direct brain tissue partial pressure oxygen monitoring
- Cerebral microdialysis brain tissue biochemistry
- Jugular bulb venous oximetry monitoring
- Near Infrared Spectroscopy (NIRS)

Tissue partial pressure oxygen monitoring

A catheter is placed into the brain tissue through drill hole into the subcortical white matter



The diffusion of oxygen molecules through an oxygen-permeable membrane into an electrolyte solution causes an electric current that is proportional to Po2.

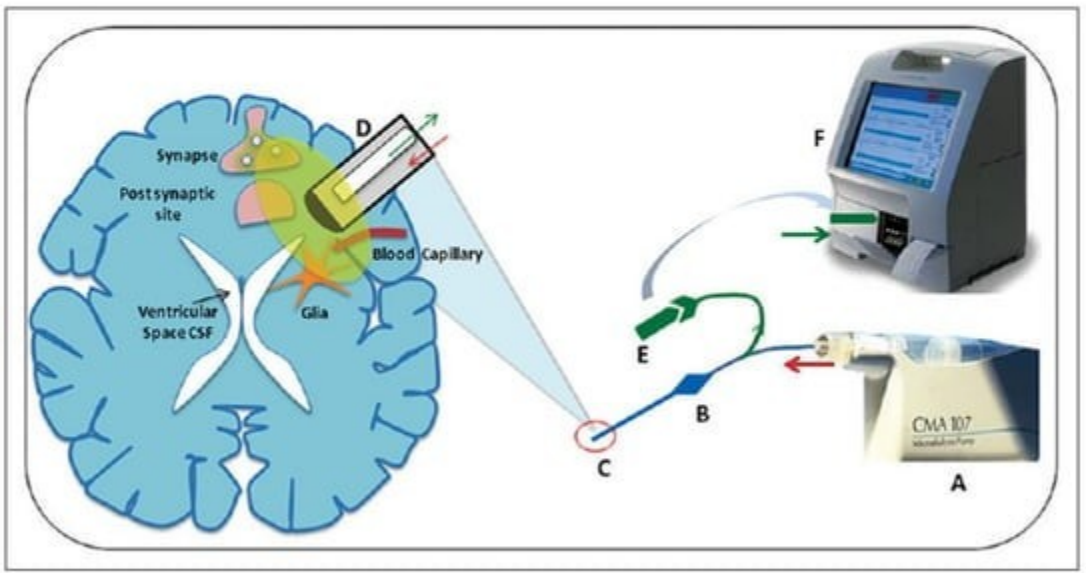


In patients with cerebral ischaemia the values are 10 ± 5 mmHg as against 37 ± 12 mmHg in normal individuals

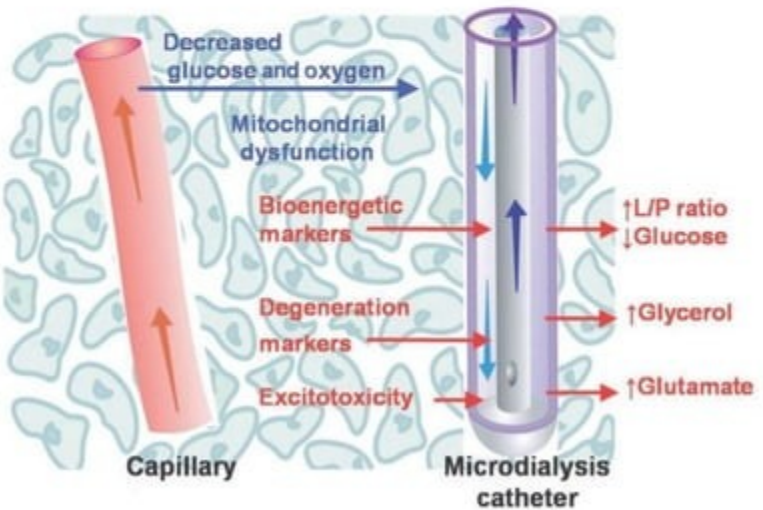


Cerebral microdialysis brain tissue biochemistry

- Small catheter inserted with ICP/tissue PO2 monitor

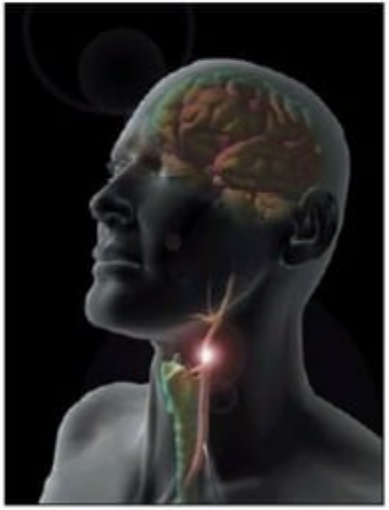


- Artificial cerebrospinal fluid equilibrates with extracellular fluid,chemical composition analysis
- Markers:
  - Lactate/pyruvate ratio : onset of ischemia
  - High level glycerol: inadequate energy to maintain cellular integrity
  - Glutamate: neuronal injury a



Jugular venous oximetry

Continuous monitoring of jugular venous oxygen saturation (SjVO2) is carried out by a catheter placed retrograde through the internal jugular vein into the jugular bulb.



Indices obtained from SjVO2

1.Jugular venous oxygen saturation (SjVO2)

2.Cerebral arteriovenous oxygen difference (A-VDO2) (difference between arterial and jugular venous oxygen content)

3.Cerebral oxygen extraction(CEO2) (the difference between SaO2 and SjVO2).

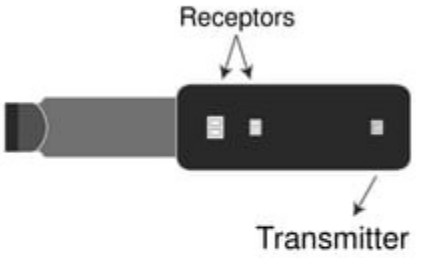
1. $SjVO_2$	: Normal : Hyperaemia : Low flow	- 60-80% > 90% < 50%
2. $(A\text{-}V)DO_2$ $(CMRO_2/CBF)$	: Normal : Hyperaemia : Low flow	- 5 - 7.5 vol % < 5 vol % > 7.5 vol %
3. CEO_2	: Normal : Hyperaemia : Low flow	- 24-40% < 24% > 40%

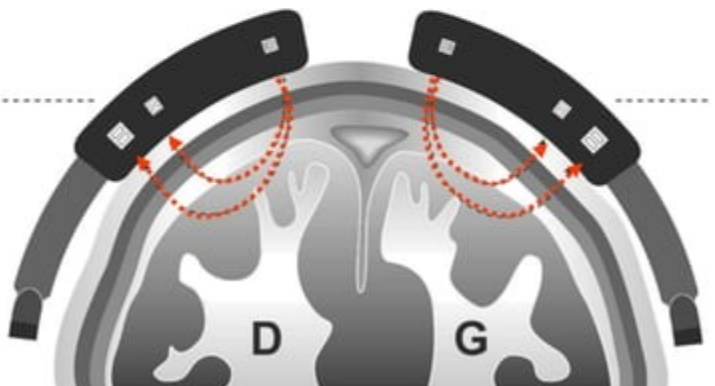
Near infrared spectroscopy "NIRS"
"cerebral oximetry"

cerebral oximetry is non-invasive and continuous "real-time" detection of cerebral oxygen saturation (SctO2)

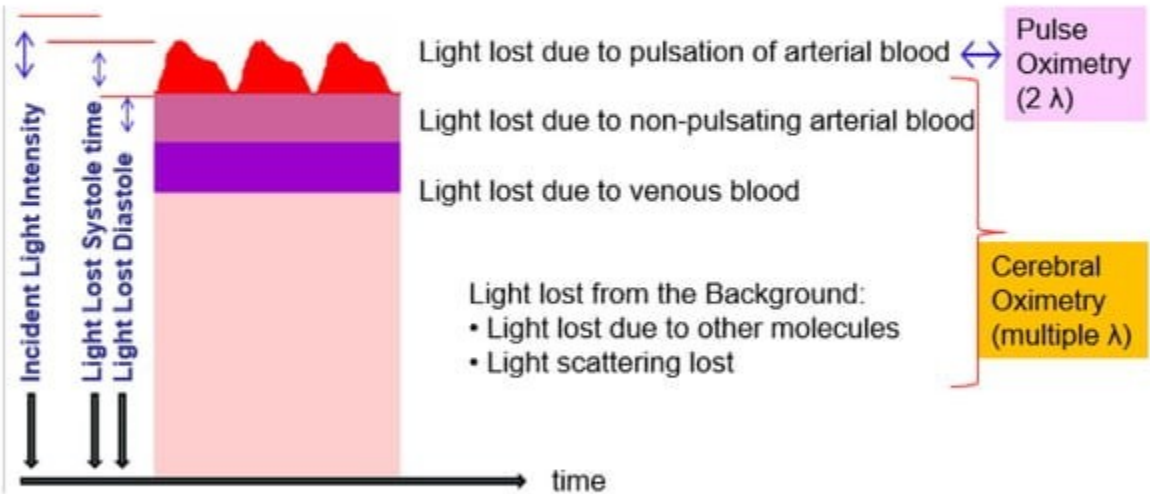


Light travels from the sensor's light emitting diode to either a proximal or distal detector, permitting separate data processing of shallow and deep optical signals

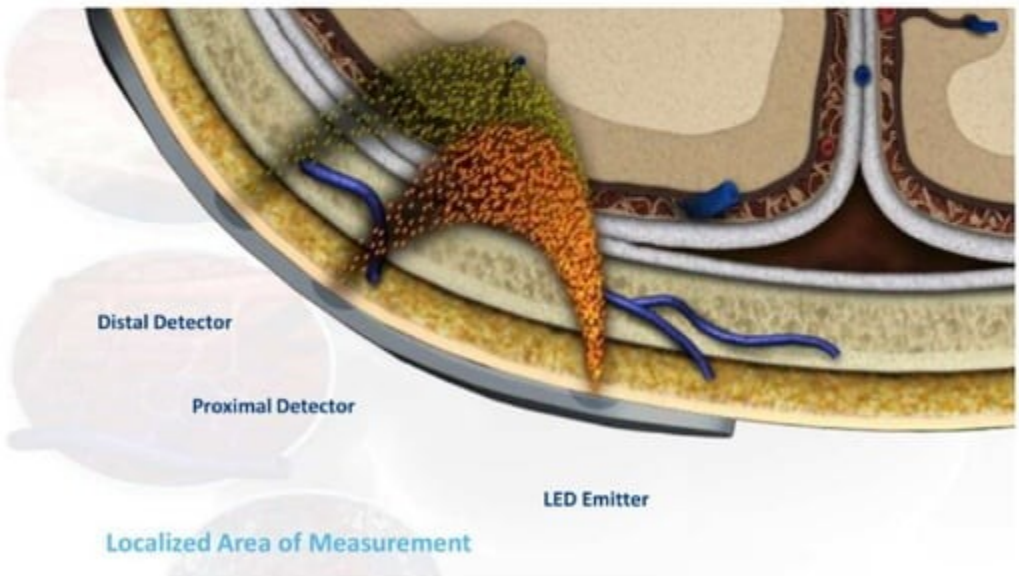




Thus, cerebral oximetry measures venous and arterial blood and includes contributions from both of them in a 3:1 ratio



Data from the scalp and surface tissue are subtracted and suppressed, reflecting rSO2 in deeper tissues



Brain oximetry: what does it predict?

A: «Airway» for true hypoxia

B: «Breathing» adequacy

C: Circulatory monitor

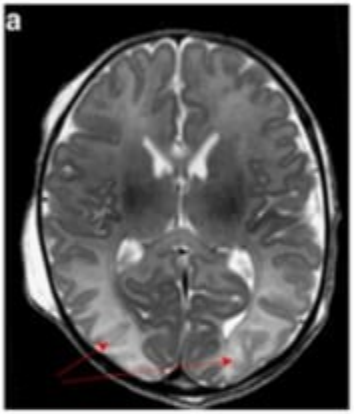
D: Diagnostic

E: Expectency of survival (biomarker)

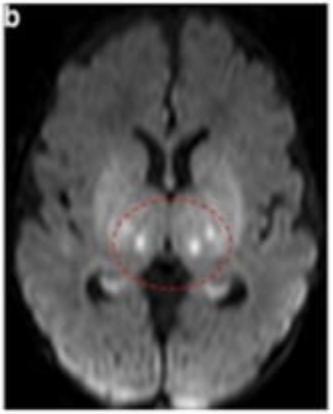


LIMITATIONS:

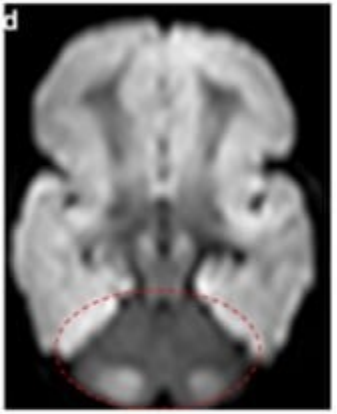
the sensors are placed over the frontal lobes and cannot detect involvement of other brain parts



Post cerebral watershed.



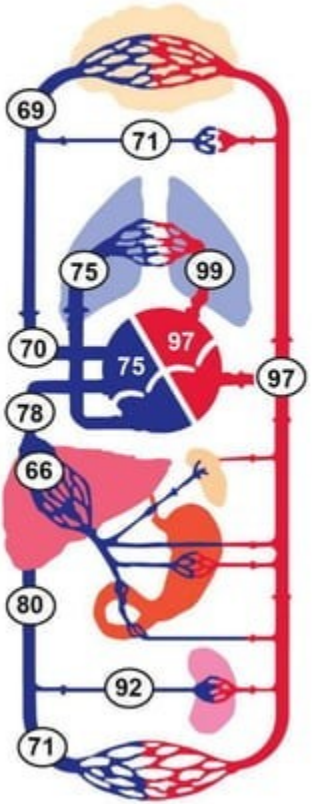
Basal ganglia infarct



Cerebellar infarct

LIMITATIONS: What is the cause





Know how Different Organs
Behave Under Different Conditons

Ischemia (Poor Flow)

Vs

Hypoxia (No Oxygen)

Vs

Venous Congestion


Thank You!