THE ELECTROENCEPHALOGRAM (EEG) IN ANAESTHESIA

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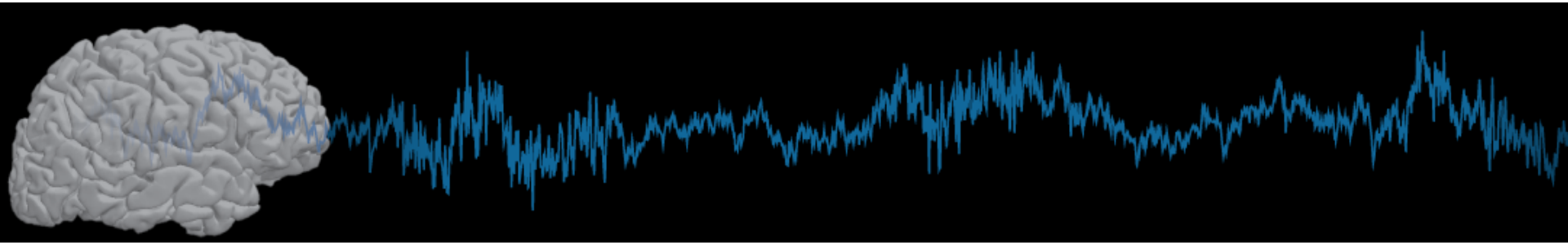


Learning Outcomes

To be able to describe:

- The basic physiology and waves of the EEG
- How the EEG changes under general anaesthesia
- Factors that influence the EEG (other than anaesthetic agent concentration)
- Use and limitations of processed EEG Indices

EEG: Definition

"Electrical activity of the brain plotted over time"

- Voltmeter for the cerebral cortex
- Measured in microvolt range (typically scale of 5-10 μV)
- Extracellular potentials or Local field potentials
- 1 V = 10^6 μV = 1000000 μV
  = 10^3 mV = 1000 mV

EEG Electrodes

Bipolar

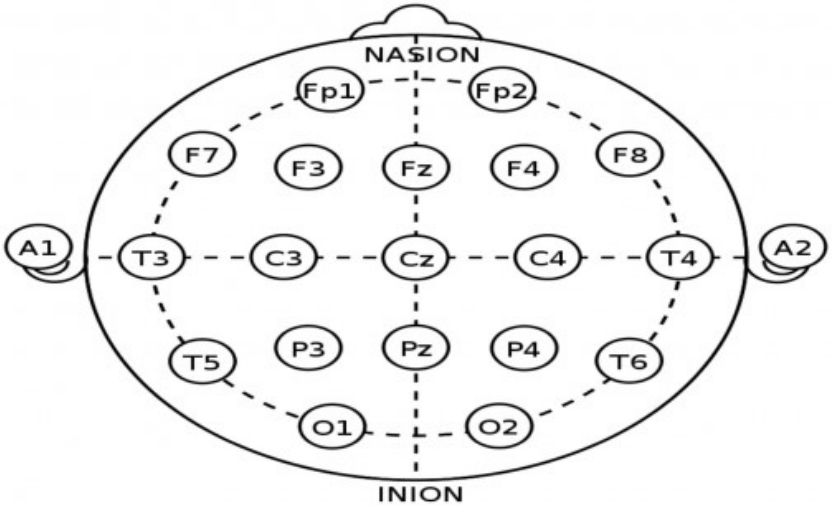
- Voltage measured between 2 electrodes
- Most commonly type used in clinical EEG monitors

Referential Montage

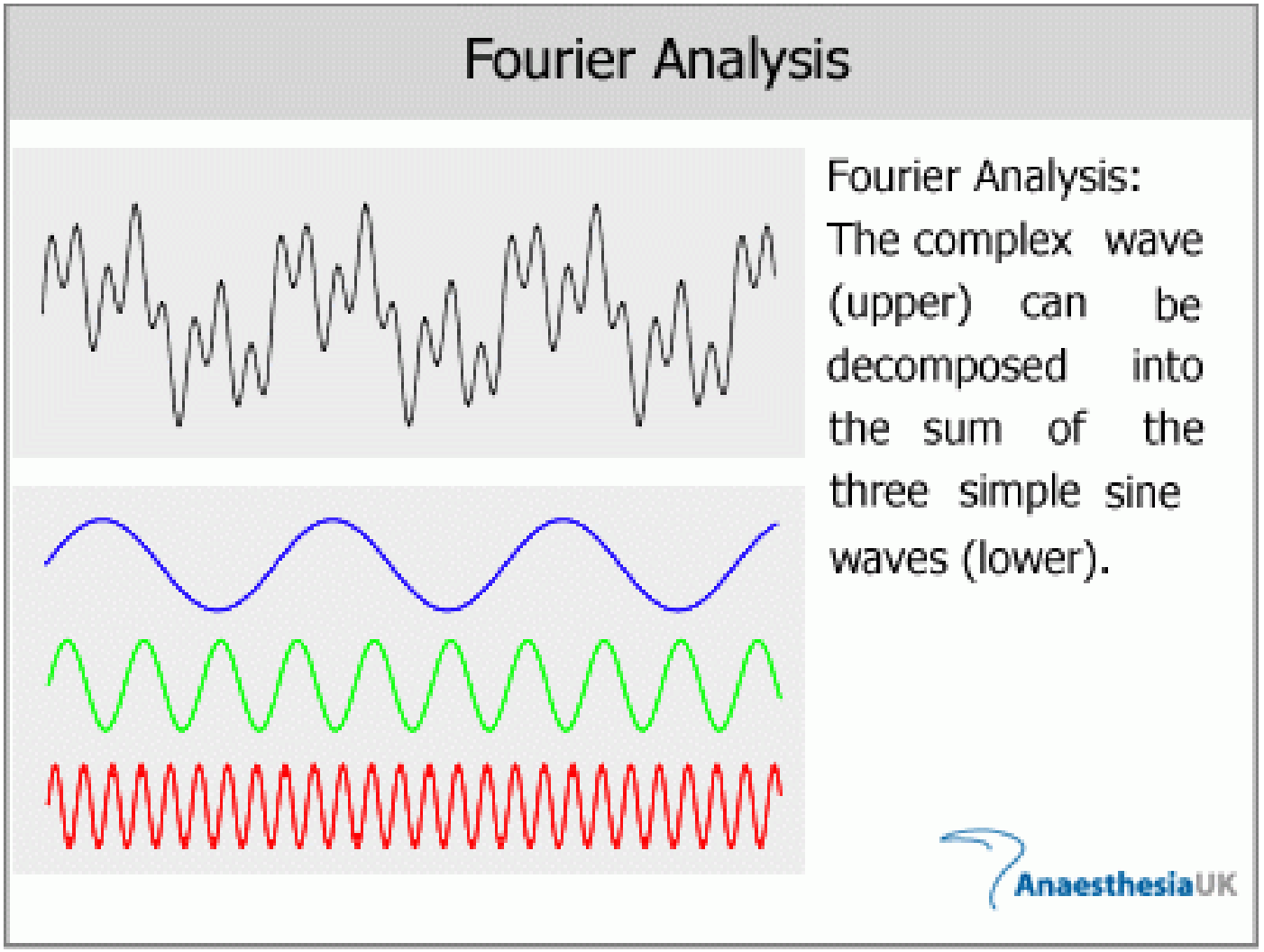
- Multiple electrodes

all with reference to

a single common electrod



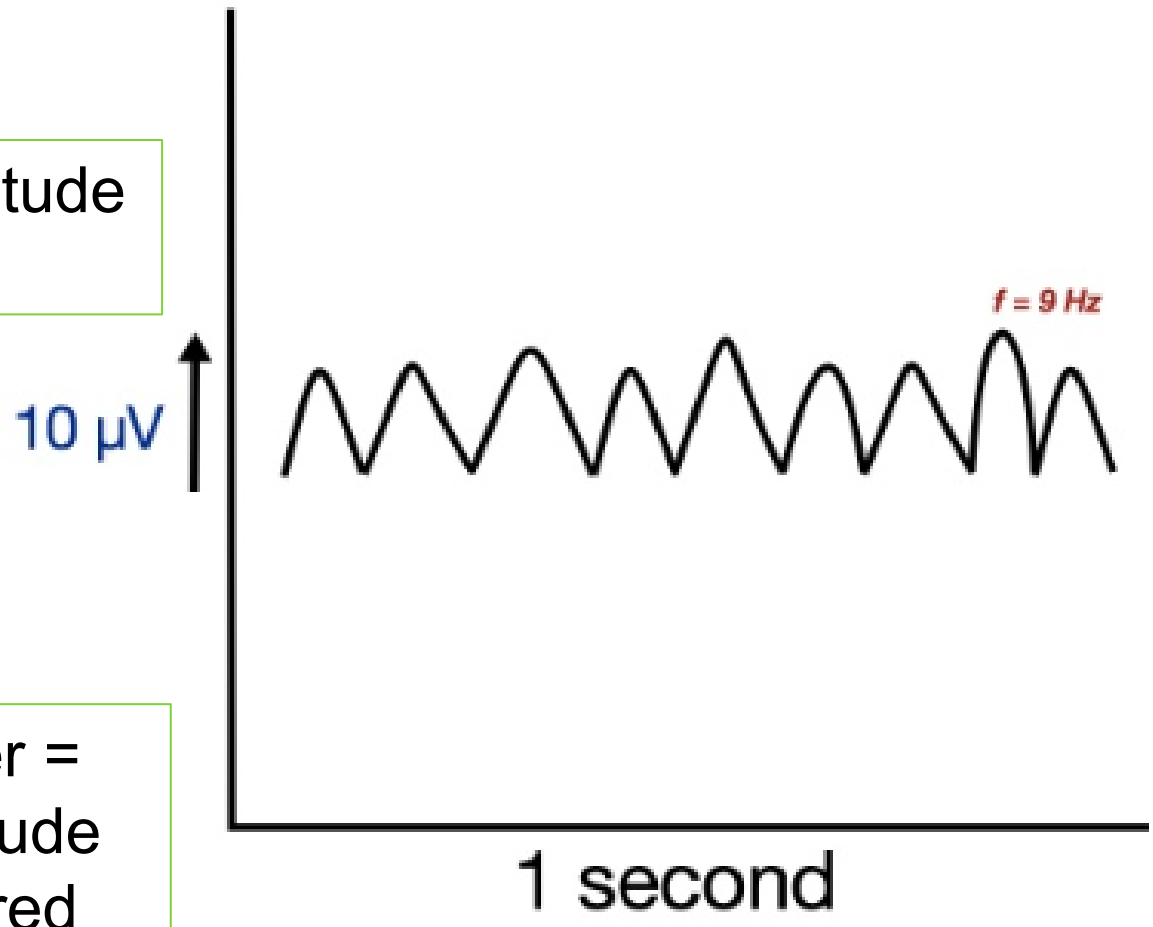
Raw EEG


Fourier Analysis
Fourier Analysis:
The complex wave (upper) can be decomposed into the sum of the three simple sine waves (lower).
AnaesthesiaUK

Main Characteristics of EEG Waves

Amplitude

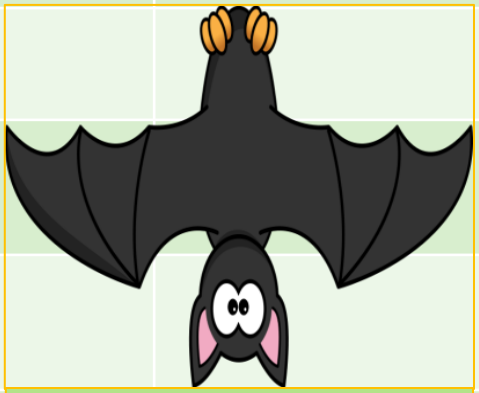
Frequency



Power = amplitude squared

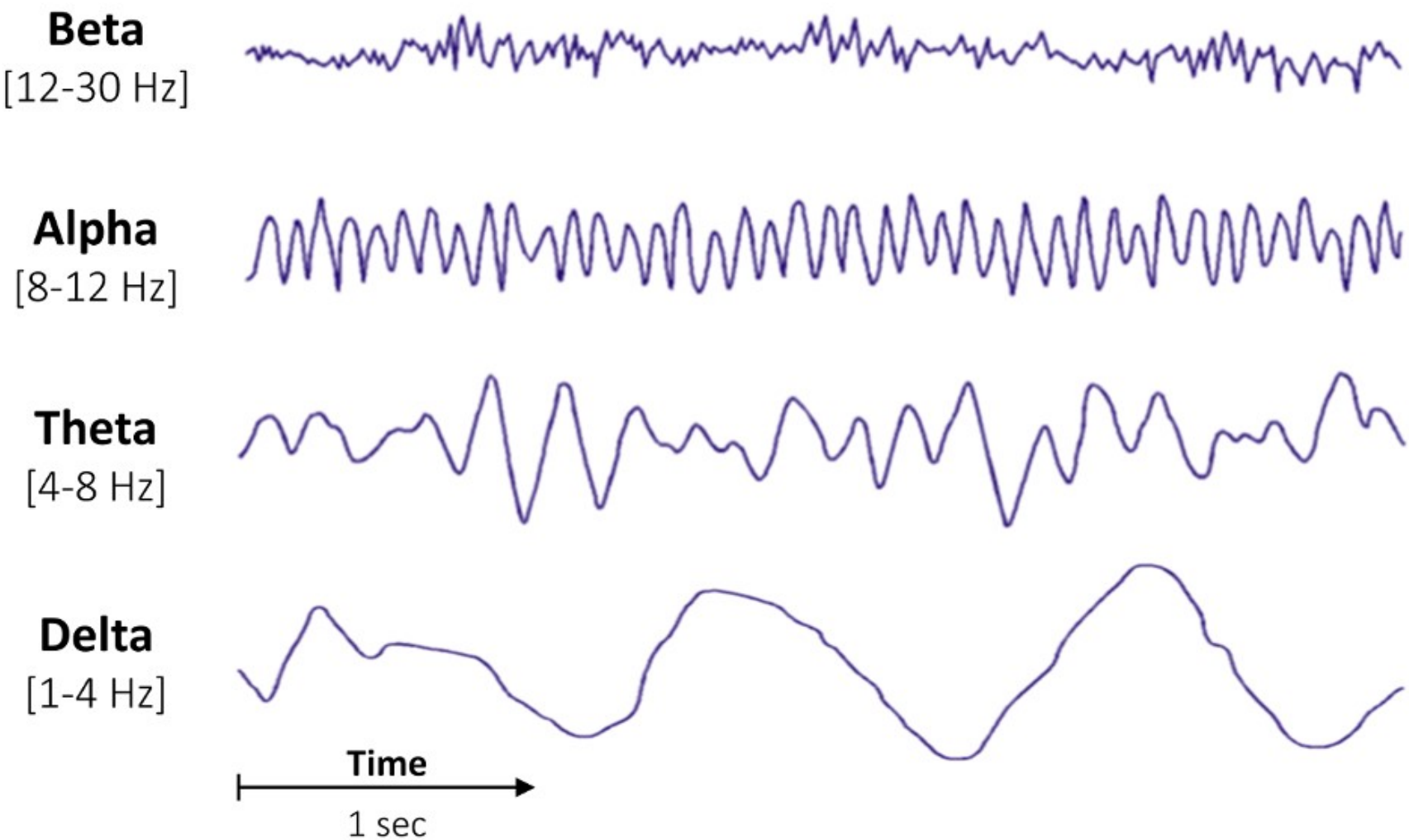
Frequency Changes under GA

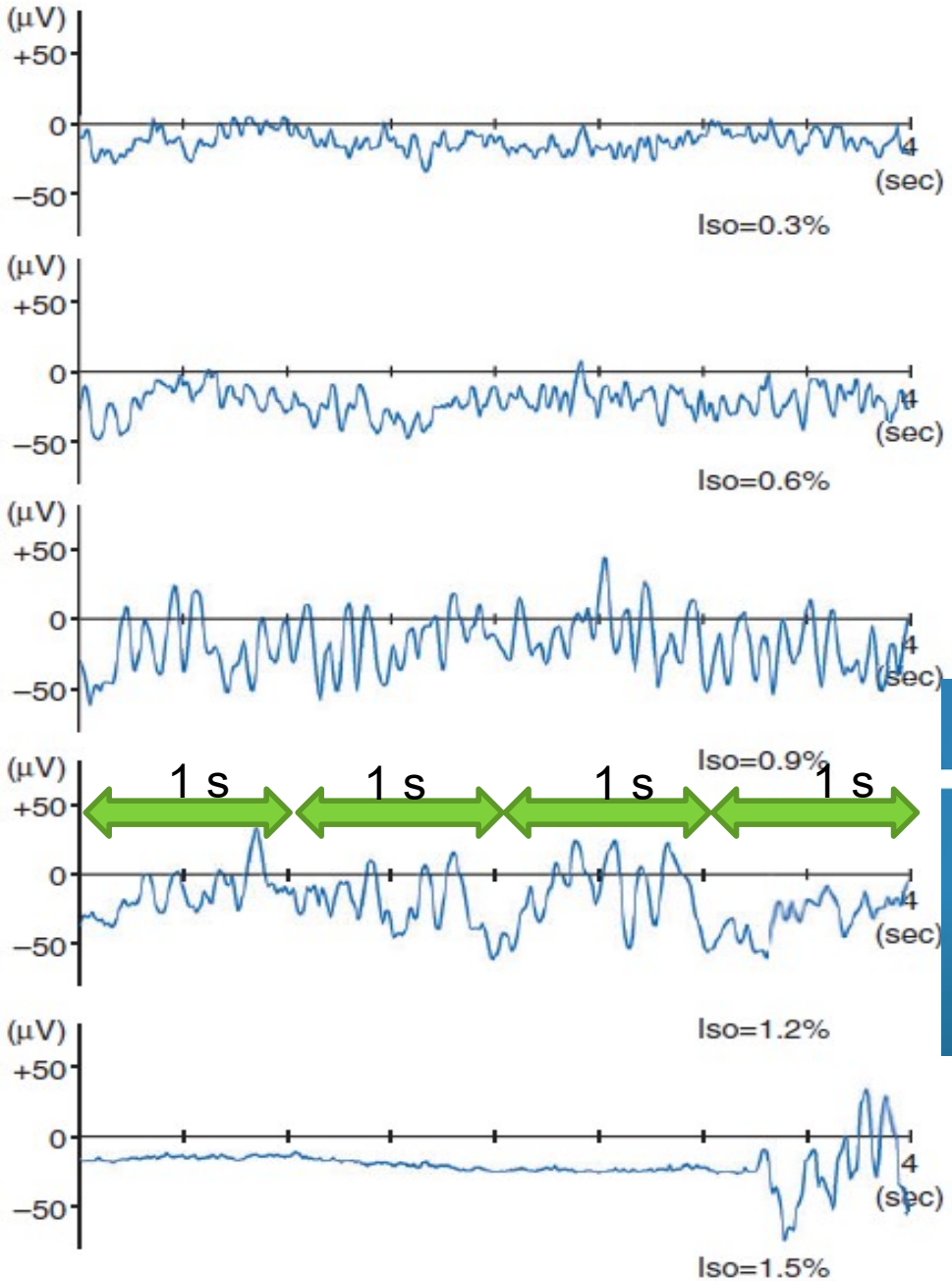
Wave	Frequency Range (Hz)	Depth of GA
Gamma	100 - 30	Awake
Beta	30 - 12	
Alpha	12 - 8	
Theta	8 - 4	
Delta	4 - 1	
Burst Suppression	“Brain asystole”	‘Deep’ GA



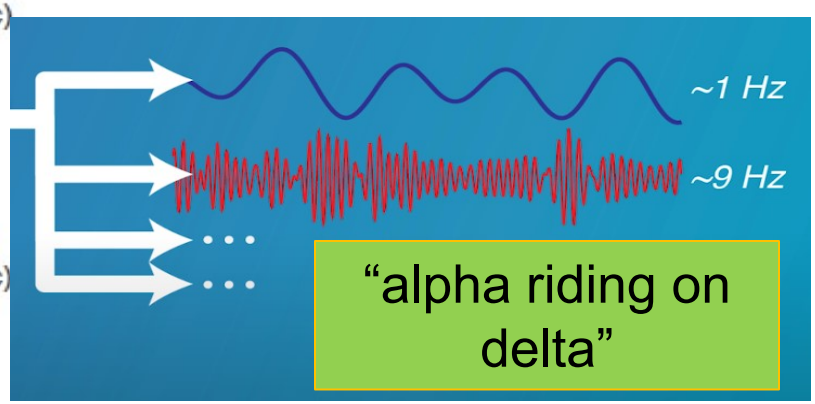
‘D’ for Deep

Power (amplitude) changes under GA





Beta waves Predominate



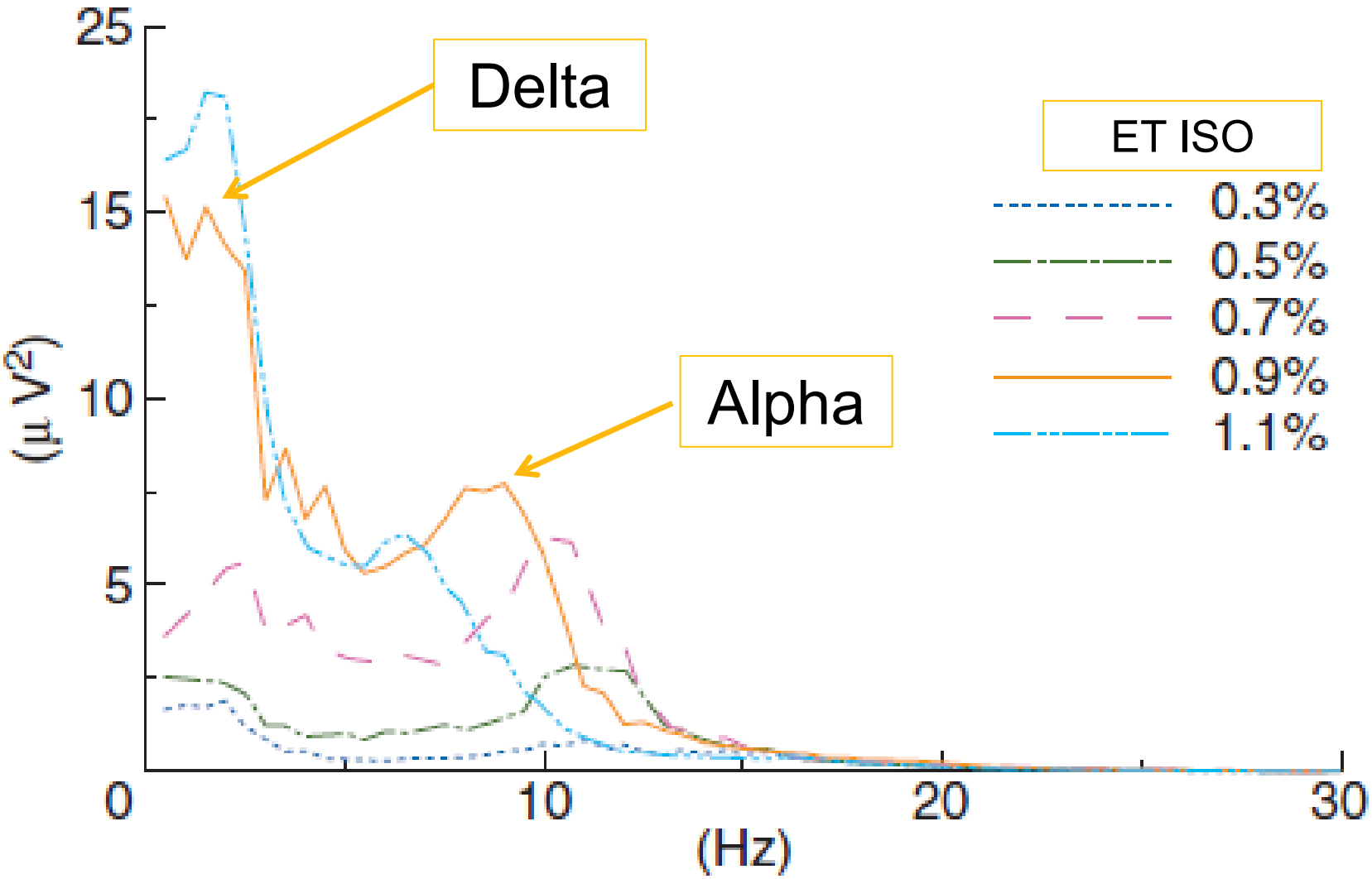
Burst Suppression

Burst Suppression

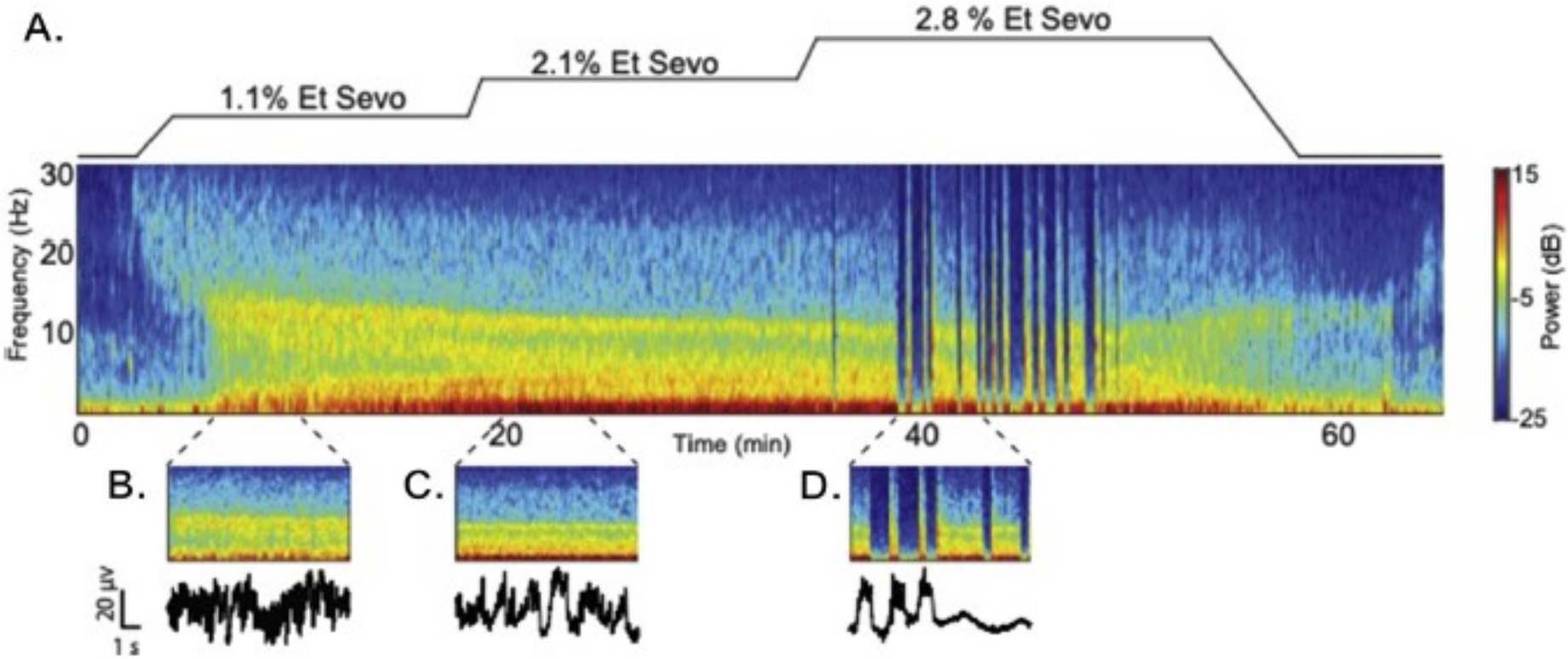
- Seen in deep anaesthesia and pathological brain states
  - Hypoxia
  - Brain trauma
  - Hypothermia
  - Severe developmental conditions

- Associated with post op delirium
- ??? Harmful

Spectrum Plot



Spectrograms



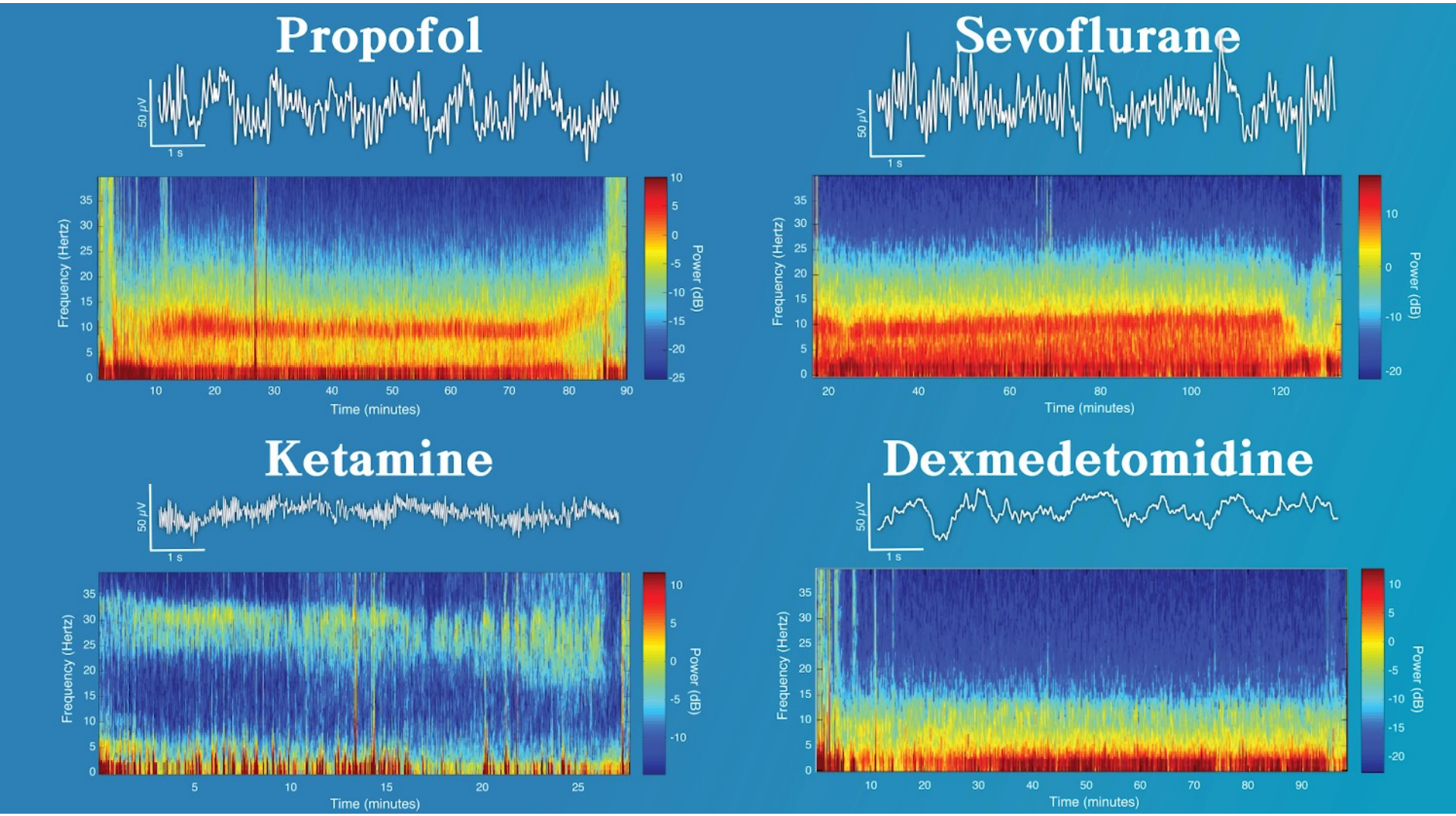
Numerical Methods to describe the EEG

- Spectral Edge Frequency (SEF95)
  - Frequency below which 95% of the total power lies
- Burst Suppression Ratio 0 -100
  - Percentage of each minute spent in burst suppression
- Proprietary Indices (typically 0 to 100)
  - BIS / E Entropy / Narcotrend

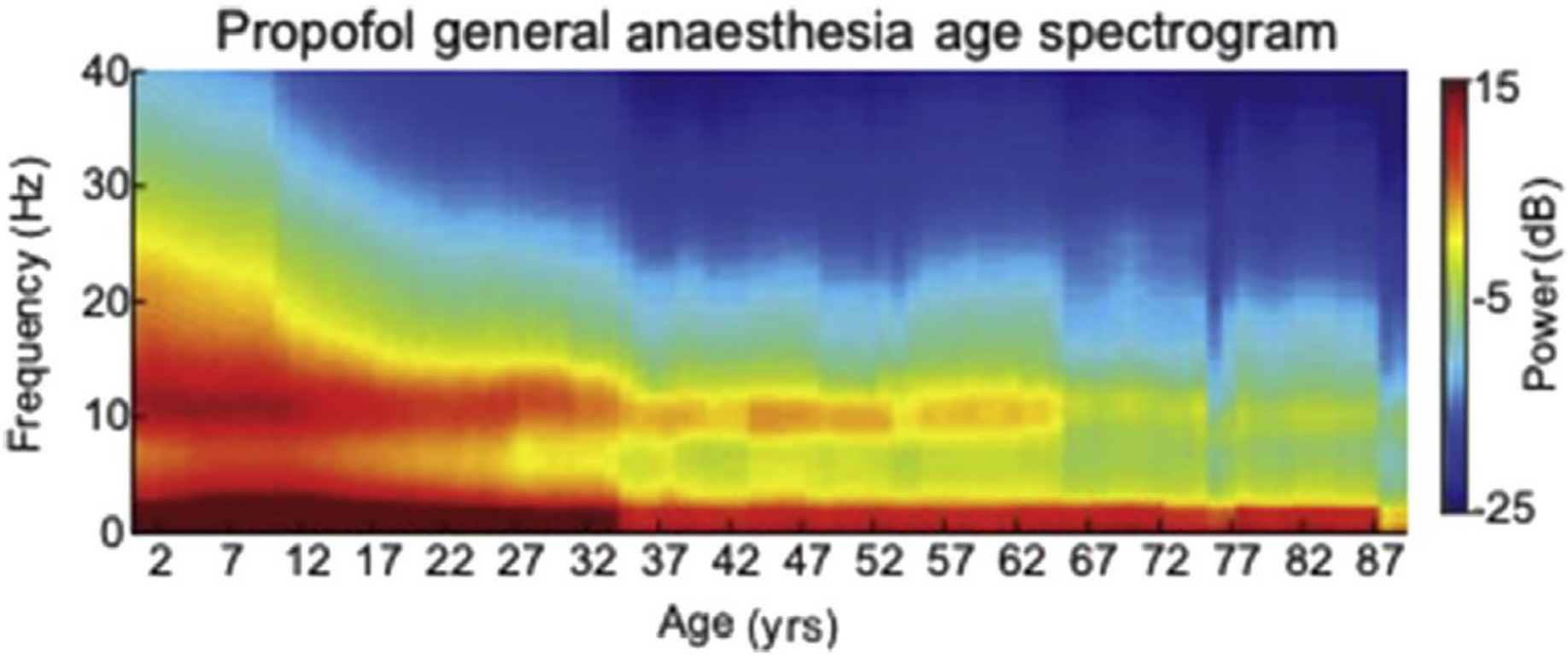
What else affects the EEG?

- Agent used
  - Volatiles and Propofol similar
  - Different patterns with nitrous, ketamine, xenon and alpha 2 agonists
- Age (or more accurately how elderly the brain is)
- Artefacts
- (EMG)

Changes with different agents



Changes with Age

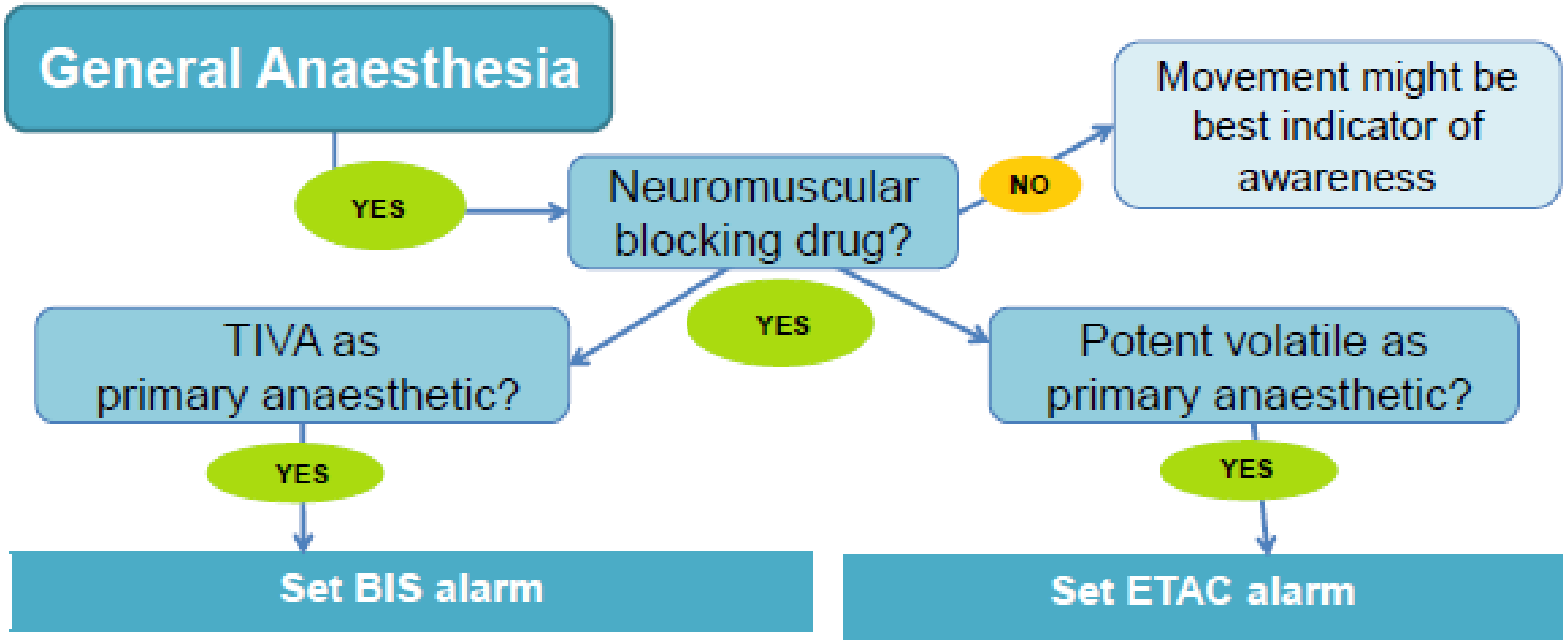


Advantages of EEG Monitoring

Related to Awareness:

- ? Decreased incidence of awareness
- ? Decreased severity of awareness when it does occur
- Ability to monitor continuously from induction to emergence (cf. end tidal gas monitoring)
- Recommended by:
  - AAGBI guidelines* for TIVA + NMB.
  - NICE: recommended as an ‘option’ for ‘higher risk’ patients and TIVA

Decision Tree



Advantages of EEG Monitoring (2)

<u>Non-Awareness Advantages:</u>

- ? Reduced rates of post op delirium
- ? Shorter recovery times (time to extubation and time in PACU)
- ? Decreased PONV

- Identifying at-risk patients
  - ‘Vulnerable’ brains: elderly phenotype, not just old
  - But is this risk modifiable?

EEG Indices: Limitations

<u>Numbers may not reflect actual hypnotic state</u>

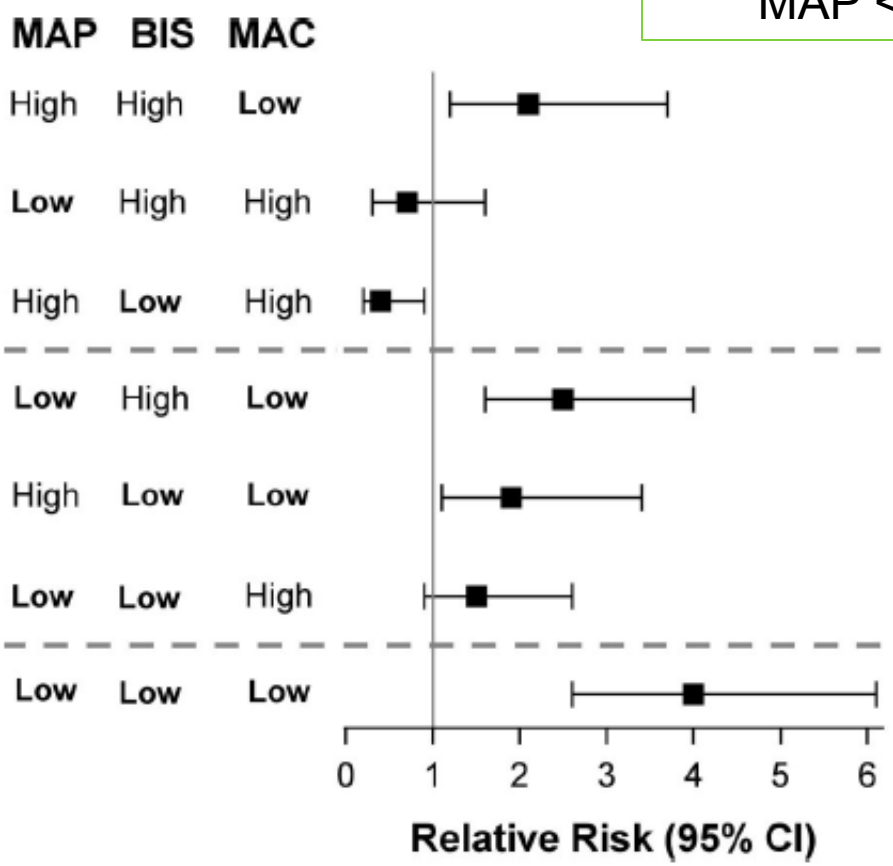
- Interference: EMG / ECG / electrical / diathermy
- Often combined with EMG activity, therefore affected by neuromuscular blocking agents
- Older patients BIS overestimated by ~ 3.5 points
- Ketamine / nitrous oxide give higher numbers

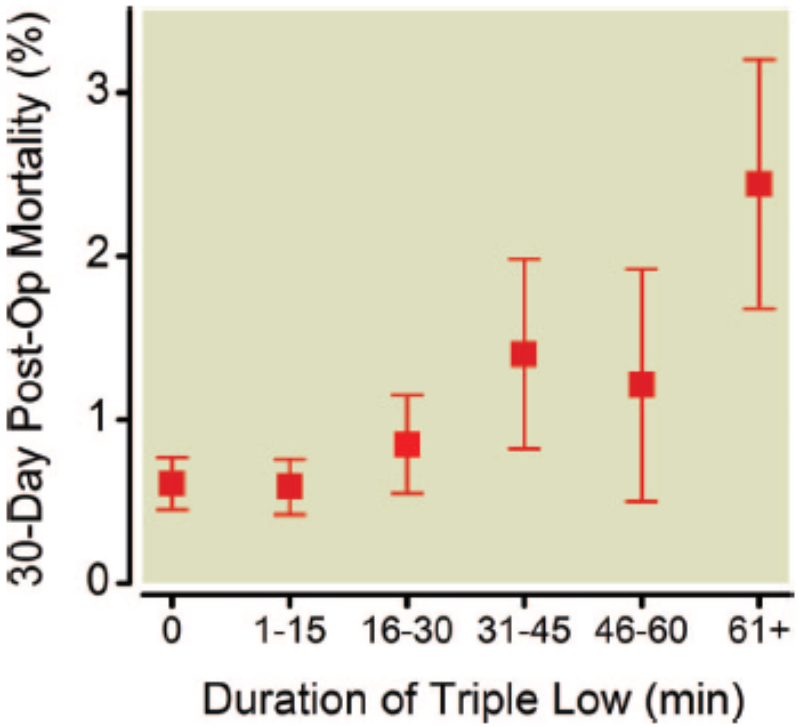
EEG Indices: Limitations (2)

- Slow to respond to changes in patient state (lag of ~25 s)
- ? No better than using an ET gas alarm of 0.7-1.3 Mac
- BIS is a proprietary algorithm
- Reduce the EEG to a single value
  - Loose valuable Information: “Like summarising to ECG just using heart rate”

Controversies: The 'Triple Low'

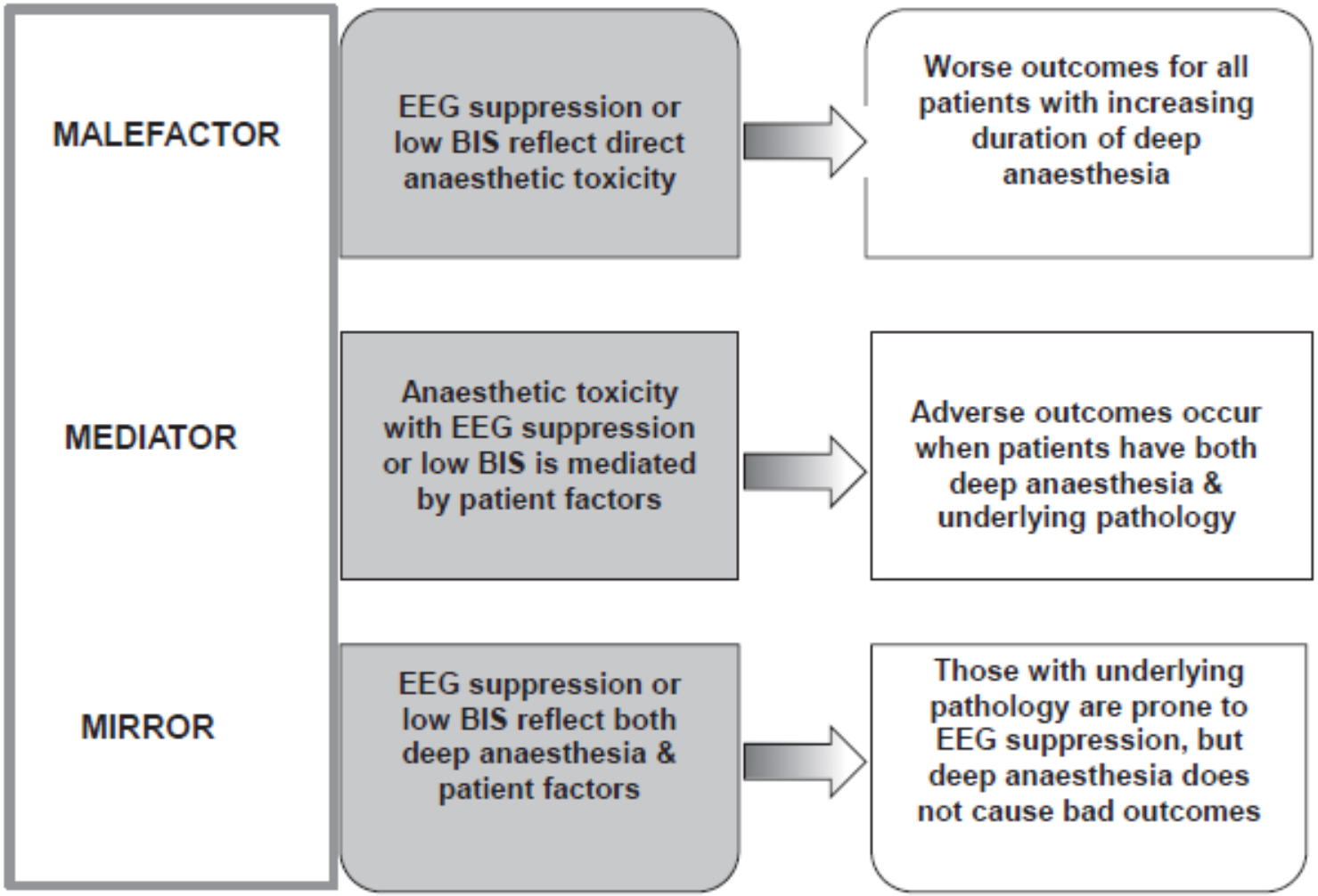
MAP < 75 mmHg, BIS < 45, and MAC < 0.8





Sessler DI, Sigl JC, Kelley SD, et al. Hospital stay and mortality are increased in patients having a "triple low" of blood pressure, low bispectral index, and low minimum alveolar concentration of general anesthesia. Anesthesiology. 2012;116:1195-1203

Controversies: Low BIS and Outcomes



Summary

- With increasing anaesthetic dosing the EEG:
  - Shows an overall decrease in frequency
  - The power (amplitude) increases
  - Eventually results in burst suppression
- The EEG is affected differently by:
  - Different anaesthetic agents
  - By increasing age
- Use of the pEEG may help prevent awareness and reduce other negative post-op outcomes (Controversial)

References

Hagihira S. Changes in the electroencephalogram during anaesthesia and their physiological basis. BJA 2015 https://doi.org/10.1093/bja/aev212

Kim et al Role of electroencephalogram oscillations and the spectrogram in monitoring anaesthesia BJA Education 2020 https://doi.org/10.1016/j.bjae.2020.01.004

https://icetap.org/

https://eegforanesthesia.iars.org/

SBA QUESTIONS

Question 1

For a healthy 40 year old patient undergoing GA with propofol and remifentanil TIVA, which of the following EEG parameters is most likely to indicate a profound level of anaesthesia?

A. A BIS value of 40
B. A burst suppression ratio of 2%
C. The presence of slow 4Hz delta waves
D. An isoelectric EEG trace for around 40 seconds of every minute
E. A spectral edge frequency (SEF95) of 20Hz

Question 2

Which of the following clinical scenarios would be most likely to result in an EEG showing clear alpha waves (8-12Hz) on a background of delta waves (1-4Hz)?

A. An ASA1 25 year old patient undergoing day case surgery with TIVA: Propofol Cpt 4mcg/mL and Remifentanil Cpt 4ng/mL
B. A healthy 75 year old undergoing day case surgery with sevoflurane (end tidal 1.8%) in air
C. A 20 year old trauma patient undergoing an emergency laparotomy who was induced with a ketamine and rocuronium RSI
D. A healthy 20 year old patient undergoing day case surgery with sevoflurane (end tidal 2%) in nitrous oxide oxygen 50:50
E. A 70 year patient undergoing urgent burrhole evacuation of subdural haematoma with TIVA: Propofol Cpt 3mcg/mL and Remifentanil Cpt 3ng/mL

Question 3

Which of the following is <u>not</u> a typical EEG change seen on induction of general anaesthesia with propofol?

A. A fall in processed EEG indices
B. A decrease in overall frequency
C. An decrease in overall amplitude
D. A loss of high beta waves (20-30Hz)
E. An increase in slow delta waves activity (1-4Hz)

Question 4

In which of the following scenarios would intraoperative EEG monitoring be most beneficial in reducing the risk of accidental awareness under anaesthesia (AAGA)?

A. A 30 year old ASA 1 patient undergoing an ACL reconstruction with sevoflurane maintenance and an LMA

B. A 50 year old patient undergoing a laparotomy with propofol/remifentanil TIVA

C. A 60 year old patient undergoing panendoscopy with inhalational maintenance (desflurane) and a microlaryngoscopy tube

D. A 55 year old patient undergoing middle ear surgery with propofol/remifentanil TIVA

E. A 60 year old patient undergoing carpal tunnel release under GA with propofol/remifentanil TIVA and an LMA