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Using the EEG to Manage Unconsciousness in the Operating Room

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Learning Objectives

1. Learn the neural circuit mechanisms of action of the commonly used anesthetics.

2. Learn how the EEG signatures of the commonly used anesthetic relate to the neural circuit mechanisms of action.

3. Learn how the EEG and its spectrogram can be used to track the brain of patients receiving general anesthesia and sedation.

4. Learn how to read the EEG and spectrogram of combinations of anesthetic drugs.

Disclosures

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Dr. Brown has signed a licensing agreement with Masimo and has served as a consultant for Masimo.

Three-States of General Anesthesia-Induced Altered Arousal

GABAA RECEPTOR AGONISTS: UNCONSCIOUSNESS AND SEDATION

ALPHA RECEPTOR AGONIST: PHARMACOLOGICAL NON-REM SLEEP

NMDA RECEPTOR ANTAGONISTS: ANALGESIA, HALLUCINATIONS AND DISSOCIATIVE ANESTHESIA

What is General Anesthesia?

A drug-induced, reversible state comprised of

Unconsciousness

Amnesia (loss of memory)

Analgesia (loss of pain perception)

Akinesia (loss of movement)
and
Stability and Control of the cardiovascular, respiratory thermoregulatory and autonomic nervous systems.

How Drugs Cause General Anesthesia is Unknown?

Brown, Lydic, Schiff (2010)

Loss of Consciousness from Propofol

ShiNung Ching

Patrick Purdon

Nancy Kopell

Emad Eskandar

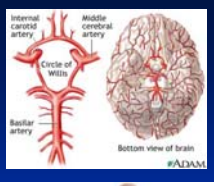
Eric Pierce

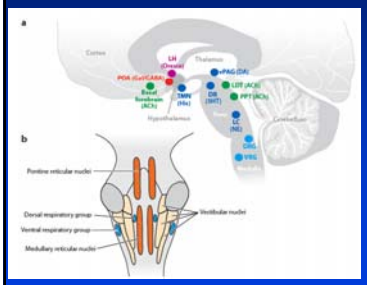
Laura Lewis

Syd Cash

Brain Stem Effects of Propofol

A. Apnea
B. Atonia
C. Unconsciousness





Brown , Purdon, Van Dort, *ARN* (2011)

EEG States of Propofol-Induced Unconsciousness

Awake

Paradoxical Excitation

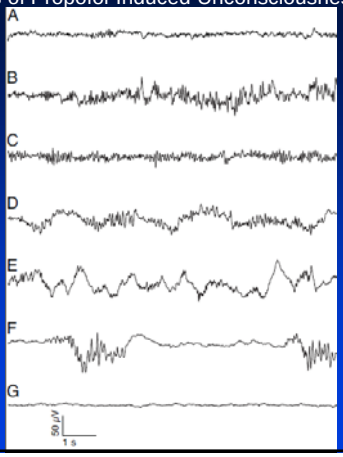
Sedation

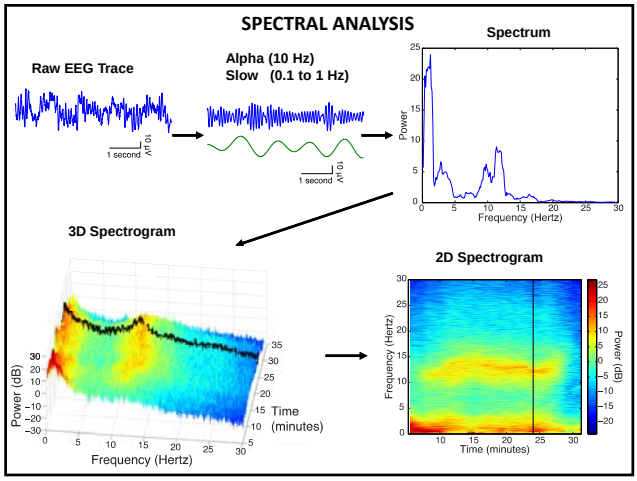
Slow-Alpha Oscillations (<1 Hz) (8-12 Hz)

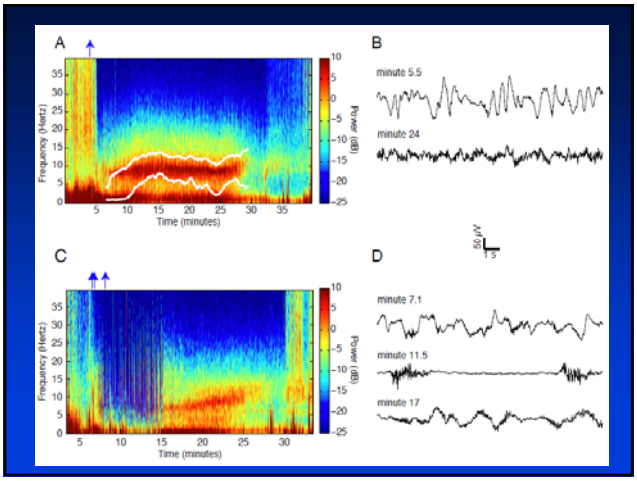
Induction
Slow Oscillations(<1 Hz)

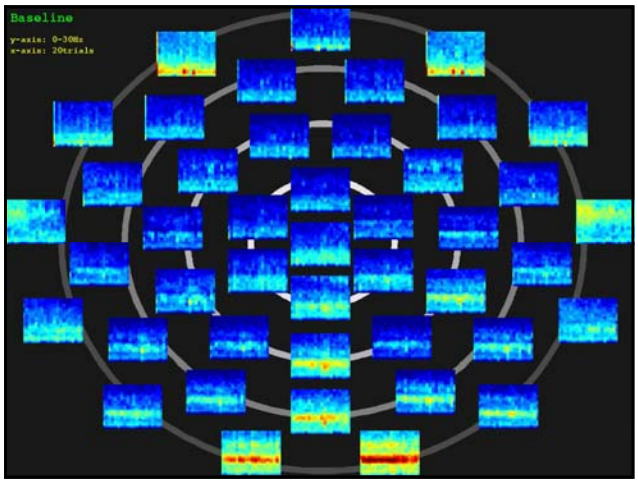
Burst Suppression

Isoelectric



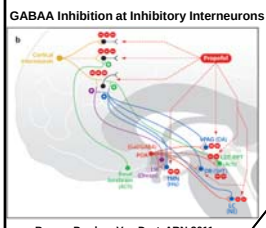






Mechanisms for Alpha and Slow Oscillations

GABAA Inhibition at Inhibitory Interneurons



Brown, Purdon, Van Dort, ARN 2011

Ching et al. *PNAS*, 2010 Cimenser et al. *PNAS*, 2011 Purdon et al. *PNAS*, 2013 Lewis et al. *PNAS* 2012

Summary

Why Does Propofol Make You Unconscious?

Cortex and Thalamus

alpha (8-12 Hz) rhythms strongly couple the thalamus and cortex restricting communication

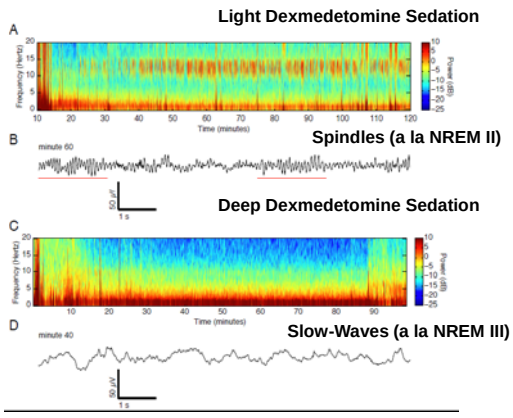
slow-wave (< 1 Hz) rhythms create local islands preventing communication within the cortex

anteriorization as a mechanism for frontal-parietal disconnection

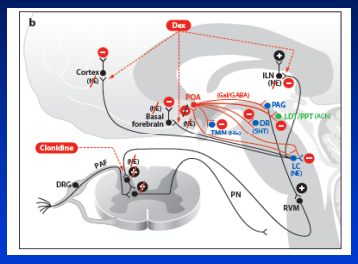
Brain Stem

blocking the brain stem arousal pathways prevents communication of the lower parts of the brain with the cortex

Dexmedetomidine ("Sleep Like")

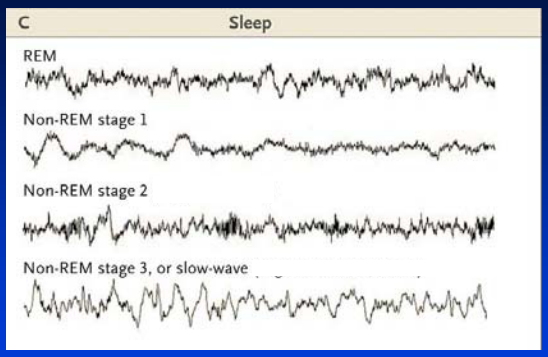


Dexmedetomidine



Brown, Purdon, Van Dort (2011)

EEG Patterns during the Awake State, General Anesthesia, and Sleep.



Brown EN et al. N Engl J Med 2010;363:2638-2650

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Summary

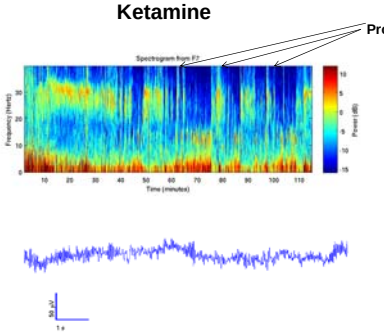
Dexmedetomidine acts on the locus coeruleus projections to the preoptic area, the basal forebrain, intralaminar nucleus of the thalamus and in the cortex.

Given that dexmedetomidine's targets it is no surprise that its EEG of mimics aspects of the EEG of non-REM sleep.

Clinical Implications

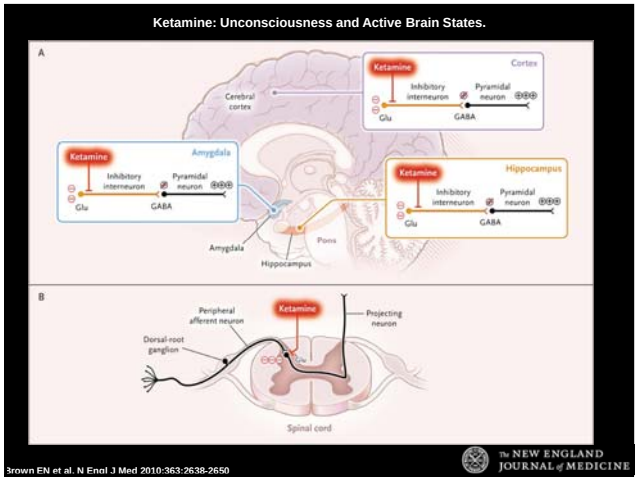
Changing the receptor targets and the circuits in which the anesthetics act changes how the altered state of arousal is produced.

Ketamine



Ketamine: Blocking of NMDA receptors on inhibitory interneurons
Prominent beta, gamma and supra gamma oscillations

Propofol: Enhanced GABA inhibition
Initiation of cortical slow oscillations with loss of intracortical connectivity
Induction of coherent alpha oscillations in the thalamo-cortical loops



Ketamine-Induced Hypnosis and Activated EEG: A Hypothesis

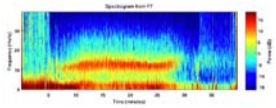
Seizures as a way to disrupt neural transmission and lose consciousness.

Propofol: decreased neural activity (Inactive Communication).

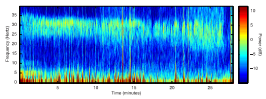
Ketamine: enhanced non-random neural activity in the cortex, limbic system (amygdala, cingulate) and hippocampus (Noisy Communication).

Ergo: Unconsciousness and Hallucinations

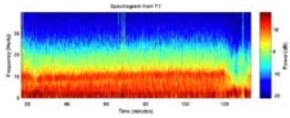
Different Anesthetics Have Different EEG Signatures



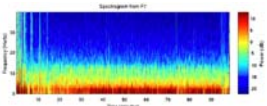
Propofol (+GABA)



Ketamine (-NMDA)



Sevoflurane (+GABA)



Dexmedetomidine (+α2 adrenergic)

Conclusions

The EEG and its spectrogram can be used to manage patients in the operating room.

Use of this approach requires that anesthesiologists have a deeper neuroscience understanding:

A. Neuroanatomy and Neurophysiology (Emphasis on Neural Circuits!)

B. Clinical Neurology Examination

C. Neurophysiology of the EEG (The Brain's ECG)

D. Brain and CNS-based Pharmacology (Anesthetic effects are in the brain not in the lungs or the blood!)