Regional Neural Dynamics of Dexmedetomidine Anesthesia: Informing Use In Awake Craniotomies

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Introduction

Dexmedetomidine (Dex) is being explored as a superior anesthetic for achieving conscious sedation in awake craniotomies, a preferable method for resection of glioma and epileptic foci near eloquent regions. Multiple studies have shown Dex provides optimal sedation for longer periods, while reducing narcotic use and retaining the ability to perform neurocognitive testing. There have been limited studies and mixed results on the effect of Dex on electrocorticography (ECoG) activity. The objective of this study is to determine neural oscillations associated with consciousness and return-of-pre-anesthetic-performance (ROPAP).

Methods

We conducted microelectrode array intracortical recordings in the somatosensory (S1) and frontal ventral premotor (PMv) **(Fig 1a)** areas of non-human primates (NHPs).

Location of the recording sites

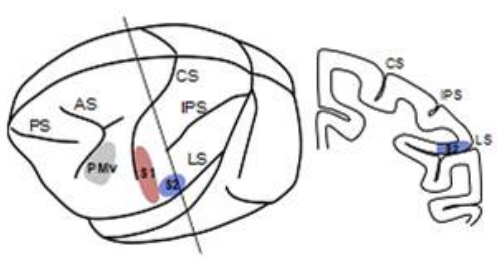

Figure 1. Neural recording is performed in the primary somatosensory cortex (S1, red), secondary somatosensory cortex (S2, blue) and ventral premotor cortex (PMv, gray). CS, central sulcus; IPS, intraparietal sulcus; LS, lateral sulcus; AS, arcuate sulcus, and PS, principal sulcus.

Dex infusion was administered through a vascular port, following a behavioral task. NHP task performance was analyzed during loss-of-consciousness (LOC), return-of-consciousness (ROC), and ROPAP. Behavioral Task: Two NHPs were trained on a somatosensory vs auditory sensory discrimination task to analyze engagement and performance during anesthesia **(Fig. 1b)**.

Multisensory Task

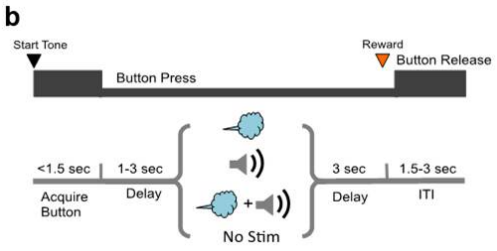

Figure 1. Behavioral task sequence of events during behavioral trials.

Analysis: LFP and single neuron analyses were performed using existing and custom-written functions in MATLAB (MathWorks Corp). Multitaper spectral and coherence analysis were performed using the Chronux and standard signal processing toolbox for MATLAB. The state-space model was used for analysis of trial-by-trial behavioral data.

Results

Spectral Analysis

During wakefulness, beta oscillations dominated in S1 and PMv, while the onset of LOC was identified by a brief increase of alpha power oscillations more obvious in S1 than PMv **(Fig 2a & b)**. Throughout anesthesia, slow-delta oscillations appeared, while ROC was associated with a return of alpha oscillation dominance and decrease of slow-delta waves. As the animal recovered, alpha waves appeared to increase its frequency toward the beta range.

Somatosensory Spectrogram

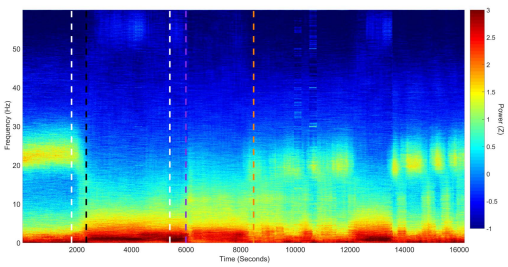

Figure 2.A. Representative spectrogram during dexmedetomidine anesthesia.

Coherence

Ventral Premotor Spectrogram

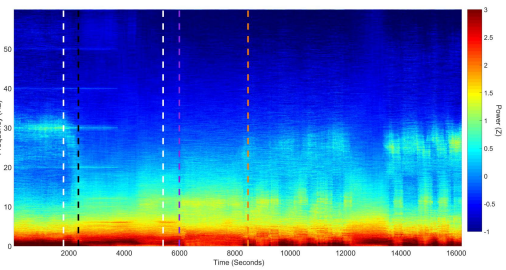

Figure 2.B. Representative spectrogram during dexmedetomidine anesthesia.

Representative Coherogram

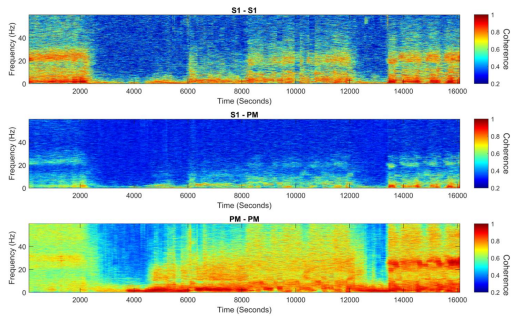

Figure 3. S1 intra-regional coherence (top), PMv intra-regional coherence (bottom) and S1-PMv inter-regional coherence (middle) during dex anesthesia and recovery.

Regional Firing Rate

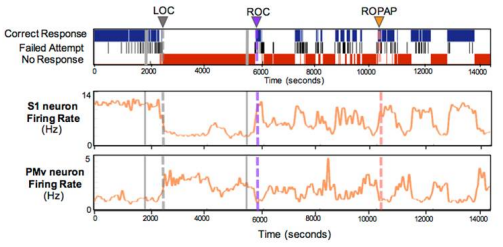

Figure 3. Single neuron spike analysis showed PMv spike firing rate increased upon LOC while S1 neurons decreased; a response that continued through recovery.

Single Neuron

Conclusions

- These findings suggest that Dex-induced LOC and ROC are both associated with an increase of alpha oscillations in S1 and PM. The slow-delta oscillations are dominant while the animals are unconscious.
- Spike firing response appears to be region specific, but clearly associated with consciousness changes.
- Understanding Dex-induced regional spiking activity could perhaps inform neurosurgeons on areas of increased epileptiform susceptibility.
- Effects on task-related performance could help guide appropriate use of intraoperative anesthetic titration and neurological assessment.

Learning Objectives

1. Describe the neurophysiological effects of dexmedetomidine anesthesia.
2. Analyze the isolated effects of dexmedetomidine on the neural dynamics of task-performance.

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Acknowledgments