Analysis of Anesthetic Depth with Processed EEG and NIRS

PURM
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Background

Over many years, neurocognitive abnormalities have been observed within infants undergoing general anesthesia, especially during cardiovascular and neonatal surgeries. Currently, neurologic injury has occurred within multiple infants as a result of anesthetic neurotoxicity or cerebral hypoxia-ischemia during surgery.

In order to improve anesthetic safety and predict the likelihood of neurologic injury occurring within infants during surgery, cerebral saturation and electrical brain activity could be monitored during surgeries. Near infrared spectroscopy (NIRS) is a brain imaging method that measures light absorbance to calculate the cerebral tissue oxygen saturation ($rSco_2$) within cardiac, neonatal, and pediatric patients. Using this method of measurement allows surgeons to detect when cerebral oxygen levels decrease therefore predicting when a neurologic injury may occur. In addition to this, electroencephalography (EEG) is a method that measures electrical brain activity using small, metal electrodes attached to the scalp. The EEG consists of four independent channels that may flat-line during a surgery therefore informing the surgeon of a potential neurologic abnormality. These two measurement techniques are used in this study to understand and help determine when a possible neurologic complication may occur during surgery.

More specifically, a low regional cerebral $rSco_2$ is defined as less than 50% for more than 7h in neonatal care or less than 45% for more than 3h in pediatric cardiac intensive care. Low oxygen saturation often leads to decreased brain tissue energetics, slower EEG measurements, and brain ischemic lesions. Of course various anesthetic drugs were found to have various impacts on oxygen saturation. Sevoflurane is often used with many infants (below age 2) as it usually increases $rSco_2$.

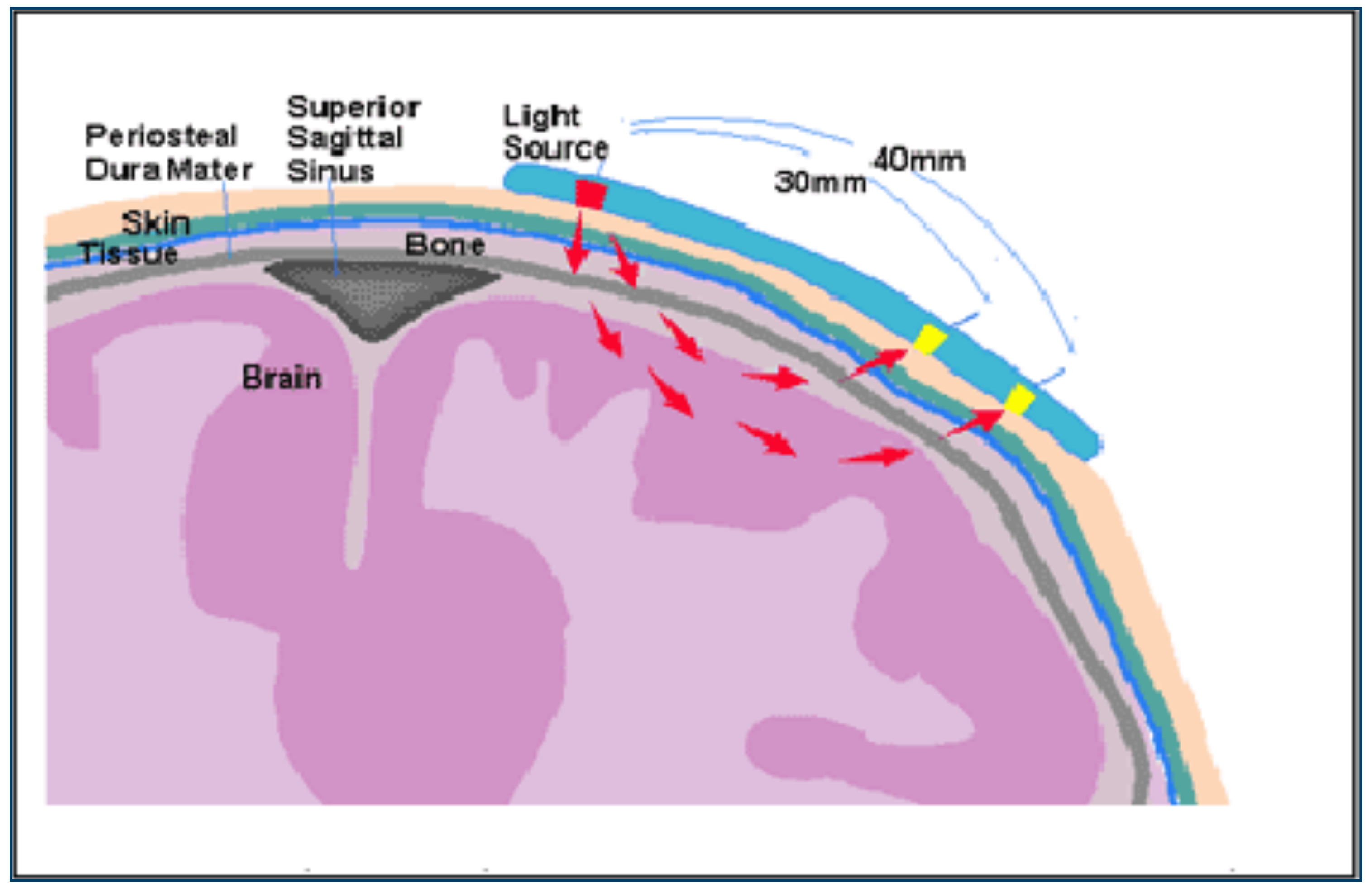


Figure 1: Schematic of Near Infrared Spectroscopy

Methodology

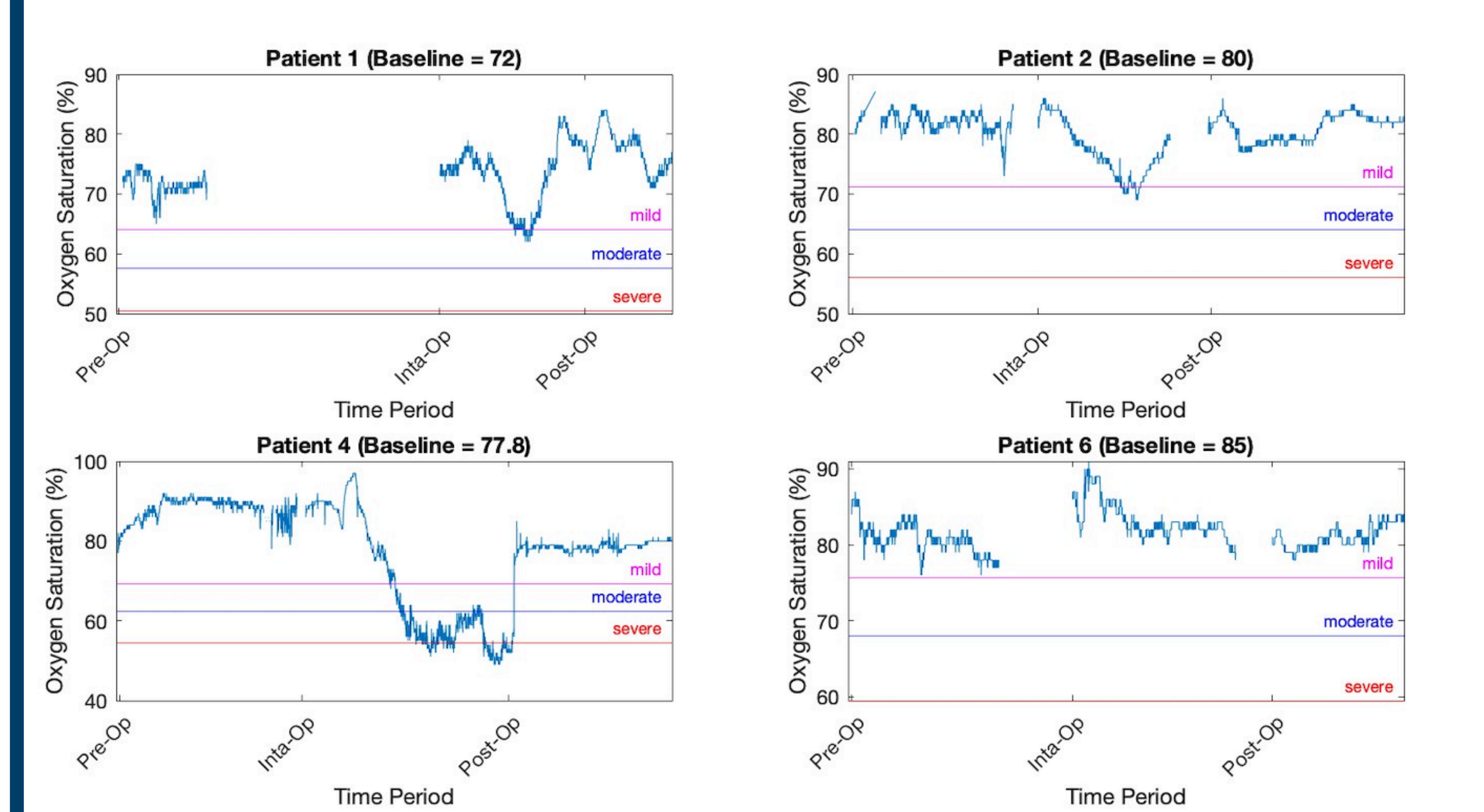
In this study, the surgical data of 53 infant patients were collected from the Children's Hospital of Philadelphia. For each patient, the NIRS and EEG were tracked throughout time at various timestamps. This data included the general timestamps (pre-op, intra-op, and post-op) along with the following other time periods:

- **Induction:** the timeframe when the drug is first being administered to the patient.
- **Start Surgery:** the first incision on the patient.
- **Paralytic Time:** paralytic medication (neuromuscular blocking agent) is administered to the patient.
- **End Surgery:** time period when the last stitch is completed on the patient
- **Emergence:** timeframe three minutes after the last stitch or dressing was placed on the patient.

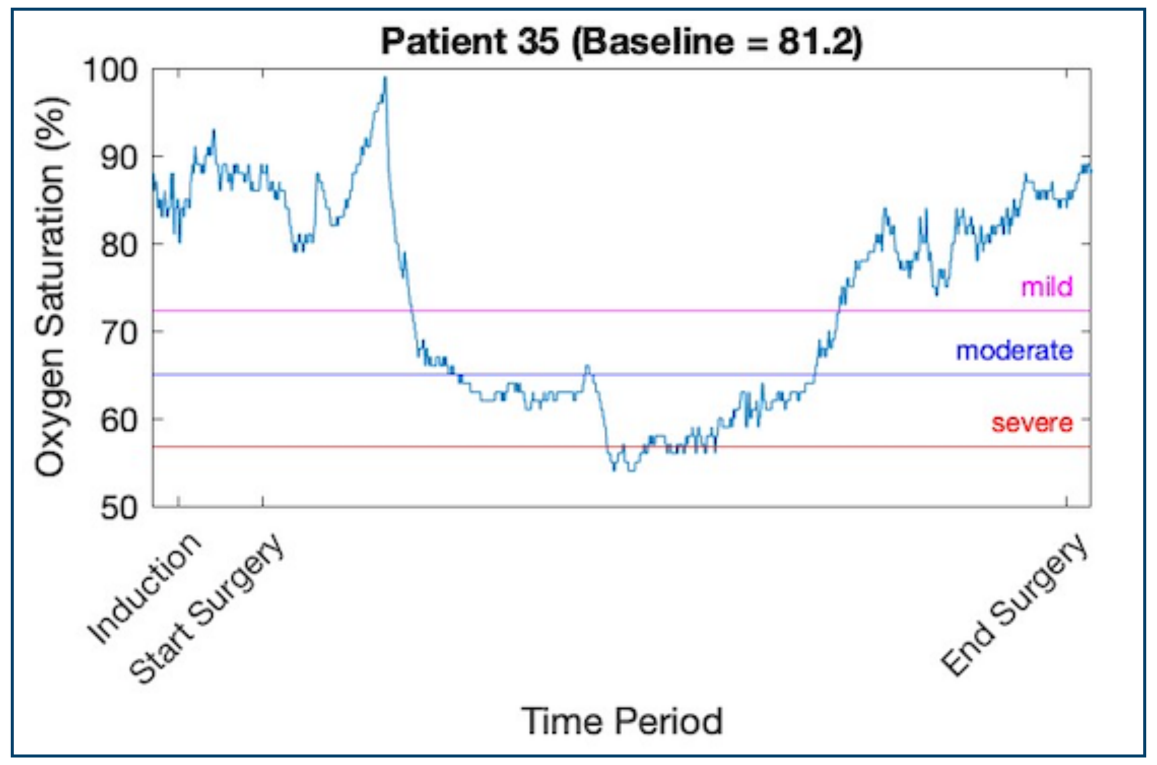
An oxygen saturation baseline was also calculated for each patient by averaging the first five $rSco_2$ values. This baseline was then used to determine when the oxygen saturation was considered mild (11% below baseline), moderate (20% below baseline), or severe (30% below baseline).

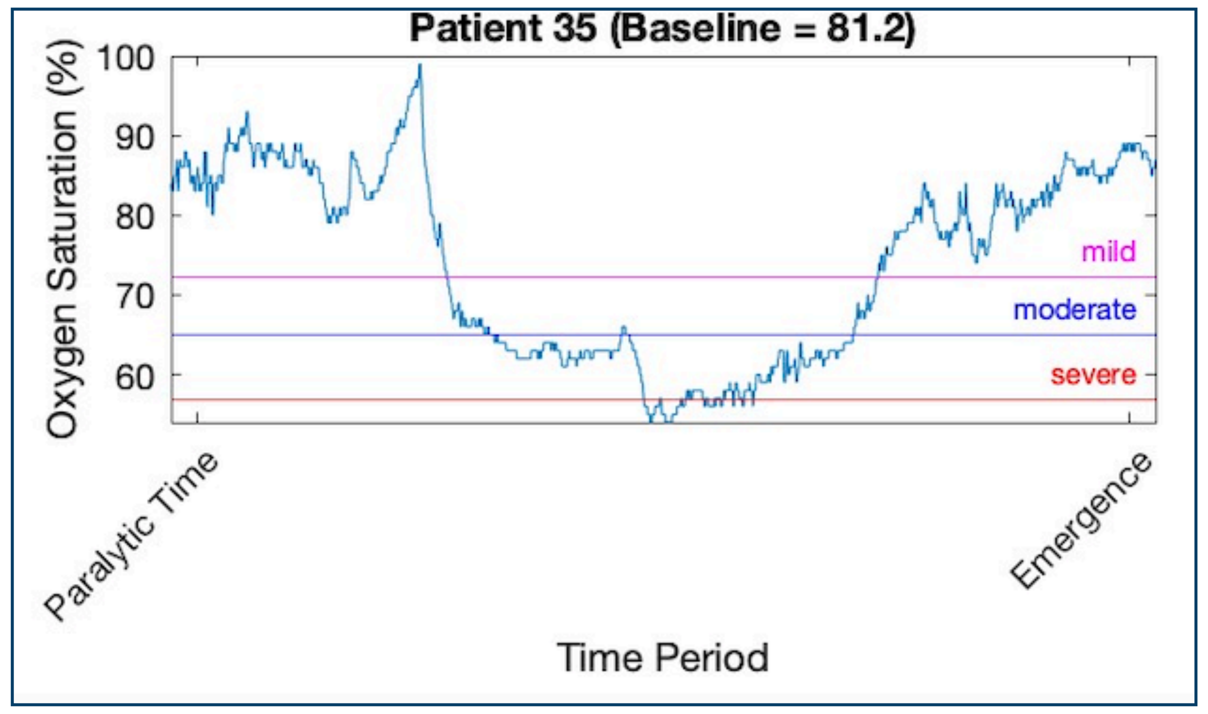
The MATLAB programming software was used to calculate and process all the data for each patient. The timeline for each patient was first converted into seconds (relative to the first $rSco_2$ value) in order to allow for effective plotting and comparison between time periods. After plotting a time (timestamps) versus oxygen saturation for each patient, the data was further processed to find the time intervals where the oxygen level remained below the mild, moderate, or severe threshold for more than 3 minutes. A table was then created to track the frequency of desaturation, average desaturation time, and % desaturation relative to the total time period.

In addition to this, MATLAB analysis was also used to combine the EEG datasets (28 min segments) into a continuous dataset for further processing. A script was developed to find the time intervals where the channels flat-lined ($-0.05<x<0.05$) for at least 10 seconds.



Data Collection





Discussion

As presented by the data, the $rSco_2$ of some patients decline below their corresponding thresholds (for greater than 3 minutes) most likely due to the administered anesthesia. Moving forward, this data will be further processed which may help determine a trend in the overall data and propose a possible explanation for these anesthetic drug complications. In addition to these patients, additional data was collected from other surgeries performed at various hospitals in the United States, Australia, China, and Italy.

Given that the NIRS technique only tracks the oxygen saturation at the frontal lobe of the patient, it is also possible that low cerebral oxygenation occurred in deeper parts of the brain. However, prior imaging studies have shown that a uniform change in blood flow and metabolism occurs throughout the brain therefore making this possibility unlikely. Regarding future studies, it is encouraged that the learning and behavioral development of infants experiencing this complication should be further studied.

Citations

Olbrecht, Vanessa A et al. "An International, Multicenter, Observational Study of Cerebral Oxygenation during Infant and Neonatal Anesthesia." *Anesthesiology* vol. 128,1 (2018): 85-96. doi:10.1097/ALN.0000000000001920