TITLE: NEURAL NETWORK ESTIMATION OF ANESTHETIC DOSE USING EEG SPECTRAL SIGNATURES

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Introduction: Assesment of anesthetic depth using univariate descriptors of EEG [i.e. spectral edge frequency (SEF)] remains unreliable. Artificial Neural Networks (ANN) are computer programs with variable connection strengths among a complex network of layered nodes. In the type of ANN we used in this study, data enters at an input layer (30 nodes), travels via variable strength connections through a hidden layer (6 nodes), and exits at an output layer (3 nodes). The ANN is "trained" by entering known input to produce a specific output, which is then used to adjust connection strengths ("back-propagation") to facilitate the "correct" input/output pathway. Consequently, ANN can recognize and classify patterns. We have applied ANN to EEG correlates of anesthetic dose/depth.

Methods: With Institutional approval, general anesthesia was mask-induced in 10 greyhound dogs using oxygen, nitrous oxide (N_2O) and isoflurane. Following induction and intubation, N_2O was discontinued and an IV line started for maintenance fluids and drugs. EKG, arterial catheter, and infra-red end tidal gas analysis monitors were applied. Pancuronium was used for neuromuscular blockade, mechanical ventilation kept end tidal CO_2 between 35 and 40 torr, and blood pressure was maintained within 20 percent of baseline with phenylephrine when necessary. End tidal isoflurane was continuously measured and adjusted using infra-red spectroscopy. Subdermal EEG needle electrodes were placed in the frontal and occipital regions of the left and right cerebral hemispheres. End tidal isoflurane concentration was initially set at 0.7 % and increased by 0.7 % every 15 minutes to achieve 3 stable anesthetic levels (0.5, 1.0, 1.5 MAC). EEG raw waveforms were recorded on FM tape using a Hewlett Packard 3964A. For each dog at each of 3 anesthetic levels a twenty second EEG epoch (4000 pts) was digitized at 200 Hz and analyzed for spectral content 256 points at a time using ASYST laboratory software. The average spectral signature of each 20 second epoch was stored as a 30 point array to test the ANN and train it to categorize each epoch signature as either 0.5, 1.0 or 1.5 MAC. The ANN was trained on 9 out of 10 data sets and tested on the excluded data set. This was done 10 times so that each epoch signature was excluded and tested for once.

Results: Visual inspection of the EEG waveforms and spectral signatures showed considerable intra-dog and inter-dog diversity. Burst suppression occurred in 4 dogs at 1.5 MAC. Average SEF among MAC levels exhibited no statistically significant differences at $p < .05$ (Fig. 1). The trained ANN was able to correctly identify the anesthetic level of unknown EEG epochs with an overall accuracy of 77 % (Table 1).

Discussion: Despite considerable diversity in spectral signatures, the ANN performed categorization with greater accuracy than that achievable with a single parameter such as SEF. It should be noted that the controlled variable was anesthetic concentration, not "depth" of anesthesia. Therefore, some of the apparent misclassifications may be attributable to variation in apparent "depth" at a given end tidal concentration.

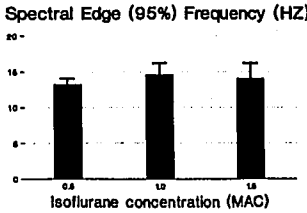

Figure 1

MAC	0.5	1.0	1.5
%	100	50	80

Table 1. % correctly identified by ANN.

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Title: **THE INFLUENCE OF HEAD CIRCUMFERENCE AND PROBE CONFIGURATION ON THE OPTICAL PATHLENGTH OF LIGHT THROUGH THE HEAD AS ASSESSED BY PHASE-MODULATION SPECTROSCOPY IN CHILDREN**

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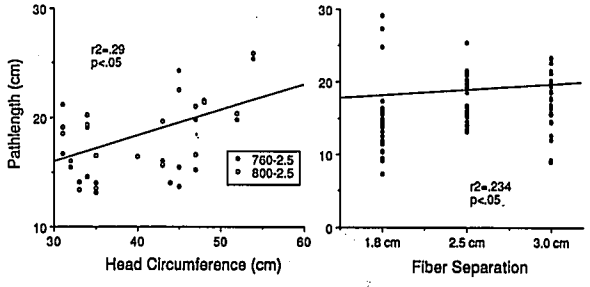
Introduction: We have previously reported a technique that enables the continuous noninvasive determination of relative changes in brain oxyhemoglobin concentration by measurement of absorbance changes in reflected light at 760 and 800 nm wavelengths (near-infrared reflectance spectroscopy-NIRS).[1,2] While we have demonstrated reproducible results in homogeneous populations (*e.g.* neonates on cardiopulmonary bypass),[1] comparisons between subjects of differing sizes or precise quantification of oxyhemoglobin by Beer's law ($A=\varepsilon Cl$) would require a knowledge of the optical pathlength of light (l) at these wavelengths. Phasic modulation of the incident light (PM-NIRS) enables an instrument to time the photon migration from emitter to detector and thus calculate the optical pathlength using the speed of light.

Methods: A PM-NIRS instrument was designed using a 220 MHz transmitter to provide phase modulation and 3 mW laser diodes at 754 and 816 nm wavelengths. The photodetector is capable of resolving phase shifts (Φ) in the picosecond range. In order to render Φ determinations insensitive to changes in the amplitude of the returning signal, measurements must be made either from phase peak to peak, or at zero amplitude crossing points. After IRB approval, l determinations were made on 21 neonates, infants and children at both wavelengths and three emitter-detector fiber separations (1.8, 2.5 and 3 cm.).

Results: The patients varied in age (range 1 day to 4.7 years, mean 9 mo), weight (2.7-19 kg) and head circumference (31-54 cm).



Figures. Relationship of l to fiber separation and head circumference, the latter using a fiber separation of 2.5 cm. The relationship between head circumference and l was weaker at the other fiber separations ($r^2<.1$ at 1.8 and 3 cm.)

Discussion: This study demonstrates that optical pathlength is related to head circumference and emitter-detector fiber separation, but the weak correlation coefficients suggest other variables are perhaps more important. PM-NIRS revealed that l can vary substantially. Thus in order to evolve into broader applications, NIRS instruments must become capable of precise and accurate measurements of optical pathlength as well as absorption.

1. *Anesthesiology* 71:A1035, 1989
2. *Rev Sci Instru* 22:634, 1951.