

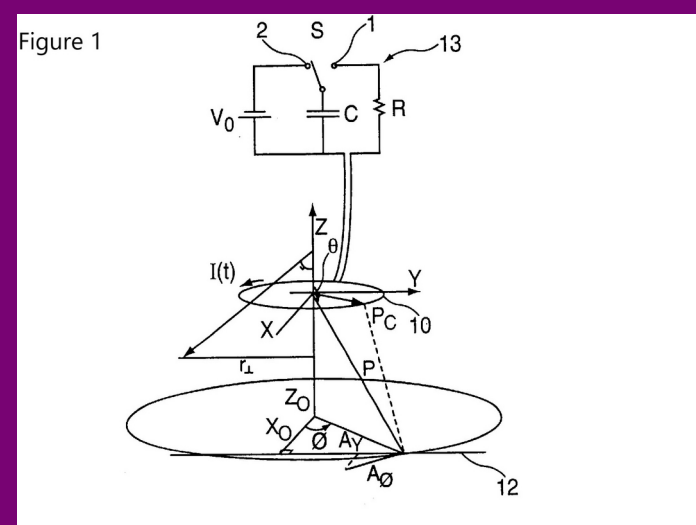
MODEL AND COMPUTER SIMULATION FOR PRECISION CONTACTLESS ANALGESIA

Manne, Joseph and Zou, Shengping

Introduction

Can We Create a Contactless Form of Analgesia and Anesthesia?

Methods



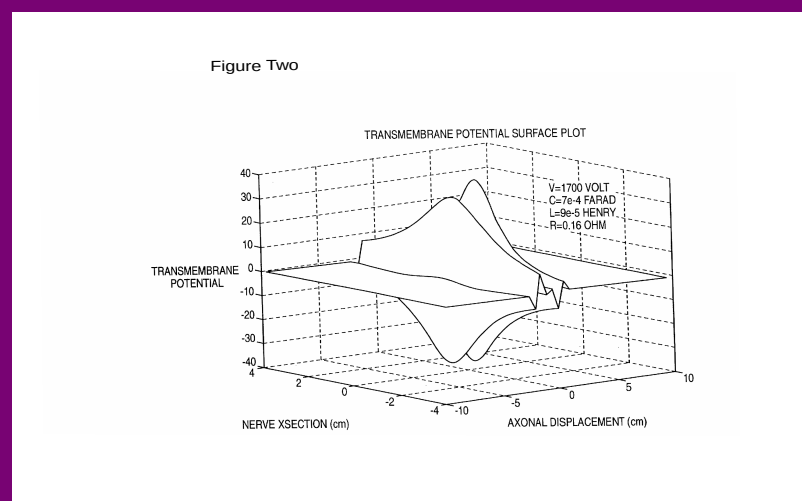
1. Mathematical Model of Magnetic Coil Placed over Neuron
 2. Coil Discharges and Creates Electrical Field at Neuron
 3. Computer Simulation Shows How Coil Can Alter the Neuron
- Results

Coil Can Hyperpolarize or Depolarize Neuron

Discussion

Coil has ability to Block

Neuron While it's Discharging



Introduction

One of the first ways to develop a mathematical model and subsequent computer simulation for a technology that can provide neural stimulation in a contactless form. It is known that the electric field providing an electrode proximity to a neuron will create an electric field that can affect hyperpolarization or depolarizing a neuron¹. The object of this study is to create an electrical field that will provide an electric field of a given plane, varying magnetic field of block action potentials transverse signals to the brain in the form of an electrical potential. The electric field will be hyperpolarized to greater than -100mV hyperpolarized to the action potential with positive 40mV depolarization and the electric field will be $< 100\text{mV}$. The electric field will be hyperpolarized to greater than -100mV . Therefore the hyperpolarization produced by the external magnetic flux will be hyperpolarized or more, and $< 100\text{mV}$ is preferable to have a safe margin. This then would cause a nerve block.

Materials and Methods

The mathematical model of electrical conduction in the neuron which has been widely accepted is the modified cable equation:

$$R_m \frac{d^2 V}{dx^2} = -R_i \frac{dV}{dx} - \frac{dV}{dt} \quad (1)$$

where:

- R_m represents voltage.
- The gradient of the electric field on the right side of the equation is referred to as the transmembrane voltage.
- The left side of the equation is referred to as the total transmembrane voltage.
- The right-hand side equation represents current.

The mathematical model was constructed to model an electrical coil connected into an AC circuit with a variable current in the coil. The coil is placed in a given plane parallel to a plane containing a peripheral nerve. The y position of the coil relative to the nerve plane can be adjusted to control the induced magnetic field. The induced magnetic field will create a secondary electric field.

Results

Eq. 1

1.Rattay F J. *J Theor Biol* (1987) 153:339-349

A magnetic wave potential with a time varying current, such as a coil in the present study, the equation for the induced magnetic vector potential has been described¹.

$$\frac{A}{c} = \mu_0 \frac{RSE}{c} \frac{\cos \theta}{r} \quad \text{eqp.3}$$

the equation simplifies to:

$$A = \frac{4\pi I R^2}{c} \quad \text{eqp.4}$$

where k is defined by:

$$k^2 = \frac{4\pi I R^2}{c}$$

k and K are the elliptic integrals of this variable k

then the expression for the magnetic vector potential is:

the electric field along the axis of the acon II if component (Figure 1)

The axial electric field gradient is the source term in the modified cable equation (Equation 1) for nerve conduction.

There have been many publications describing the solution of the modified cable equation.²

Your author has the nerve is divided into N

Ziaeiwan JO. Classical Electrodynamics. 1962 New York
 [Department of Sci, University of New South Wales, Effects of Induced Electric Fields on Finite Homocentric Spherically A Simulation Study, Transactions on Biomedical Engineering, 1977; appt711-11

segments and modelled as a lumped circuit.¹ The axial component of the magnetic field is assumed to be uniform over the cross-section of the wire and the voltage gradient along the axis of the wire is assumed to be negligible. The external magnetic field is assumed to be uniform over the cross-section of the wire and the external field magnetic field. The current can be assumed to be uniform over the cross-section of the wire. These assumptions are reasonable for the wire being successively treated as the center node on the completion of the use of the next terminal node.

$$V_{\text{ext}} = \sum_{j=1}^N V_j V_j = \sum_{j=1}^N E_j M_j = \sum_{j=1}^N E_j \int_{\text{ext}} M_j dV$$

Where $N = 2, 3, 4, \dots, \infty$
 E_j = the external magnetic field
 M_j = the total number of nodes in the wire segment of interest
 V_j = the voltage induced in the wire segment of interest
 V_{ext} = magnetic induction
 $\int_{\text{ext}}$ = the axial component of the magnetically induced electrical field

There are three equations in 1 unknown. The unknowns are the external magnetic field, the transverse voltage located in the vector $V = V_1, V_2, V_3, \dots, V_N$. The known quantities in the equations are the external magnetic field difference E_j to the externally induced electrical field V_j and the external magnetic field V_{ext} . The external magnetic field E_j and the external magnetic field V_{ext} are the coefficients for $V_1, V_2, V_3, \dots, V_N$ and the product of the matrix V and the vector E_j is the product of $E_j, V_1, V_2, V_3, \dots, V_N$ leading to the following equation

$$A \cdot V = B$$

The A can be solved for

$$V = B \cdot A^{-1}$$

V = transverse voltage

4. Report 1. Flatman W and Burke H. "Computational Models of Charge Transfer" *Technical Journal of Nuclear Model* (from Synapse to Research, Kluwer C and R. H. E. Eds, Cambridge, MIT Press, 1998, pp. 163-179)

[illegible]

EQUATION NUMBER	EQUATION	VARIABLES
1	$\delta^2 \frac{\partial^2 V}{\partial x^2} - V - \alpha \frac{\partial V}{\partial x} = \delta^2 \frac{\partial E}{\partial x}$	where: V represents voltage, to time x= axis of neuron δ = space constant Ex=electric field
2	$E = -\Delta\varphi - \frac{1}{c} \frac{\partial A}{\partial t}$	E = electrical field A= magnetic vector potential leading to magnetic field
3	$\frac{A}{c} = I(t) \frac{\rho c \mu}{\pi} \int_0^{\frac{2}{\pi}} \frac{\pi \cos \varphi d\varphi}{\sqrt{(\rho c)^2 + \rho^2 - 2\rho c \sin(\pi \cos \varphi)}}$	
4	$A = \frac{4\pi c}{\sqrt{(\rho c)^2 + \rho^2 + 2\rho c \sin \theta}} \left[\frac{(2-k^2)K(k) - 2E(k)}{k^2} \right]$	E and K are the elliptic integrals of this variable k
5	$\frac{2}{k} = \frac{4\rho c \sin \theta}{\rho^2 + \rho c^2 + 2\rho c \sin \theta}$	
6	$V_{n+1} = \left(\frac{a}{v_n} + 2 \right) v_n + V_{n-1} = \int_{(n-1)\Delta t}^{(n+1)\Delta t} (a - k) dx - \int_{(n-1)\Delta t}^{(n)\Delta t} (a - k) dx$	Where n=2,3,4... L-1 Δx is the internode distance L = the total number of nodes a=segmentinflow rate along axon G=membrane conductance Ex is the axial component of electrical field

