A Model of Nerve-Bundle Fibre-Stimulation using
Implantable Cuff Electrodes - Geometrical Structure and
Layout
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May 10, 2011

1 Selection and Justification

This model will aim to demonstrate the nonphysiological recruitment of type II fast twitch then
type I slow twitch muscle fibres and try to alter this so that only the fatigue resistant type I fibres
are recruited.

There are two groups of nerves: those of a greater diameter that innervate the type II fibres,
and those of a smaller diameter that innervate the type I fibres.

These will have different conduction velocities, as the Hodgkin-Huxley\cite{1} modelling of the action
potential will determine.

After initial stimulation, another cuff electrode located down the nerve will attempt to create
an anodal block that employs hyperpolarisation\cite{2} to stop the action potential in type II fibres only,
utilising the time gap between the action potentials created by the nerves’ different conduction
velocities.

When cuff electrodes have been implanted in surgery it is difficult to know their exact position
and orientation, making selectivity extremely difficult if using specific arrangements of multiple
electrodes around the nerve to steer the current. While this can be achieved and modelled in
theory, the anodal block method is much more reliable in a practical situation.

2 Geometry

The geometry used is based on the actual physiology\cite{3} and models previously developed\cite{4, 5, 6, 7}.

While the structure of nerve bundles vary throughout the body, a general form was deduced as
Figure 1 demonstrates in the $y - z$ domain, continuing uniformly down the $x$ domain.

![Figure 1: A simplified general form of the physiology we wish to model](image)

The is obviously too complex to model accurately, and there would be no point since it is a
general form, so we then approximate the general form\cite{7} as seen in Figure 2.
The connective tissues are 3D concentric cylinders on which the voltages in the nerve are mapped after stimulation, while the axons are 1D Hodgkin-Huxley modelled cables which will determine the conduction velocity. A few cables will be picked at various radii and depths to model the different propagations. They are excited by the voltage created by the first set of electrodes, then pass another set of electrodes that will attempt to block the faster nerves.

### 3 Parameters and Boundary Conditions

Past models[7], reference books[8] and papers[9] provide estimates of the conductance values and dimensions so that we can map out the voltages throughout the nerve model, as seen in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_{\text{saline}}$</td>
<td>$25/\text{m}$</td>
<td>$d_{\text enc}$</td>
<td>$40\mu\text{m}$</td>
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<tr>
<td>$\sigma_{\text enc}$</td>
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<td>$d_{\text epi}$</td>
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<td>$\sigma_{\text epi}$</td>
<td>$8.26 \times 10^{-2}/\text{S/m}$</td>
<td>$d_{\text peri}$</td>
<td>$25\mu\text{m}$</td>
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<tr>
<td>$\sigma_{\text peri}$</td>
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<td>$r_{\text endo}$</td>
<td>$300\mu\text{m}$</td>
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<tr>
<td>$\sigma_{\text endo}_{\text y,z}$</td>
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<td>$r_{\text cuff}$</td>
<td>$500\mu\text{m}$</td>
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<tr>
<td>$\sigma_{\text endo}_{\text x}$</td>
<td>$0.571/\text{S/m}$</td>
<td>$r_{\text max}$</td>
<td>$10\mu\text{m}$</td>
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<td>$\sigma_{\text fibre}_{\text y,z}$</td>
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<td>$r_{\text min}$</td>
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<tr>
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<td>$d_{\text elec}$</td>
<td>$5\text{cm}$</td>
</tr>
</tbody>
</table>

The Hodgkin-Huxley part of the model is obtained directly from the literature[1]. The only changes made are for the radii of the respective axons, so that $r$ is between $r_{\text{min}}$ and $r_{\text{max}}$. This will determine the different conduction velocities of the action potential down the axons.

The axons are created sufficiently long to avoid any unrealistic modelling from the Dirichlet boundary conditions at the ends of the cylinders and to give the electrodes enough distance from each other to demonstrate the anodal block ($d_{\text elec}$ is subject to change).

Lastly, the applied current must be kept within certain magnitude and time parameters to avoid damaging the human tissue. These are yet to be obtained.
References


