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Forward Modelling in MagnetoEncephaloSpinography

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Optically Pumped MagnetoEncephaloSpinography (OP-MSEG) offers a promising new avenue for concurrent non-invasive imaging of spinal cord and brain activity. However, the accuracy of source localisation in the cord critically depends on the quality of the forward model; particularly given the spinal cord's complex geometry, deep location, and conductive environment. In this study, we evaluate how anatomical and numerical modelling choices determine forward model accuracy.

A previous simulation study has shown that the inclusion of bone in the anatomical model considerably affects the expected OPM signal[1], a phenomenon not otherwise observed in traditional brain MEG. Hence, we look to compare three models featuring different representations of the vertebral column: a homogeneous toroidal model, an inhomogeneous toroidal model, and a continuous vertebral structure. Two forward modelling frameworks, finite element (FEM) and boundary element (BEM) methods, are used to generate magnetic field predictions under multiple dipole orientations and positions within a segmented spinal cord mesh. Our initial results show that the choice of bone model significantly influences the predicted field strength and topography.

To validate the forward models, we are currently acquiring anatomical and functional data with a novel, custom-built scanner cast made for a single subject. This has been developed to ensure consistent and reproducible co-registration between the OPM sensor array and spinal cord anatomy, enabling precise spatial alignment across modalities. Validation of the forward models will be performed by comparing predicted and measured magnetic field topographies using quantitative similarity methods.

The aim is to identify a forward model that balances anatomical accuracy with computational efficiency, which also provides a suitable comparison to experimental data. Thereby enabling robust, scalable OP-MESG pipelines suitable for use across participants and research sites.

1. George C. O'Neill, Meaghan Spedden, Maike Schmidt, Stephanie Mellor, Matti Stenroos, and Gareth R. Barnes. Volume conductor models for Magnetospinography. *bioRxiv*, 2024. Preprint

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