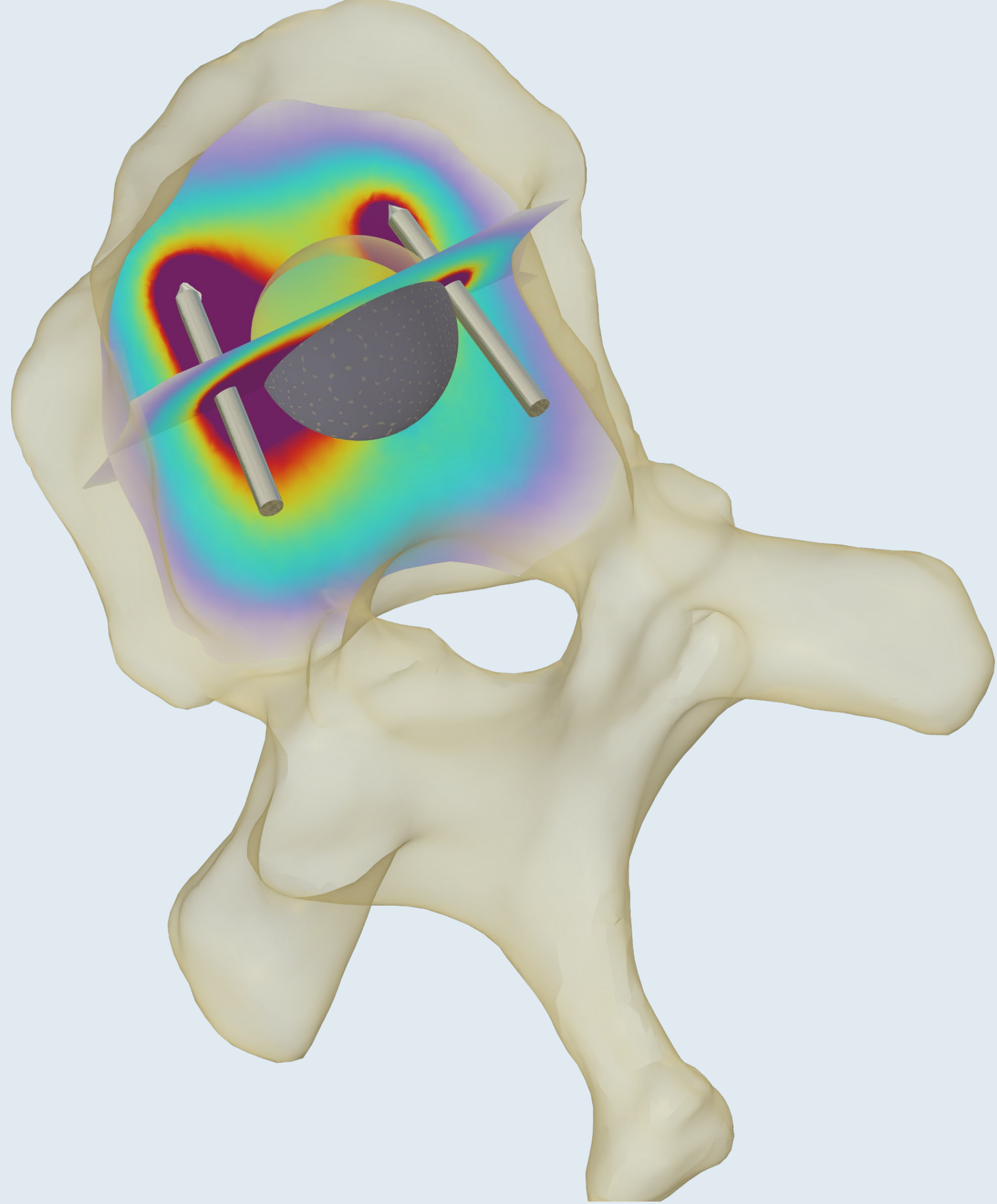




Optimization of Electrochemotherapy Treatment Parameters in 3D Anatomical Models

An iterative optimization framework for electrode placement using spatial electric field information in patient-specific vertebral models

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Background

Electrochemotherapy (ECT) combines chemotherapy with high-voltage electric pulses to enhance intracellular drug delivery. Successful treatment requires complete **tumor coverage with an electric field above the ECT threshold value**.¹

Electric field distribution **depends strongly on patient anatomy and electrode placement**, making treatment planning patient-specific. Current planning procedures rely on extensive operator experience and repeated manual simulations.

Objective: Develop an automated, simulation-driven framework for optimizing ECT treatment parameters in vertebral tumors by combining **COMSOL Multiphysics® simulations** with a **MATLAB® based decision-making algorithm**.²

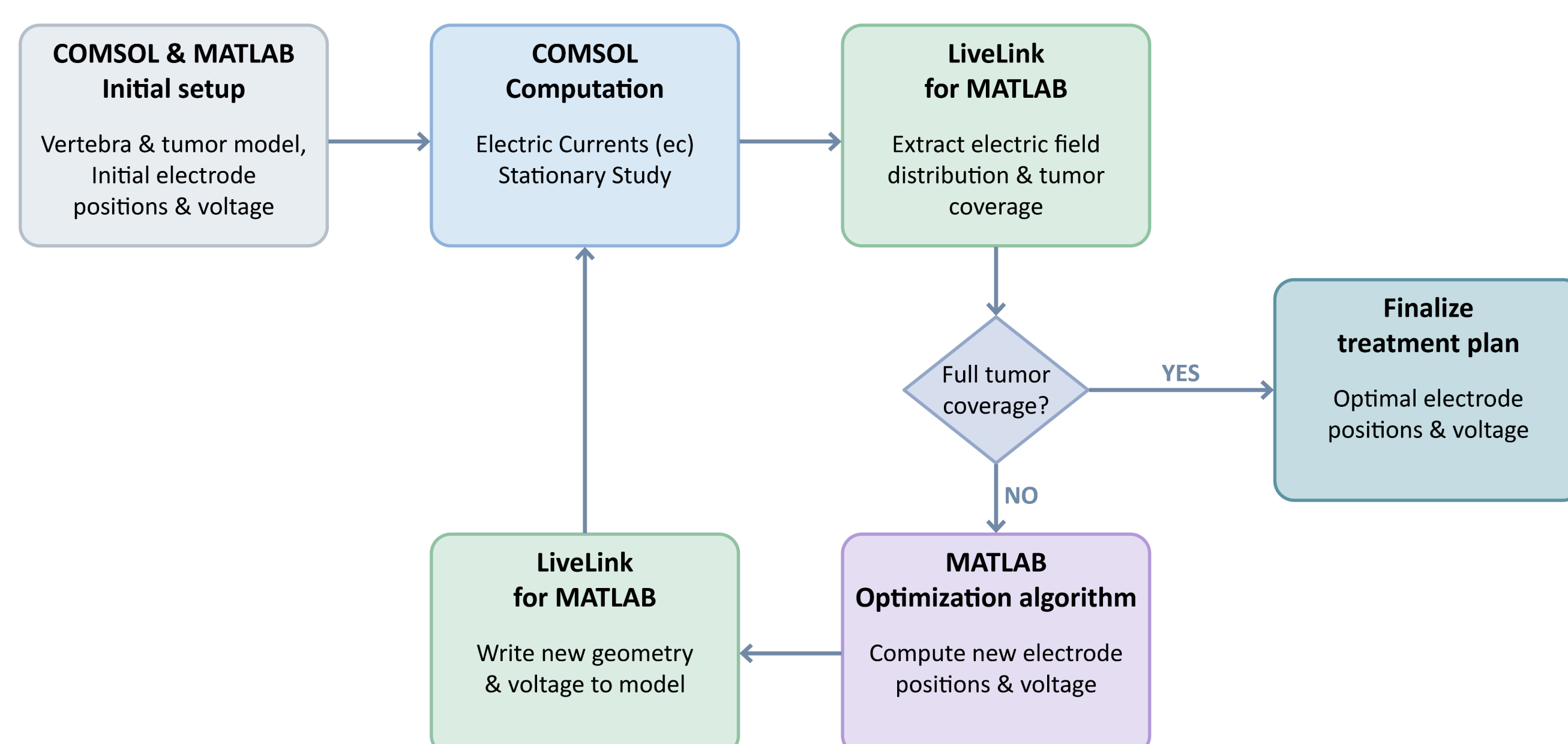


FIGURE 1: Closed-loop optimization framework. MATLAB® is coupled with COMSOL via LiveLink™ for MATLAB® to iteratively update electrode positions and voltage until full tumor coverage is reached.

Methodology

Patient-specific vertebral models were reconstructed from CT images and imported into COMSOL Multiphysics®. A spherical tumor, surrounding tissue, and needle electrodes were added, and the **electric field distribution was computed** for the initial electrode configuration.

The optimization algorithm was implemented in MATLAB® and coupled to COMSOL via LiveLink™ for MATLAB® (Figure 1). The algorithm analyzed the spatial distribution of the electric field, identified undertreated tumor regions, and computed corrective electrode displacements and voltage adjustments.

Electrode positions and pulse voltage were iteratively updated until **complete tumor coverage or hardware limits** were reached.

Results

The framework was evaluated on **108 patient-derived vertebral models**. Optimization converged in an average of **4.9 iterations** and required **71 s** on average per treatment plan.

Complete tumor coverage was achieved in most cases, with near-complete coverage in the remaining models after voltage adjustment.

Apart from the initial setup, the framework required **no manual interaction** during optimization.

By exploiting the **spatial information in the electric field solution** (Figure 2) to **guide electrode repositioning**, the framework avoided computationally intensive genetic algorithms, enabling fast optimization.²

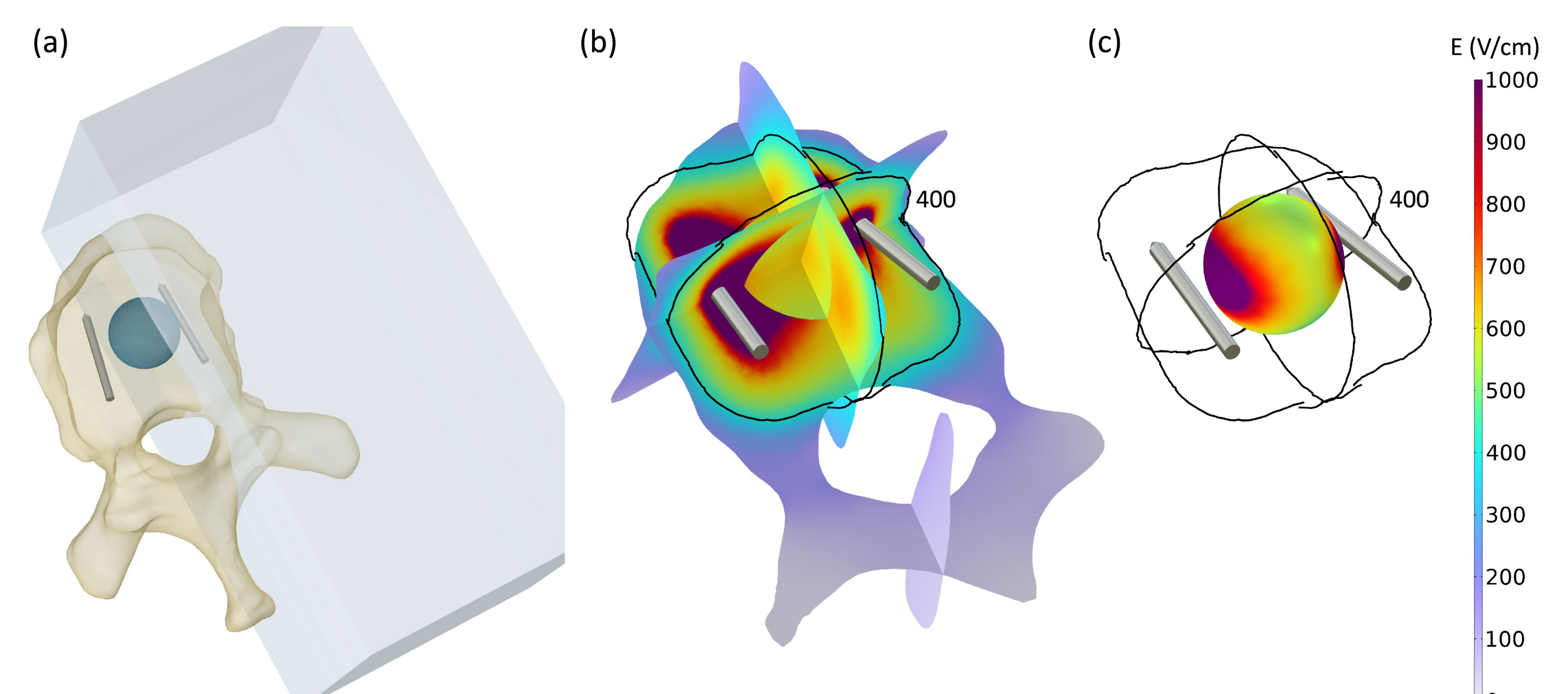


FIGURE 2: Model geometry (a), electric field distribution in the vertebra model (b), and in the tumor (c). The contours outline the tissue volume in which the electric field exceeds the selected ECT threshold (400 V/cm), indicating technical treatment success.

REFERENCES

¹ D. Miklavčič, et al. “Towards treatment planning and treatment of deep-seated solid tumors by electrochemotherapy”, *BioMed Eng OnLine*, vol. 9:10, 2010.

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