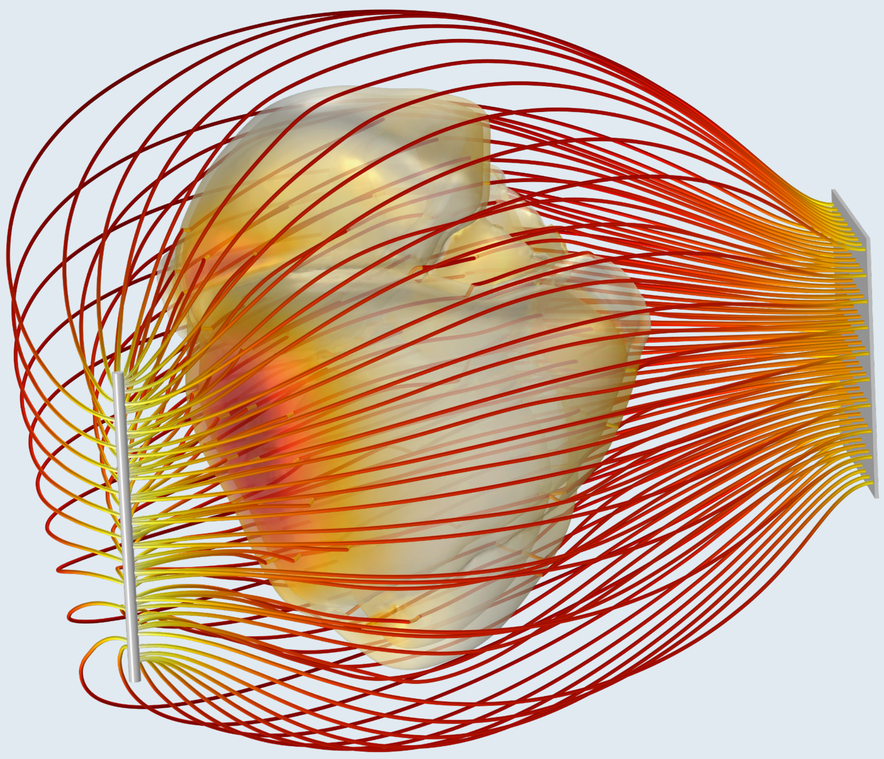


Electric Field Computation on Realistic Cardiac Geometries

From publicly available CT-derived meshes to realistic electric field simulations for defibrillation studies.

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Abstract

Computational studies of cardiac defibrillation currently utilize homogenous electric field distributions[1-3]. However, inside the heart, the electric field depends strongly on the underlying cardiac geometry and the configuration of the defibrillation electrodes. Computing this field on an anatomically realistic geometry, however, is non-trivial. The aim of this work is to demonstrate a pragmatic workflow in which COMSOL Multiphysics® is used to import a realistic four-chamber heart mesh, place realistic electrode patterns and compute the resulting electric field.

The workflow successfully reproduces the anatomically detailed heart geometry as a usable simulation domain and yields smooth, physically plausible electric field and current density distributions for the chosen electrode configurations. Our approach of using COMSOL Multiphysics® lowers the barrier to incorporating anatomically realistic geometries and electrode patterns into defibrillation research.

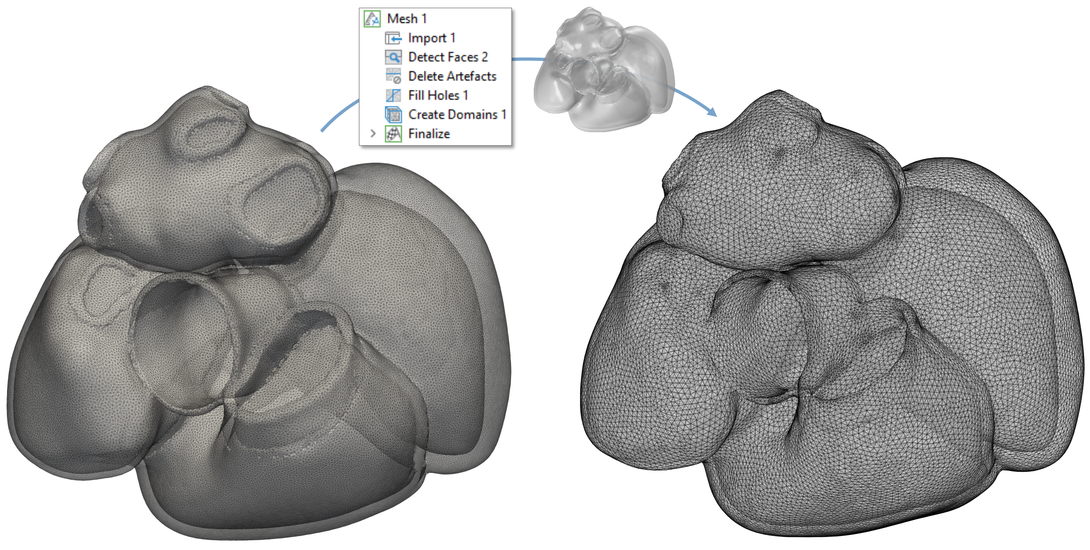


FIGURE 1. Original mesh (left) and COMSOL Multiphysics® created mesh (right) after importing and repairing an intermediate STL surface mesh.

Methodology

We use a heart geometry from a human CT-scan, which is publicly available[4]. A central challenge is that COMSOL Multiphysics® does not support the native *EnSight Gold Case* mesh format in which these geometries are distributed (see Fig. 1, left side). We therefore use ParaView to convert the mesh into the STL surface format, which COMSOL Multiphysics® can import directly. The CAD Import Module is used to repair the imported geometry so that a valid heart mesh domain is obtained (Fig. 1, right side). Via the Mesh Part functionality this domain can be used alongside the geometric modelling of the defibrillation electrodes in the Geometry node as well as for the Physics definition in the Electric Currents interface of the AC/DC Module for the computation of the electric potential, field, and current distribution throughout the cardiac tissue.

Results and Outlook

Figure 2 shows the computed norm of the electric field on the cardiac surface and in a cut-plane for the S-ICD-like electrode configuration shown in the title graphic. The field decays smoothly into the myocardial bulk, with no artifacts from the underlying mesh repair, indicating that the imported geometry is suitable for quantitative field analysis. For these preliminary simulations, thorax structures beyond the heart (lungs, ribs, subcutaneous fat) are omitted; adding their conductivities is a natural next step, since they are known to reshape the field outside the myocardium.

The exported field distribution serves directly as input for cardiac dynamics simulations[1,2], allowing us to test how electrode placement and shape affect defibrillation success on an anatomically realistic geometry.

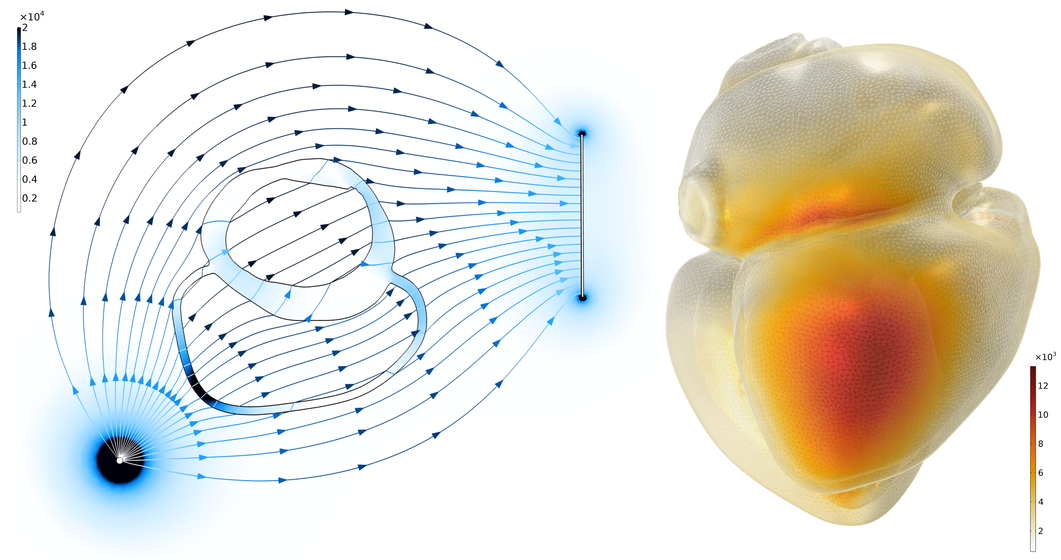


FIGURE 2. Norm of the electric field (V/m) in a cut-plane (right) and on the cardiac surface (left) for the electrode configuration shown in the title graphic. The semi-transparent rendering shows the field on the outer epicardial surface, with the inner endocardial surface visible through it.

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