The Effect of Finite Element Mesh Quality on Electrical Bidomain Simulations

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The simulation of electrical activity in the heart, such as normal and abnormal ventricular rhythms and ischemia, utilize computational methods that rely on an underlying geometric model, or polygonal mesh of cardiac tissues and boundaries. Because of the complex shape of many biological structures, it is often difficult to create meshes that conform to the boundaries between distinct regions. The resulting meshes can be non-conformal, ie., they have element faces that do not align with the surface tangents and the elements represent what is a smooth surface as a jagged boundary. We hypothesis that these jagged, non-conformal meshes produce local concentrations of current that lead to artifacts large enough to distort the resulting potential fields and generate misleading results. In simulations of acute ischemia, these artifacts can alter the location and severity of the epicardial elevations and depressions, which, in turn, can impact clinical diagnosis.

We used a bidomain simulation of ischemia to determine the effects of conformal versus non-conformal mesh boundaries on epicardial potentials. Within an anatomically correct heart geometry, we set elliptically shaped ischemic regions with elevated (30 mV) extracellular potentials. The ischemic regions were modeled using both conformal and non-conformal meshes.

Comparisons of epicardial potentials for both conformal and non-conformal meshes showed that when the ischemic region was located within 3 mm of the surface, there was greater than 200% difference in the resulting potential amplitudes. Although error decreased with distance from the epicardium, it always exceed 120%.

These results demonstrate that substantial errors in epicardial potentials from bidomain models can arise from jagged, non-conformal tissue boundaries in geometric models, underscoring the importance of geometric mesh quality in simulations of cardiac fields.