Comparison of Two Formulations for Computing Body Surface Potential Maps

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We want to compute QRS complexes from activation maps and a predefined shape for the transmembrane voltage v. In the context of ECGi, it would allow to directly reconstruct activation maps, without resorting to reconstruction and post-processing of cardiac electrical potentials. Here we compare two possible formulations to compute QRS complexes.

Several methods exist to simulate an ECG. Assuming that the transmembrane voltage v is given in the heart H, the electrical potential in the torso (extracardiac T and cardiac extracellular H) u may be retrieved following two approaches. Either it solves a Laplace equation with discontinuous conductivity coefficient (heart and torso) and ionic current as a source (source formulation (1)), specifically,

$$\begin{aligned} &-\operatorname{div}(\sigma_e \nabla u) = \partial_t v + f(v) && \text{in } H, \\ &-\operatorname{div}(\sigma_T \nabla u) = 0 && \text{in } T; \end{aligned} \tag{1}$$

or the quasi-stationary electrical balance between the intra and extracellular fields (balance formulation (2)), specifically

$$\begin{aligned} &-\operatorname{div}(\sigma_e \nabla u) - \operatorname{div}(\sigma_i \nabla (u+v)) = 0 && \text{in } H, \\ &-\operatorname{div}(\sigma_T \nabla u) = 0 && \text{in } T. \end{aligned} \tag{2}$$

Commonly, the potential u is computed from the balance formulation. Anyway, we may also use the source formulation. Note that both formulations coincide only if v solves the complete bidomain equations. We compute reference activation maps and QRS complexes with a bidomain code. Afterwards the electrical field u is also calculated from the activation maps and a predefined v (and ionic model $f(v)$), using the two different formulations.

We compare the potential fields u and the QRS complexes obtained by these two methods to the reference ones. Preliminary results show some significant differences between the two methods, with a better accuracy for the most popular balance formulation (2), for a smoothed heaviside form of v.