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Strength – Interval Curves using a Minimal Ionic Model and the Bidomain Model

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Abstract

The complex behavior of cardiac tissue when stimulated by an electrode has been studied using different models over the years. These models have varying degrees of complexity with different numbers of variables, parameters and ion currents. Each model has its own strengths and weaknesses. Some of these models have large number of variables making it difficult to identify how each variable effects the action potential (AP), the action potential (APD) duration, and the excitation threshold. Other models have fewer number of variables but may not produce realistic results. The strength-interval (SI) curve plays a major role in understanding how the cardiac tissue responds to an electrical stimulus. The complex behavior of cardiac tissue has been previously studied using the bidomain model with the Beeler-Reuter model and the Luo-Rudy dynamic model. Strength-interval curves obtained in both these studies show similar results for both cathodal and anodal stimulations.

The focus of this study is a recently developed minimal ionic model with fewer variables and parameters and only two ion currents, a sodium current that activates rapidly upon depolarization I_{Na}, and a time-independent inwardly rectifying repolarization current I_{rep}. The minimal model reproduces many experimentally measured human ventricular APs and combined with the bidomain model produces SI curves that are similar in shape to the previous studies. Even this simplest of ion current models produces the distinctive dip in the anodal SI curve and predicts the transition of excitation from break to make in both cathodal and anodal SI curves, implying that the bidomain nature of the tissue is crucial to the tissue excitability. A simple model with an excitable sodium current and a non-linear repolarization current with the bidomain model is sufficient to predict the dip in the anodal SI curve.