A Mathematical Model of Atrioventricular Node during Atrial Fibrillation

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During atrial fibrillation (AF), a high number of atrial impulses bombard the atrioventricular (AV) node, that, acting as a filter, blocks some of them. Some models of the AV node during AF have been proposed, but all of them have certain limitations. The aim of this study is to present an AV node model which can be used on short-term surface ECGs to estimate AV node characteristics. The proposed AV node model is characterized by: the arrival rate of atrial impulses; two different refractory periods, corresponding to dual AV nodal paths; the probability of an atrial impulse choosing either of these pathways; a parameter modeling prolongation of the refractory period due to different physiological reasons. Atrial impulses are assumed to arrive to the AV node according to a Poisson process with a mean arrival rate, estimated by the AF frequency obtained from the surface ECG. Each atrial impulse is supra-threshold, i.e., it results in a ventricular contraction, unless it is blocked. The atrial impulses are blocked at the AV node according to a time dependent probability, which models the prolongation of the refractory period due to relative refractory period and concealed conduction. The smaller functional refractory period is obtained from the lower envelope of the Poincaré plot of the RR series; the other parameters of the model are obtained from the RR series by mean of maximum likelihood estimation. The model was tested on simulated signals (where convergence velocity was assessed) and on ECGs of 33 patients with AF. The average normalized absolute error between the normalized RR histogram and the estimated model probability density function (PDF), computed for bins of 20 ms size spaced between 0 and 2 s, was 0.0023 + 0.0016. These preliminary results are encouraging as AV nodal properties can be noninvasively assessed by a set of statistical parameters with a simple electrophysiological interpretation.