Effect of Physiological Changes in Heart Rate Turbulence using a Lumped Parameter Model

Óscar Barquero-Pérez, Inmaculada Mora-Jiménez, Rebeca Goya-Esteban, Julio Ramiro-Bargueño, Arcadi García-Alberola and José Luis Rojo-Álvarez*

Signal Theory and Communications, Universidad Rey Juan Carlos, Fuenlabrada, Madrid, Spain

Heart Rate Turbulence (HRT) is a strong risk stratification criterion in patients with cardiac disorders. Several physiological factors affect HRT, e.g, heart rate, circadian rhythm, prematurity. However, the relationship between these factors and HRT still needs to be further clarified. We propose to use a modified version of a detailed lumped parameter model, capable of handling the generation of ectopic beats and the subsequent hemodynamic regulation, to study the relationship between different physiological factors and the HRT. We started from the detailed model of cardiac regulation previously developed by Ursino and Magosso. Unlike previous models using time-counters and electrical description, we modified ventricle activation function phi [1 maximum contraction, 0 complete relaxation], in order to generate the hemodynamic effect of ectopic beats. We described the ectopic beat with three parameters: complementary prematurity CP (percentage of the original rr-interval), maximum contraction (MC), and systole duration (Tsys, sec).

In order to characterize the relationship between the HRT and phi parameters, we computed TS and TO parameters for three different combinations among them: (1)MC=0.5, Tsys = 0.3 sec, and CP=[10,20,30,40,50]%; (2)MC = 0.5, P=20%, and Tsys = [0.1, 0.2, 0.3, 0.4, 0.5]; (3)Tsys=0.3, P=20%, MC=[0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7]. HRT was reduced as CP increased: TS=[75.3, 72.4, 70.6, 69.8, 68.9]ms/beat, and TO=[-22.8, -21.3, -20, -18.9, -17.9]. Increasing Tsys yielded a reduction in HRT pattern: TS=[89.0, 79.4, 72.4, 67.3, 64.2]ms/beat, and TO=[-26.1, -23.4, -21.3, -19.7, -18.4]. Finally, increasing MC of the ventricle activation also yielded a reduction in HRT pattern: TS=[104.1, 106.4, 100.1, 86.2, 72.4, 60.6, 51.1]ms/beat, and TO=[-30.4, -30.2, -28.2, -24.6, -21.3, -18.4, -15.9]. Nevertheless, a general trend could be observed to TS and TO being slightly larger than those reported in the literature. Relationships between different physiological factors and HRT can be analyzed by using a detailed lumper parameter model of cardiac regulation, by including the hemodynamic effect of ectopic beats. Changes in prematurity, systole duration and contraction, modify the resulting HRT pattern. This issue should be taken into account when quantifying it by TS and TO parameters.