Study of Cardiac Activity due to Variability in the Action Potential in Isolated Mice Heart

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In this study, mice hearts are isolated and electrically stimulated with electrical train pulses with additive white noise in order to analyze the cardiac response due to inherent variability in the cardiac action potential. Our results show that with the presence of variability induced in the stimulus, the range in which the heart rate responses appropriately to stimuli increases and the fibrillation threshold is displacing up to high frequencies, compared with stimulus without variability induced. This is due to a phenomenon known as stochastic resonance.

***Keywords*: Isolated heart, pacing heart, variability, stochastic resonance.**

I. Introduction

For the heart to perform its biological functions two phenomena of different nature are carried out. One is an electric type in which the plasma membrane of pacemaker cells are depolarized in order to transmit the impulse. Following an electrical stimulus there is a mechanical response in which the heart contracts ejecting blood into tissues and subsequently relaxes [1]. Under normal conditions there is a synchronization between these two phenomena. However, this synchronization is lost at high heart rate levels where some pathologies are presented, as is the case of fibrillation. Electrical stimulation also known as cardiac action potential, has some inherent variability in biological systems because it is the average of an inward-outward flow of various ions (mainly Na, K and Ca) in the cell [2][3]. Although the heart is an autonomous system because is capable of stimulating himself, its rhythmicity can be altered by contact with other systems, including the renin-angiotensin system, respiratory system and endocrine system, also affecting the cardiac response in frequency and contraction force. Therefore, to develop a study of the variability in the cardiac action potential, is necessary the heart isolation.

II. Methodologies and Results

For this study we used CD1 male mice weighing approximately 30 to 40g [4]. The isolated hearts were retrogradely perfused with Krebs Solution, oxygenated with Ph equal to 7.4 at a flow rate of 3 ml/min and a temperature of 37°C in the Langendorff Percussion System [5]. For electrical pacing, electrical train pulses are generated from a model developed in LabView® where it is possible to control the amplitude (200mV), frequency (6-20Hz) and the intensity of additive white noise to the signal. This signal is then transmitted directly to the isolated heart through two platinum electrodes placed superficially on the right atrium. For measurement of cardiac response (contraction force and frequency), a tensiometer is connected by a pulley to the heart apex. To monitor the current state of the heart, a pressure transducer (60-110mmHg) is used. All data are analized in MatLab®.

The results show (for n=8) that without variability induced in the electrical pacing, only a few hearts follows the rhythmicity imposed at 6Hz. This is because the basal average frequency is 6.33Hz. However, from 7 to 11 Hz linear response between stimulus and response is showed, so there is a synchronization between the electrical stimulus and the mechanical event. This synchronization is lost at 12Hz, which represents the fibrillation threshold and this desynchronization continues to 20Hz. On the other hand, for electrical stimulation with variability of 10% respect with the original signal, it is observed that most of the hearts follows the rhythmicity imposed from 6Hz maintaining synchronization till 12Hz, displacing the fibrillation threshold to 13Hz and, in fibrillation stage of 13 to 19Hz an almost linear behavior is observed although less efficiently. Finally, for an electrical stimulation with 30% of variability, a linear behavior at high frequencies, (between 13 and 16Hz) is observed.

III. Conclusion

The results so far obtained, allow us to determine that variability induced in the electrical pacing affects heart response. This is due to the presence of a phenomenon known as Stochastic Resonance.

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