2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

Computational Study of the Funny Current on the Regulation of Heart Rate

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***Abstract*—A cardiac pacemaker cell was modeled through the use of MATLAB. Modifications to the individual parameters of the model were studied and it was subsequently determined that the funny current directly affected the frequency of the action potential wave, ultimately impacting the calculated heart rate.**

***Clinical Relevance*— Understanding the significance and correlation of abnormalities seen during the repolarization phase of a cardiac pacemaker cell action potential and arrhythmias.**

I. INTRODUCTION

The sinoatrial node (SAN), located in the wall of the right atrium, regulates the generation of repetitive spontaneous action potentials for cardiac rhythmic contractions in pacemaker cells. SAN myocytes are differentiated by the occurrence of a slow diastolic depolarization phase of the action potential which ultimately increases until it reaches the firing threshold for a new SAN action potential [1]. The activation of the funny current (I_f), a mixed sodium and potassium inward current, during the diastolic depolarization phase is thought to be responsible for rhythmic pacemaker activity and controlling heart rate [2]. An increase in studies have been focused on the relationship of repolarization abnormalities, including the ionic basis of irregular prolongation of the action potential duration and the presence of arrhythmias [3].

II. METHODS

A MATLAB model of a cardiac pacemaker cell was generated by a modification method produced by Noble to accurately depict an action potential in a cardiac pacemaker cell. The only qualitative difference between the Hodgkin-Huxley model and the one generated by Noble is that the potassium current is presumed to flow through two non-linear resistors that are in series with a potassium battery [4].

III. RESULTS

A MATLAB model incorporating the equations developed by the Hodgkin-Huxley model and the proposed modifications made by Noble was implemented and the generated action potential simulation of a cardiac pacemaker cell is represented in Fig. 1.

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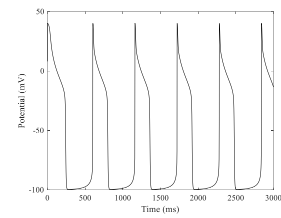

Figure 1. MATLAB generated time profile of the membrane action potential of a cardiac pacemaker cell.

By varying the values of the voltage of the leak channel, which is used to calculate I_f, a range of optimal heart rates was determined and is represented in Fig. 2.

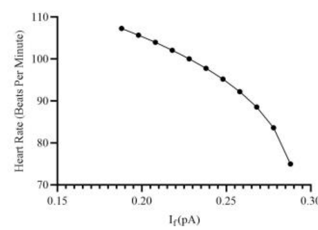

Figure 2. The effects of the variation of I_f upon heart rate determined by MATLAB modeled action potential of cardiac pacemaker cell.

IV. DISCUSSION & CONCLUSION

The combined behavior of the pacemaker cell and I_f was examined through the use of the developed model. The effects caused by modifications to the individual constants were tested and the results were comparable to the data compiled by Verkerk and Wilders [5]. It was determined that I_f directly affected the frequency of the action potential wave and subsequently affected the calculated heart rate.

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