Molecular Communications for cardiomyocytes

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***Abstract*— The continued miniaturization of electronics makes it realistic to monitor internal cardiac disease processes by wireless implantable medical sensors and actuators incorporated in implantable cardiac devices. In order to deal with some cardiac diseases, this paper introduces the molecular communication methods for cardiac muscle cell communications.**

I. INTRODUCTION

In recent years, cardiovascular diseases have led to high morbidity and mortality, and have become one of the main causes of death worldwide. Some heart diseases are mainly affected by the malfunction of heart conduction system, such as the heart arrhythmia. Embedding tiny devices, like leadless pacemaker, into the body can monitor and cure these kinds of heart diseases.

Moreover, with the development of nanotechnology, single nanomachine can perform a simple specific task at nano-level e.g. communicating, computing, data storing, sensing and/or actuation. Nanoscale communication approaches, especially molecular communications, can be utilized to study how the action potential change in nanoscale level and make the heart beat normally.

II. HEART CONDUCTION SYSTEM

The origin of the electrical activity of the heart is normally in the Sinoatrial (SA) node, which is a node of specialized myocytes that initiate a synchronised electrical impulse. The SA node is also known as the natural pacemaker. The electrical activity of the SA node spreads to the right and left atria, depolarising the atria of the heart and causing them to contract subsequently to optimise cardiac performance. The impulse then spreads to the ventricles through the Atrioventricular (AV) node and the right and left bundle branches, causing the ventricles to rapidly depolarise and contract instantaneously as the atria depolarise and relax.

III. MOLECULAR COMMUNICATION OF HEART

Cells in human body use ions, proteins and enzymes to communicate through gap junctions. And cell communication in heart plays an important role for a healthy heart. In [1], the authors have studied the cell communications in the heart, whereas in [2], cardiac ion channel is proposed, which helps researchers to have a better knowledge of the cardiac ion channels. In [3], the authors analyzed the significance of cardiac ion channels in both inherited and acquired heart diseases.

All these research work laid a good foundation for us to investigate the molecular communication with pacemakers. Recently, Kilinc and Akan [4] have studied the feasibility of the communication between cardiomyocytes, and also introduced information theory tools to analyze their communications from the aspect of molecular communication, which will provide physicians a good approach for investigation, prediction, diagnosis and treatment of several cardiac diseases in nanomedicine field. Moreover, Barros et al[5] analyzed three specific cell types that utilize Ca^{2+} signaling: epithelium cells, smooth muscle cells and astrocytes, and proved that Ca2+ plays an important in the excitable cells. As heart muscle cells are the excitable cells, the same approaches can be used to analyze the communication among heart muscles. All these work proved that the molecular communication methods can be useful to study how the heart contracts.

IV. CONCLUSION

This paper briefly reviewed research topics and aspects related to molecular communications for heart cells. The cardiac conduction system was introduced with an explanation on ion channels and electrical pulse generation and transmission which leads to the heart contraction and pumping. Combining the molecular signaling, ions for electric pulse transmission in fibers, and nanoscale wireless technology could lead to a paradigm shift in designing and develop the next generation heart pacemakers.

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