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An implantable radio-telemetry system for detecting multiple bio-parameters of a small animal based on wireless energy transmission

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ABSTRACT

Background and problem: The bio-parameters such as the blood pressure, the core body temperature and the biopotential are very important clinical clues to evaluate the physiological and psychological conditions of an animal. And these bio-parameters are also important for other clinical application. However, it is difficult to get the bio-parameters of a small animal for the long term under its normal state. It is a challenge for researchers to propose a method to acquire the bio-parameters of a small animal for the long term under its normal state. *Method*: This paper proposes an implantable radio-telemetry system to simultaneously detect long term blood pressure, temperature and biopotential of a small animal under its normal state. This system comprises an implantable capsule, a data logger and wireless energy transmission system. Three sensors are integrated into the implantable capsule. A pressure sensor is designed to detect the blood pressure, a temperature sensor to detect the inside body temperature, two tiny soft silver wires as the third sensor to detect the biopotential. The analog outputs of the three sensors are conditioned by their respective amplifiers. The three amplified bio-parameters are digitalized by an AD7683 (a 16-bit, charge redistribution, successive approximation, PulSAR analog-to-digital converter). Microprocessor PIC16F690 reads the digital data and sends it out of the animal's body through a wireless communication chip. A data logger can receive the data and save it with time stamps into a SD card. The data in the SD card can be processed with a computer. Curves of three bio-parameters can be used for evaluating physiological and psychological conditions of the animal. Wireless energy transmission system provides energy to the implantable capsule under the animal's normal conditions. A 3D secondary coil of the wireless energy transmission system enables itself to receive enough energy in an arbitrary position and posture. *Results*: In vivo experiment results show that the implantable radio-telemetry system can detect the blood, the temperature and biopotential of a rabbit. It meets the expected requirements.

1. Introduction

The bio-parameters such as the blood pressure, the core body temperature and the biopotential are very important clinical clues to evaluate the physiological and psychological conditions of an animal. These bio-parameters are also crucial clues for evaluating the effects of some new medicines in animal's clinical trials before these medicines are applied to human finally. However, it is very difficult to detect long term bio-parameters of animals under its normal condition. Numerous research work and efforts have been made to acquire long term bio-parameters of animals under its normal condition. Peng [1,2] and Young [3] proposed a microsystem for measuring the blood pressure of a laboratory mouse. This microsystem was powered by an external RF power source in a batteryless manner. An implantable device could measure the blood pressure of a mouse for the long term. However, this microsystem can only detect the blood pressure. It cannot detect the core body temperature and the biopotential at the same time. Park [4] developed a cuffless and noninvasive measurement technique of blood pressure using nanometric pressure sensor. The authors figured out MAP (Mean Arterial Pressure) based on the physiological characteristic including the elasticity of wrist tissue and the depth of blood vessel. However, this method was also only designed to get blood pressure. There are many other researches on the blood pressure acquiring [5–8]. These methods are also only designed for blood pressure acquiring at the same time. Nag [9]

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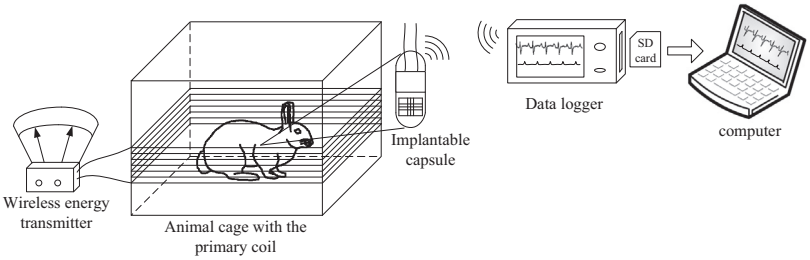

Fig. 1. Overview of the implantable radio-telemetry system.

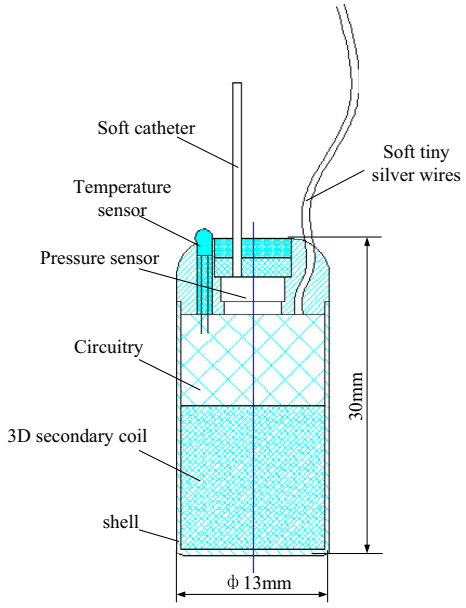

Fig. 2. Structure of the implantable capsule.

presented an e-jacket of a smart clothing system with multiple bio-parameter acquisition of electrocardiogram (ECG), pulse oximetry, body motion/tilt and skin temperature. This method could acquire the multiple bio-parameters at the same time. It is obvious that the e-jacket cannot be used in animal experiments. Risstamma [10] proposed an implantable wireless, inductively powered ECG-monitoring device. However, this device could only detect ECG, and cannot detect the blood pressure and the core body temperature. Tomasic [11] measured the charge generated due to triboelectric effect between one of the lead conductors and the inserted stylet. In order to get enough power from wireless energy transmitting system, Wenhui [12] developed a three-dimensional receiving coil. By the aid of this receiving coil, the secondary coil can get enough power in a random position. RamRakhyani [13] discussed thoroughly resonance-based wireless power delivery systems for biomedical implants. Wireless power delivery is an efficient technology to be used in biomedical implants. Russel [14] proposed a prototype of a wireless power delivery system for mouse telemeter. Four overlapped planar primary coil is designed to transmit energy to the pickup. The primary coil is driven by a full bridge series resonant inverter. This system can enable the pickup to receive the minimal power up to 20 mW. Dissanayake [15] proposed a transcutaneous energy transmission (TET) system for an implantable biomedical device. Temperature rise was considered in the TET system. The results of sheep studies showed that the efficiency of TET system was up to 82.1% and a temperature rise was up to 2.7 °C. Si [16] proposed a method to regulate the power transferred over a wireless link by adjusting the resonant operating frequency of the primary converter. This method is important on condition that the load, coupling and circuit parameters of the secondary coil are variable. Dowling [17] proposed the vivo experiment of the AbioCor Implantable Replacement Heart powered by TET system. Experiment results showed that the device worked normally. The TET system could provide energy to the implantable artificial heart. Patents [18–22] involve inventions about the transcutaneous energy transmission system for artificial heart. All the above research work and efforts prove that wireless energy transmission system is widely used in implantable biomedical devices. In this paper, wireless energy transmission system is also designed to provide energy to the implantable radio-telemetry system.

This paper develops an implantable radio-telemetry system without the aforementioned disadvantages. The system is composed of an implantable capsule, a data logger and wireless energy transmission system. The implantable capsule is designed to be implanted into an animal's body. It detects three bio-parameters of the animal simultaneously and sends the acquired bio-parameters data out of the animal body through wireless communication. The data logger can receive and save the data into an SD card. The data can be read and curves of three bio-parameters can be drawn for evaluating the animal's physiological and psychological conditions. Wireless energy transmission system can provide enough

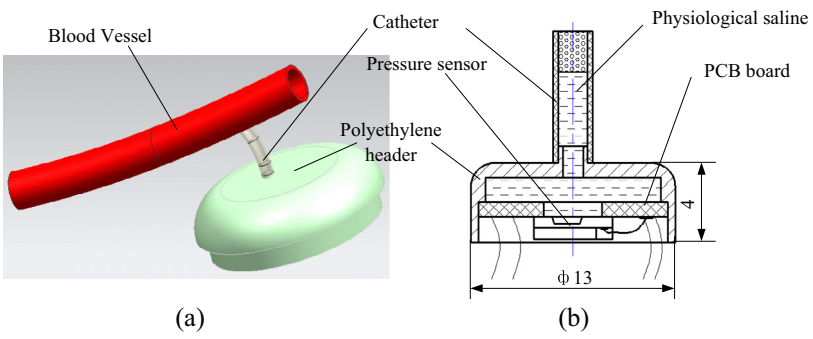

Fig. 3. Schematic of the pressure sensor and the detailed structure of the pressure sensor. (a) 3D structure of pressure sensor and (b) detail structure of pressure sensor.