8-Patient ECG Telemetry System Intended for Cardiac Rehab

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Abstract— **Cardiac rehabilitation helps heart patients recover quickly and improve their overall physical and mental functioning. A critical component of every cardiac rehab program is the monitoring of the patient's ECG signal during exercise. The detection and classification of ECG arrhythmias are of great importance in evaluating and predicting life threatening ventricular arrhythmias. This paper introduces an 8-patient low-power short-range real-time ECG telemetry system developed to provide support for cardiac rehab programs. The developed monitoring system has recently been fully deployed in operation. Both the possibility of assessing the patient's condition on a continuing basis and the self-triggered built-in alarms enable an increase in boldness in the management of heart patients to determine their optimal training pulse range for cardiovascular fitness.**

Keywords— **digital signal processing, ECG telemetry, cardiac rehab**

I. Introduction

Cardiovascular disorders are the top cause of death [1]. An aging population presents both opportunities and challenges to meet the increasing demand for cardiac rehab.

Cardiac rehab is a medically supervised program to help heart patients manage their condition, improve their health and recover their quality of life after having experienced a cardiac event.

Many benefits are observed in patients undergoing cardiac rehabilitation exercise training. This beneficial outcome has been widely reported [2, 3].

A critical component of every cardiac rehab program is the monitoring of the patient's ECG signal during exercise.

The rationale for ECG monitoring is the immediate recognition of relevant cardiac arrhythmias, allowing prompt appropriate treatment [4].

The detection and classification of ECG arrhythmias are of great importance in evaluating and predicting life threatening ventricular arrhythmias. For such purpose, simple as well as sophisticated algorithms exploiting different classification strategies have been proposed [5, 6].

An 8-patient low-power short-range real-time ECG telemetry system has been developed to provide rehab programs with monitoring capabilities.

II. The System

A. The approach

The developed system is a PC based solution for monitoring ECG patients connected to a telemetry transmitter.

It consists of three main components: the ECG telemetry transmitters, the receivers and the central station running the software application. Fig. 1 shows a perspective view of the first half of the developed ECG monitoring system.

The transmitter acquires and digitizes the patient's ECG signal. It is attached to a belt aimed to be worn around the patient's chest. The digital data is sent out to the central station using wireless radiofrequency communication.

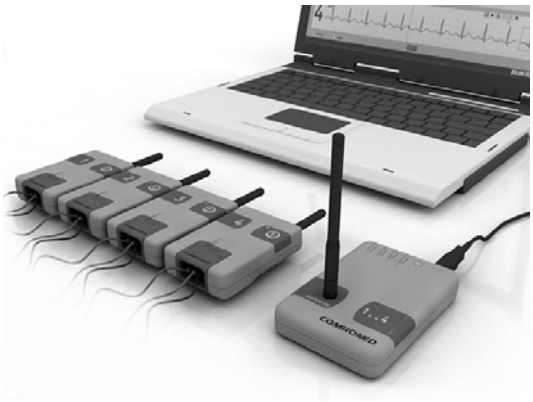

Fig. 1 Perspective view of the first half of the developed system

Fig. 2 Belt for attaching the ECG telemetry transmitter

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Receivers receive the data containing the ECG waveforms sent by the transmitters and pass it to the central station with most error control overhead removed. The central station may have up to 2 receivers installed.

The software application running on the central station retrieves the data from the receivers and performs rate and ST analysis on the signals. The results of the analysis can trigger audiovisual alarms.

It also displays and stores the real-time ECG waveforms, measurement data and alarms for all patients performing exercises. The waveforms and stored data can be reviewed and printed at any time.

The software application can simultaneously retrieve, display and analyze the ECG signal for up to 8 patients.

A belt for attaching the ECG telemetry transmitter was also developed so that patients under supervision can be conveniently monitored while moving around. Fig. 2 shows the developed belt.

Patients are deliberately identified by numbers to help cardiac rehab professionals keep track of them. This efficient patient identification strategy is based on the way in which athletes are identified.

B. The hardware

The transmitter analogue circuitry consists of an ECG preamplifier, a right-leg-drive, low and high pass filters, and a final gain stage. It is completely designed with low-power IC chips.

The radio modules of the system are based on the popular TI CC1000 transceiver [7]. Careful component placement during board layout was required to ensure optimal RF performance. The RF link enabling telemetry operates in the European 433 MHz unlicensed ISM band.

The TI MSP430F147 microcontroller [8] performs all the control functions in the telemetry transmitter. The patient's ECG signal is captured at a clinical sampling rate of 125 Hz by the ADC on the microcontroller. The transmitter stores the ECG samples in the TX ring buffer and sends the RF packet only when it is full to minimize power consumption.

The transmitter is fitted with a reduced-height helical antenna to avoid the typical mistuning caused by the influence that the human body has on the field strength of a body-worn transmitter [9, 10]. Therefore, it has been necessary to plate the inner surface of the transmitter enclosure to provide both good RF interference suppression and low noise amplification.

The transmitter measures 105 mm (L) x 70 mm (W) x 25 mm (H) and weighs nearly 150 g (including batteries). It consumes approximately 15 mA.

Powered by two 900 mAh 1.2 V NiMH AAA rechargeable batteries it achieves an overall operating lifetime of several working days.

Its data rate and RF range are 9.6 kbps and 30 m, respectively.

The receiver takes its supply from the 5 V on the USB bus. It combines two TI MSP430F147 microcontrollers to receive and process the data sent by the transmitters.

The receiver relies on the FTDI FT245R USB FIFO Interface IC [11] to handle all the somewhat complex details of transferring data to the central station through the USB bus.

It measures 135 mm (L) x 90 mm (W) x 20 mm (H) and weighs less than 200 g.

C. The application software

The application software can display at once the real-time ECG signal for up to 8 monitored patients on either 1 or 2 monitor screens.

The patient's heart rate and ST deviation are measured using an adaptive threshold algorithm.

Premature ventricular contractions are classified according to diverse criteria such as the degree of prematurity, the presence of the compensatory pause, the duration of the QRS complex and the degree of correlation with a representative QRS complex.

Specific alarms are triggered whenever any relevant measured value exceeds a preset limit.

The application software manages a patient information database that can be used to carry out research.

III. Results

The developed monitoring system has been fully deployed in operation at the Rehab Center of the Cardiology Institute of Havana since July 2008.

IV. Conclusions

Both the possibility of assessing the patient's condition on a continuing basis and the self-triggered built-in alarms enable an increase in boldness in the management of heart patients to determine their optimal training pulse range for cardiovascular fitness.

This flexible and cost-effective ECG telemetry solution helps cardiac rehab professionals to do their job faster and easier. It also lets cardiac rehab programs become more creative and practical.

The developed monitoring system is in compliance with safety standards and is therefore safe and effective for the intended use.

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