Unconstrained physiological monitoring in daily living for health care

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Abstract—This paper deals with the recent development of two types of non-invasive physiological monitoring systems for possible application in an unconstrained manner to normal subjects for health care as well as to patients and/or outpatients with disorders or with life support systems (artificial organs and organ transplantations). One is an ambulatory monitoring system which allows automatic acquisition of blood pressure, cardiac output and other cardiovascular hemodynamic parameters on a beat-by-beat basis using the volume-compensation and transthoracic electrical admittance method. The other is a home monitoring system installed in a lavatory which can measure body and excreta weight together with the ballistocardiogram as an index of cardiac ejecting function in an unaware fashion without attachment of any sensors to the subject’s body and without special operations for measurement during toilet use. Outlines of these two systems and monitoring results of laboratory and field testings are presented, and these suggest that the ambulatory and non-conscious physiological monitoring techniques described herein appear promising as a valuable and helpful means for use in research as well as in the practical field of health monitoring at home during daily living.

Key words: Unconstrained physiological monitoring; ambulatory and non-conscious monitoring; home health care; health monitoring; volume-compensation method; electrical admittance plethysmography; beat-by-beat cardiovascular variables; body and excreta weight; ballistocardiogram.

1. INTRODUCTION

The requirement for home health care or health monitoring has been increasingly raised as an effective scheme for early diagnosis and treatment of cardiovascular and other diseases, and for the prevention and control of such diseases in adults, as well as for the reduction of medical expenses. It is also expected to perform monitoring of the health condition of a patient and/or outpatient subjected to life support systems, such as artificial organs and organs transplantats, which have been available more and more for long-term use due to recent advances of medical, biomechanical and electronic technologies as well as of new biomaterial developments. Non-invasive techniques would be most desirable for this monitoring. Since a sub-
ject is usually allowed to perform activities of daily life, ambulatory or unaware (or non-conscious) physiological monitoring techniques should be introduced from the viewpoint of not causing any inconvenience and disturbance, i.e. in an unconstrained manner.

In terms of ambulatory monitoring, a Holter-type electrocardiogram (ECG) recorder, originally proposed by Holter [1], as well as a portable sphygmomanometer, based on the auscultation and/or cuff-oscillometric method [2], are well known as key devices widely used in clinical medicine. We have also concentrated on developing ambulatory monitoring systems, focussing on the design for clinical as well as home use, which can measure blood pressure (BP) at a desired interval [3] and on a beat-by-beat basis [4] using, respectively, the volume-oscillometric [5] and volume-compensation method [6], and can measure cardiovascular hemodynamic variables including BP and cardiac output (CO) on an intermittent basis [7] using a combination of the volume-oscillometric and electrical admittance method [8]. It is obvious that acquisition of beat-by-beat BP and CO together with the other cardiovascular data would be much more significant in order to analyze in detail hemodynamic responses as well as autonomic regulation of the cardiovascular system following various kinds of daily activities. Such a portable instrument, however, has never been designed until now.

The concept of non-conscious physiological monitoring is based on the fact that it would be better if the monitoring could be done in a fully automated manner without the attachment of any biological sensors to the subject’s body and any troublesome operations of measurement. Thus, the subject does not need to be aware of the measurement and the physiological data can be stored during ordinary daily living. With this in view, we note the studies by several investigators who developed methods to record ECGs in the bathtub and on the toilet seat [9], and temperature distribution [10] and cardiopulmonary function in the bed [11], all of these being regularly encountered in daily life.

In recognition of the importance of such physiological monitoring for home health care, the present study concerns our recent attempts to develop two types of systems for (i) ambulatory and simultaneous monitoring of various cardiovascular hemodynamic parameters including BP and CO on a beat-by-beat basis using the volume-compensation and electrical admittance method, and (ii) non-conscious physiological monitoring of body and excreta weight together with the ballistocardiogram (BCG) as an index of cardiac ejecting function using a highly accurate weight measuring device installed in a lavatory floor around a toilet bowl. This paper describes the outlines of these two systems as well as preliminary results. The usefulness and limitation of these techniques for home health care are also discussed.

2. MATERIALS AND METHODS

2.1. Ambulatory beat-by-beat cardiovascular monitoring system (ABCAM system)

2.1.1. Description of the ABCAM system