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Computer based real time systems for analyzing cardiovascular response to orthostatic stress

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ABSTRACT

The cardiovascular response to orthostatic (gravitational) stress has been the focus of several researches in the past. Average values of hemodynamic variables, such as arterial pressure or heart rate are recorded during changes in posture for diagnosing orthostatic stress clinically. Different methods based on varied physical principles have been developed to measure these hemodynamic variables. Carotid artery is responsible for direction of blood flow to brain and provides a vital physiological parameter which can be used to construe cardiac information. A noninvasive system has been built in which a piezoelectric sensor is positioned on the carotid artery of the subject and carotid signals of fifteen human subjects are acquired in various body postures using application softwares. RR intervals and pulse amplitudes are computed after filtering and analyzing the carotid signal recordings using these softwares. The developed system is validated by determining the percentage change in RR interval and pulse amplitude of all the subjects which is found almost same. The technique used in the proposed system may be applied to measure and manage the orthostatic stress.

1. Introduction

Standing, upright tilt table testing and lower body negative pressure (LBNP) are in practice to study the effect of orthostatic stress on physiological parameters of human body. Standing is clearly the most physiologic orthostatic stress. When changing body position or simulated by applying sub atmospheric pressure to the lower body (LBNP), orthostatic stress causes a decrease in cardiac output by 20–25% [25]. Carotid pulse palpation is a significant feature for physical examination of

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the cardiovascular system. Carotid artery is responsible for direction of blood flow to brain [32]. The contour, duration and amplitude of the carotid pulse can help in providing the vital information related to basic cardiac abnormalities [2]. Pulsatile changes of the common carotid artery are computed during diastole and systole. These are achieved by thinned segmentation by adjusting the contrast of the image obtained through ultrasound scanning in B-mode [3]. Arterial pressure values and pulse wave contours recorded in the carotid artery using the PulsePen versus intra-arterial simultaneous measurements are compared for the patients undergoing cardiac catheterization. Results show that the PulsePen allows an easy and reliable assessment of central arterial pressure and stiffness in clinical ambulatory practice [4]. Posture-related changes in ventriculoarterial hemodynamics by means of carotid artery (CA) pulse wave are analyzed and it is concluded that CA ultrasound and pulse wave analysis enable noninvasive quantification of ventriculoarterial responses to changes in posture [5]. A noninvasive technique is developed where photoelectric plethysmograph is designed to compute intraocular blood volume pulsations [6].

It is observed throughout various research works that artery pulses play significant role in detecting cardiovascular functions during various postures. A digital computer program is illustrated for automatic recognition of the clinically vital points in the externally recorded brachial pulse wave [7]. The trend is followed in the subsequent years and various methods are developed for recording different artery pulse waves. Pulse transit time (PTT) is found more responsive technique for measuring cardiac functions in retort to leg crossing postures than (HRV) Heart Rate Variability [8]. Signal duration of calculated (Electrocardiogram) ECG is a vital parameter to determine HRV. HRV calculated based on three minutes recorded ECG signal is not found equal to that of five minutes recorded signal [9]. A patient compliant ECG beat categorization system based on a similarity function and a beat database is developed [10]. A fiber-optic sensor is used to determine living activities that helps in recording body vibrations caused by breathing and the heart activity [33]. Piezoelectric sensor based systems are recommended for acquisition of carotid pulse waveforms [11,12,14,31]. HRV is not calculated only from the ECG signal but may be obtained from other signals also. A novel non-constrained technique for estimating HRV using ballistocardiogram (BCG) is introduced by Shin et al. [34].

In the present work two systems are developed which comprises of piezoelectric sensor [29,30], personal computer, MATLAB software/LABVIEW software [23,24]. Carotid signal of the subjects in various postures are acquired with the help of piezoelectric sensor and is fed to the sound port of the computer where it is amplified and converted to digital signal. Data acquisition and signal processing toolboxes of MATLAB software are used to read signal from the sound port of the computer and filter it subsequently. Similarly LABVIEW software is used to acquire and analyze carotid pulse signal with the help of the developed hardware. Results obtained from both the softwares are compared.

2. Materials and methods

2.1. *Piezoelectric sensor*

In the present work, a piezoelectric sensor with metallic plate of 2.0 cm diameter and 0.25 mm thickness is used. Ceramic layer of diameter 1.30 cm with a thickness of 0.1 mm is layered over this metallic plate. Piezoelectric materials generate an electric potential when mechanically strained. Piezoelectric sensors are used quite widely in cardiology for and internal phonocardiography. Other applications of piezoelectric sensors involve their use in determination of physiological accelerations [28].

2.2. *Data acquisition and analysis using LABVIEW*

Experimental setup and practical block diagram of the complete system for acquisition of the carotid pulse from the subject in various postures using LABVIEW are shown in Figs. 1 and 2 respectively. The complete developed system comprises of piezoelectric sensor, personal computer, LABVIEW software and the experiments are conducted on the subjects in various postures. Fifteen healthy male and female subjects of age group 30–55 participated in this work. 3.5 mm mono jack is used to interface piezoelectric sensor to the sound port of the computer. Analog signal with the support of piezoelectric sensor from the carotid pulse is acquired through sound port of the computer where analog to digital converter of the sound port converts it to digital signal. This digital signal is read from the sound port with the support of 'Acquire Sound' VI of signal express of LABVIEW software function palette. In the configuration window channel 1 is selected and time is set for 5 s. The sampling rate is chosen 8000 samples/s. The acquired raw carotid pulse is filtered using 'Filter' block of signal analysis of Function palette. FIR digital band pass filter with 100 taps with pass band 0.005–50 Hz. 'Amplitude and level measurement' VI and 'Time Transition' VI are used to measure amplitude, frequency and time period of the acquired pulse. While loop is used for controlling the execution of the system is used. Sony-Vaio is used as host PC for displaying the acquired signal. The carotid pulse waveform is acquired and

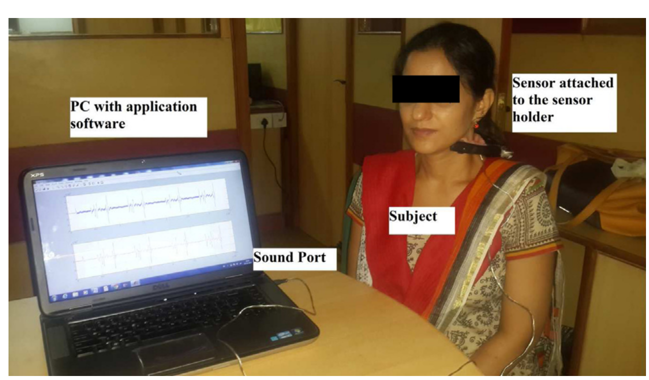

Fig. 1 – Experimental setup of the complete system for acquisition of carotid pulse signal of the subject during various postures using LABVIEW/MATLAB.