Diastolic Timed Vibrator: Applying Direct Vibration in Diastole to Patients with Acute Coronary Ischemia during the Pre-hospitalization Phase

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Abstract. A biomedical device that applies vibration to the chest of a patient during the pre-hospitalization phase of acute coronary ischemia is introduced. This device improves the blood flow in order to remove the thrombosis. In order to help the heart pumping mechanism, vibration is applied during diastole only and hence this device is called a Diastolic Timed Vibrator (DTV). We introduce two algorithms (slope-lookup and slope-energy) to detect diastole by using an electrocardiogram signal available in most ambulances and pre-emergency units. The robustness of the algorithms were examined by considering many types of arrhythmias that might occur during acute ischemia. We show that the slope-energy is a robust method and can be used to detect diastole interval in most types of arrhythmias.

Keywords: Diastolic Timed Vibrator (DTV), Thrombosis, ECG, Diastole Detection, Hamilton and Tompkins filter.

1 Introduction

According to the world health organization, ischemic heart disease accounts for 12.5 percent of annual death rate in the world [1]. The main reason for ischemia is formation of blood clot or thrombus in the blood vessel that reduces the blood flow and can have short and long term effects. Depending on the location and size of the blood clot, a heart attack or stroke can occur. Heart attack or Myocardial Infarction (MI) occurs when the blood clot prevents the flow of blood to the heart leading to destruction of the heart muscles. On the other hand, if the blockage occurs in the artery that supplies blood to the brain, stroke occurs.

Blood clotting is a complicated process which takes place during an injury to body tissues. This is very important protective mechanism. However, pathophysiological processes could potentially generate different sizes of blood clots [3]. The process of break-down or dissolution of blood clot has always been a challenge for researchers. The suggested solutions range from using non-invasive
methods such as injection of thrombolic drugs and applying low frequency ultrasound to using invasive methods such as angioplasty.

Two important studies by Pozen, et al. illustrate the importance of pre-hospitalization phase of treatment of ischemic heart disease. According to these studies, majority of acute ischemic deaths occur prior to the patient arriving to the hospital. Consequently, we propose the design of a non-invasive device that applies vibration during the diastolic cardiac cycle directly to the chest of the patient. We refer to this device as the Diastolic Timed Vibrator or DTV in short. Depending on the clot size and density, the applied vibration could potentially either directly disintegrate the clot or improve the blood flow that leads to removal of the clot. As it was previously shown, this method can be used either in conjunction with thrombolytic agent or as a stand-alone method.

While our method applies direct vibrations to the chest, other types of vibration methods have been utilized. Non-invasive ultrasonic methods use waves with different frequencies and intensities to enhance thrombolysis for therapeutic applications. Such methods apply frequencies from 48 KHz upto 1 MHz with various intensities. Furthermore, many research have shown the positive effect of mechanical vibrations in increasing the blood flow in various parts of the body.

The paper is organized as follows: In section 2, the principle operation of the DTV is explained. Section 3 illustrates a detailed implementation of our device. In section 4, we show the effectiveness of the diastole detection algorithm when applied to different types of cardiac rhythms.

2 Principle of DTV

The human heart could be represented as two synchronized pumps that circulates blood to the rest of the body. Each side of the heart consists of two chambers: atrium and ventricle. The right side receives the de-oxygenated blood from the rest of the body and pumps it to the lung whereas the left side receives the oxygenated blood from the lungs and pump it to the rest of the body. The pumping mechanism is periodic and is referred to as the cardiac cycle. During this period, the ventricle goes through two phases: systole and diastole. During diastole, the ventricles relax and blood starts to fill in slowly while the valves between atria and ventricle slowly open due to pressure difference. Just at the end of this cycle, the atria start to contract and push more blood in ventricle. During the systole, the ventricle contracts and pumps blood to the rest of the body.

As it was mentioned before, It has been shown that applying external vibrations during the diastole can essentially increase the blood flow both in humans and animals. Furthermore, studies have shown that applying low frequency vibrations can lead to recanalization of thrombosed flow system held at atrial like pressure.

The cardiac cycle is synchronized by electrical activity of the heart muscles. By placing electrodes on human body, this electrical activity can be recorded.