42 Aero Camino, Goleta, CA 93117
www.biopac.com

Biopac Student Lab® Lesson 7

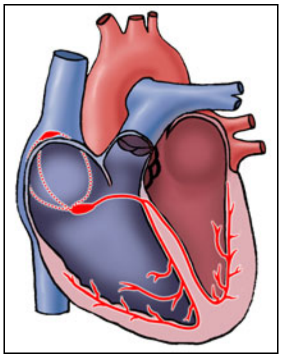
ECG & PULSE

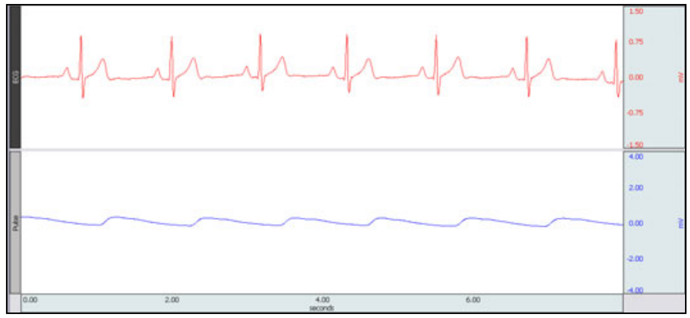
Introduction

Rev. 01152013

Richard Pflanzer, Ph.D.
Associate Professor Emeritus
Indiana University School of Medicine
Purdue University School of Science

William McMullen
Vice President, BIOPAC Systems, Inc.





I. INTRODUCTION

The primary purpose of the heart is to pump blood throughout the body. To pump blood, the heart has a rhythmical sequence of both electrical and mechanical events, the **cardiac cycle**. The electrical activity, recorded as an **electrocardiogram** (**ECG**,) initiates the mechanical activity of the heart (contraction and relaxation of atria and ventricles). When the heart chambers contract, they pump blood to the next section of the cardiovascular system. This lesson will focus on the actions of the left ventricle, which pumps blood to the systemic circulatory system, producing a pulse.

During the cardiac cycle the electrical activity of the ventricles, as represented by the QRS complex of the ECG, precedes the mechanical event of ventricular muscle contraction (**ventricular systole**). Within the range of normal resting heart rates, systole begins at the time of the R wave peak and ends at the end of the T wave. The T wave, which represents repolarization of the ventricles, occurs during the time the ventricles are in systole. **Ventricular diastole**, a period of relaxation of ventricular muscles, begins at the end of systole and lasts until the next R wave peak. Since each cardiac cycle contains one period of ventricular systole immediately followed by one period of ventricular diastole, the duration of one cardiac cycle, or heartbeat, can be measured as the time between successive R waves (Fig. 7.1). In the ECG cycle, electrical activity precedes and initiates mechanical activity.

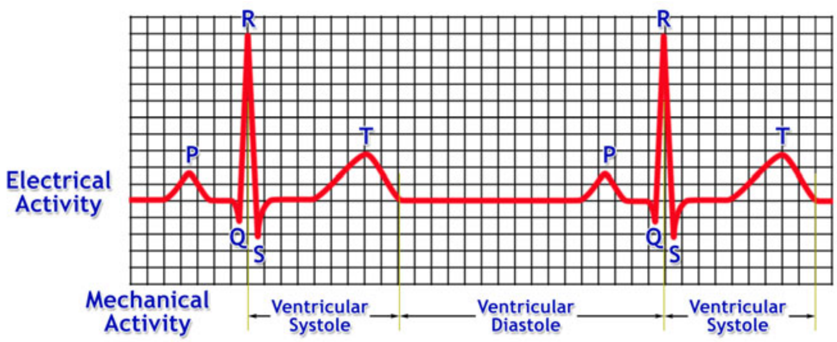


Fig. 7.1 Cardiac cycle

Contraction of the ventricles (ventricular systole) pushes a volume of blood (stroke volume) into arteries. From the left ventricle, the blood goes into the aorta and throughout the rest of the body. Each section of blood "bumps" the downstream, neighboring section of blood to facilitate *blood flow*. The aorta and other arteries have muscular walls, which allow the arterial walls to expand slightly to receive the volume of blood during systole and then, elastic recoil of the arteries helps to continue "pushing" the blood through the rest of the system. The arterial pressure throughout the cardiac cycle is the main force for blood flow.

The pumping action of the ventricles also initiates a pressure wave that is transmitted via the arterial walls. The pressure increases with systole and decreases with diastole. The stiffness of the vessel walls helps transmit the pressure wave. The stiffer the walls, the faster the transmission of the *pressure wave,* but the more work is required by the heart to move the same blood volume.

When the pressure wave is transmitted to the periphery, e.g., fingertip, there is a **pulse** of increased blood volume. The tissues and organs change in volume as blood vessels dilate or constrict and as pulses of blood pass through the blood vessels during each cardiac cycle. Changes in blood volume of organs may be brought about by the autonomic nervous system acting on the cardiovascular system, environmental factors (such as temperature,) metabolic activity of an organ, and a variety of other variables.

For example, temperature regulation involves controlling blood flow to the skin; when heat needs to be conserved, blood flow to the skin is minimized and when excess heat is being generated, the opposite occurs.

The actual blood flow is slower than the transmission of the pressure wave. The aorta has the fastest blood flow in the body at approximately 40-50 cm/sec (approximately 1 mile per hour) whereas the speed of the pressure wave can be much faster.

The travelling speed of the pressure wave from the heart to the periphery can be affected by many interrelated factors, including the heart's ability to contract strongly, blood pressure, the relative elasticity of the arteries, and the diameters of systemic arteries and arterioles. These factors change in response to body positions, sympathetic nervous system input, emotions, etc. For example, the travelling speed of the pressure wave has been shown to correlate with sympathetic influence and systolic blood pressure.

The study of blood volume changes within an organ by using volume displacement techniques is known as plethysmography. In this lesson, you will simultaneously record the ECG and subsequent pulse. The SS4LA transducer will be used to record changes in blood volume via optical photoplethysmography (PPG) methods. The transducer works by shining a beam of Near-infrared light through the skin and measuring the amount of light that is reflected. Blood is highly reflective of Near-infrared light due to the hemes subunit of hemoglobin (red pigment in blood). When the transducer is placed on the skin, in proximity to capillaries, the reflectance of the infrared light from the emitter to the detector will change in accordance to capillary blood volume. Greater blood flow will cause greater signal amplitude. Note that the PPG signal provides a relative (dimensionless,) not absolute, measure of blood flow, however in this lesson we display in units of millivolts (mV).