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Mechanical Aspects of Cardiac Performance

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1. INTRODUCTION

This chapter is a review of commonly utilized monitoring techniques performed to assess the function of the general cardiovascular system. Specifically, means to assess arterial blood pressure, central venous pressure, pulmonary artery pressure, mixed venous oxygen saturation, cardiac output, pressure–volume loops, and Frank-Starling curves are described. Basic physiological principals underlying cardiac function are also briefly discussed.

Under normal physiological conditions, the human heart functions as two separate pumps: (1) the right heart pumps blood through the pulmonary circulation, and (2) the left heart pumps blood through the systemic circulation. Each contraction of the heart and subsequent ejection of blood creates pressures that are commonly monitored clinically to assess the function of the heart and its work against resistance. In general, the mechanical function of the heart is described by the changes in pressures, volumes, and flows that occur within a given cardiac cycle. A single cardiac cycle is one complete sequence of myocardial contraction and relaxation.

2. CARDIAC CYCLE

The normal electrical and mechanical events of a single cardiac cycle of the left heart are correlated in Fig. 1. The mechanical events of the left ventricular pressure–volume curve are displayed in Fig. 2. During a single cardiac cycle, the atria and ventricles do not beat simultaneously; the atrial contraction
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Heart sounds
S1
S2
S3
S4
QRS
T
P
Atrial
Ventricular
Myocardial contraction
Systolic pressure
Pulse pressure
Diastolic pressure
stroke volume
Dicrotic notch
Diastolic pressure
Aortic valve
closed
Aortic valve
open
Mitral valve
open
Mitral valve
closed
Left atrial pressure
Left atrial pressure
Left ventricular pressure
Left ventricular pressure
60
120
volume (mL)
pressure (mm Hg)
60
120
A: Mitral valve opens, begin diastole
B: Mitral valve closes
C: Aortic valve opens, begin systole
D: Aortic valve closes
A-B: Diastole
B-C: Isovolumic contraction
C-D: Systole
D-A: Isovolumic relaxation
e: Contractility
Stroke volume

Fig. 1. Electrical and mechanical events of a single cardiac cycle of the left heart (see text for details). ECG, electrocardiogram.

Fig. 2. Pressure-volume diagram of a single cardiac cycle (see text for details).

occurs prior to ventricular contraction. This timing delay allows for proper filling of all four chambers of the heart.

Recall that the left and right heart pumps function in parallel. The diastolic phase of the cardiac cycle begins with the nearly simultaneous opening of the tricuspid and mitral valves (atrioventricular valves). The atrioventricular valves open when the pressures in the ventricles fall below those in the atria. This can be observed in Fig. 1 for the left heart, in which the mitral valve opens when the left ventricular pressure falls below the left atrial pressure. At this moment, passive filling of the ventricle begins. In other words, blood that has accumulated in the atria behind the closed atrioventricular valves passes rapidly into the ventricles, and this causes an initial drop in the atrial pressures. Later, pressures in all four chambers rise together as the atria and ventricles continue to fill passively in unison with blood returning to the heart through the veins (pulmonary veins to the left atrium and the superior and inferior vena cava to the right atrium).

Contractions of the atria are initiated near the end of ventricular diastole, which is initiated by depolarization of the