Phases of Systole

Isovolumic Contraction

Isovolumic contraction is the period between AV valve opening and the start of ventricular ejection. During this phase, the ventricular pressure continues to rise, and the ventricular volume remains constant. The period of isovolumic contraction is measured from the onset of ventricular contraction to the point of aortic valve opening. Two key events during this phase are:

- **Aortic Valve Opening (AO)**: This occurs when the pressure in the LV exceeds the pressure in the aorta, allowing blood to flow into the aorta.
- **Mitral Valve Closure (MC)**: This occurs when the pressure in the LV falls below the pressure in the left atrium, preventing blood from flowing back into the LV.

The duration of isovolumic contraction is usually measured from the onset of ventricular contraction to the point of aortic valve opening (AO) or mitral valve closure (MC). The duration of isovolumic contraction can be estimated from pressure-volume loops or directly measured from electrocardiograms (ECGs) using specialized algorithms.

Reduced Ejection (Deceleration) Phase

Approximately 200 ms after the onset of ventricular contraction, ventricular repolarization occurs. Repolarization leads to a decrease in the rate of ejection and ventricular emptying. Ventricular pressure falls slightly below the pulmonary artery and aortic pressures; however, some ejection still occurs due to kinetic (or inertial) energy of the blood flow. During this phase, the ventricular volumes continue to decline but at a slower rate than during rapid ejection. The ventricular volume at the end of ejection (end-systole) is the smallest ventricular volume.

Pressure-Volume Loops

By combining the ventricular pressure and ventricular volumes, a pressure-volume (P-V) loop can be derived to more precisely describe the relationship between pressure and volume over the cardiac cycle. To generate a P-V loop for the LV, the LV pressure (LVP) is plotted against LV volume at multiple points throughout a single cardiac cycle (Fig. 2.10). The P-V loop for the left ventricle is rectangular in shape. The point at mitral valve closure (MC) illustrates the LV pressure and LV volume at the end of ventricular filling (end-diastole); this correlates to the LV end-diastolic pressure (LVEDP) and the LV end-systolic pressure-volume relationship (LVEDV).

The vertical line between MC and aortic valve opening (AO) represents isovolumic contraction. During isovolumic contraction, the LV begins to contract and the LV pressure increases but the LV volume remains the same because all valves are closed. At the end of ejection, ventricle is completely relaxed and the LV pressure and LV volume are at their lowest values (LVESV).

Basic Cardiac Physiology

Ventricular systole is defined as the period between AV valve opening and semilunar valve opening. During this phase, the ventricle contracts and ejects blood into the aorta and pulmonary artery. Ventricular systole is divided into three phases:

- **Isovolumic Contraction**
- **Rapid Ejection**
- **Reduced Ejection**

Rapid Ejection (Acceleration) Phase

When the pressure within the ventricles exceeds the pressure within the respective great arteries, the semilunar valves snap open. This results in the rapid ejection of blood from the ventricles into the aorta and pulmonary artery. As a result, ventricular volumes also rapidly decline. Rapid ejection occupies approximately the first half of systole.

Reduced Ejection (Deceleration) Phase

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Pressure-Volume Loops

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The vertical line between MC and aortic valve opening (AO) represents isovolumic contraction. During isovolumic contraction, the LV begins to contract and the LV pressure increases but the LV volume remains the same because all valves are closed. At the end of ejection, ventricle is completely relaxed and the LV pressure and LV volume are at their lowest values (LVESV).

The maximal pressure that can be developed by the ventricle at any given LV volume is defined by the end-systolic pressure-volume relationship (ESPVR), which represents the contractile state of the ventricle.