Series 8 – Solutions

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Chapter 14: Pump Function

Exercise 14.1 - Solution

1) Using the definition for elastance

$$E(t) = \frac{P(t)}{V(t) - V_d} \tag{1}$$

with $P(t)$ the pressure and $V(t)$ the volume for a given time t, and V_d the dead volume of the ventricle, we solve for $V(t)$ and set t to be the end-diastolic time, t_{ed}:

$$V(t_{ed}) = \frac{P(t_{ed})}{E(t_{ed})} + V_d \tag{2}$$

With $P(t_{ed}) = P_{ed} = 5$ mmHg, $E(t_{ed}) = E_{min} = 0.5$ mmHg/ml and $V_d = 0.75$ ml we obtain $V_{ed} = V(t_{ed}) = 10.75$ ml.

2) With a clamped aorta, the ventricle will perform an isovolumic contraction until a maximum pressure P_{max} is reached. This maximum pressure is determined by the maximum contraction of the muscle, which is reached at maximum elastance E_{max}. If we set $V(t) = V(t_{ed}) = V_{ed}$ and $E(t) = E_{max} = 40$ mmHg/ml and solve (1) for P_{max} we get:

$$P_{max} = E_{max}(V_{ed} - V_d) \tag{3}$$

which is 400 mmHg for the given values.

3) The mean cardiac output at the zero load state can be regarded as the maximum mean flow of the heart. The maximum mean pressure that the heart can overcome is equal to the mean pressure at zero flow, which is the value calculated in Eq. (3) by replacing E_{max} with E_{mean}:

$$\overline{P}_{max} = E_{mean}(V_{ed} - V_d) \tag{4}$$

This results in a maximum mean pressure $\overline{P}_{max}$ = 71 mmHg. Using the parabola fit function proposed by N. Westerhof and G. Elzinga

$$\overline{P}\left(\overline{Q}\right) = \overline{P}_{max}\left[1 - \left(\frac{\overline{Q}}{\overline{Q}_{max}}\right)^2\right] \tag{5}$$

and the maximum mean flow $\overline{Q}_{max}$ = 8.5 ml/s we obtain the following curve: