

# The Circulation Model

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# WindKessel Model

► <https://www.youtube.com/watch?v=Bx9Nu2PkPsE>

# Single Compartment WindKessel Model

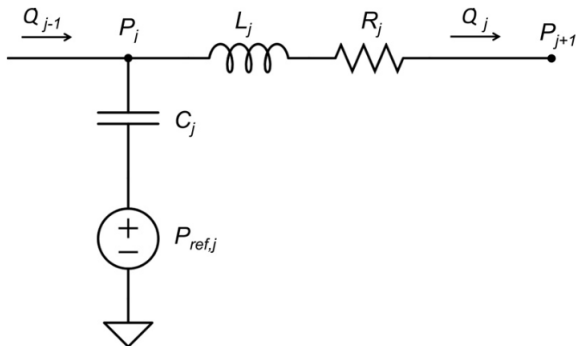


Fig. 3. Single-compartment, windkessel-type model.  $Q$ , outgoing blood flow rate;  $R$ , resistance;  $C$ , compliance;  $L$ , inertance;  $j, j + 1, j - 1$ , compartment index;  $P_{ref}$ , extravascular pressure reference (atmospheric pressure or  $P_{pl}$ , depending on the location of  $j$ ).

# Schematic diagram of cardiovascular system

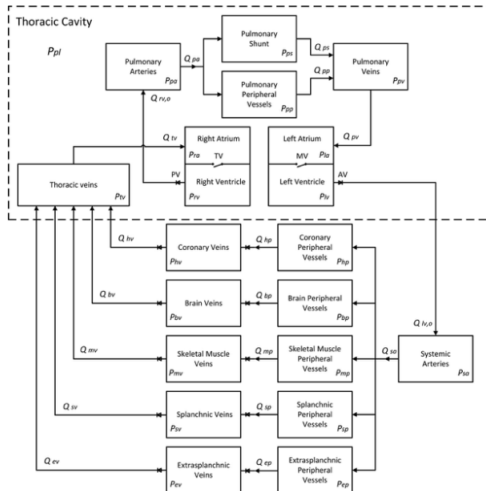


Fig. 2. Schematic diagram of the cardiovascular system model. P, pressure; Q, blood flow; MV, mitral valve; AV, aortic valve; TV, tricuspid valve; PV, pulmonary valve. Subscripts: la, left atrium; lv, left ventricle; lv, o, left-ventricle output; sa, systemic arteries; sp, splanchnic peripheral compartment; sv, splanchnic veins; ep, extrasplanchnic peripheral compartment; ev, extrasplanchnic veins; mp, skeletal muscle peripheral compartment; mv, skeletal muscle veins; bp, brain peripheral compartment; bv, brain veins; hp, coronary peripheral compartment; hv, coronary veins; tv, thoracic veins; ra, right atrium; rv, right ventricle; rv, o, right-ventricle output; pa, pulmonary artery; pp, pulmonary peripheral circulation; ps, pulmonary shunt; pv, pulmonary veins; pl, pleural space.

# Equation of Pressure and Flow

$$V_j = \frac{C_j \cdot P_{tm,j}}{V_{e,j}} + V_{u,j} \quad (I)$$

# PV Relationship of Thoracic Vein Compartment

$$P_{tm,tv} = \begin{cases} D_1 + K_1 \cdot (V_{tv} - V_{u,tv}) - \psi & V_{tv} \geq V_{u,tv} \\ D_2 + K_2 \cdot e^{\frac{V_{tv}}{V_{tv,min}}} - \psi & V_{tv} < V_{u,tv} \end{cases} \quad (2)$$

with  $\psi = K_{xp} / \left( e^{\frac{V_{tv}}{K_{xv}}} - 1 \right)$

# Resistance of Thoracic Vein Compartment

$$R_{tv} = K_R \cdot \left( \frac{V_{tv,max}}{V_{tv}} \right)^2 + R_{tv,0} \quad (3)$$

# Auxiliary Equations

$$C_{sa} \cdot \frac{dP_{sa}}{dt} = Q_{lv,o} - Q_{sa} \quad (A1)$$

$$L_{sa} \cdot \frac{dQ_{sa}}{dt} = P_{sa} - P_{ep} - R_{sa} \cdot Q_{sa} \quad (A2)$$

$$V_{sa} = C_{sa} \cdot P_{sa} + V_{u,sa} \quad (A3)$$

$$C_{p,eq} \cdot \frac{dP_{ep}}{dt} = Q_{sa} - \sum_j Q_{jp} \quad (A4)$$

$$P_{ep} = P_{sp} = P_{mp} = P_{bp} = P_{hp} \quad (A5)$$



# The End