The Aortic Reservoir-Wave Model: A Theoretical Approach using One-Dimensional Navier-Stokes Equations

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For decades, arterial hemodynamics has been dominated by the notion that the arterial system operates in a condition of steady-state oscillation; therefore, aortic waveforms were considered to be the superposition of sinusoidal wavetrains. We demonstrated earlier that "waves" alone cannot explain aortic waveforms and we proposed an alternative model: in the arterial system, waves propagate upon a time-varying reservoir. According to our model, measured aortic pressure is the instantaneous sum of a pressure due to wave motion and a pressure due to the charging and discharging of the aortic reservoir. The governing equations for our model were derived using the control volume approach standard in fluid dynamics. In contrast to Womersley's assumption, vessel tapering and frictional losses are included in the model. In a straight tube filled with ideal fluid as assumed by Womersley, the relationship between pressure and flow can be adequately described by wave motion. However, in a tapering vessel, an extra term, , was presented, where A is the cross-sectional area and U is the local velocity, averaged over the cross-section. This term has the unit of pressure and is responsible for the reservoir pressure of this infinitesimal control section, since the numerator is the net flow rate (inflow minus outflow) of the section and the denominator is the compliance of the section. The derivation demonstrates that, at any small section of a tapering tube (aorta), the measured pressure is composed of a pressure due to wave motion and a pressure due to local volume storage.