Coronary capacitive effects on estimates of diastolic critical closing pressures

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Until recently, coronary pressure-flow relationships have been considered only in terms of resistance characteristics. However, evidence suggests that the zero flow pressure intercept (Pzf) is of significant magnitude and must also be considered. Bellamy (1) analyzed the instantaneous diastolic coronary pressure-flow relationships in chronically instrumented dogs. Pressure-flow relationships were found to be linear with Pzf as high as 50 mmHg in the presence of coronary tone. During reactive hyperemia or adenosine induced vasodilation, the instantaneous pressure-flow relationships revealed a greater slope (interpreted as coronary conductance) and a decrease in the Pzf to about 20 mmHg. These results have been confirmed by other groups (2) in open-chest anesthetized preparations.

The question remains as to the correct interpretation and the physiologic significance of these high diastolic pressure intercepts. If coronary inflow as measured by an epicardial electromagnetic flowmeter correctly represents the flow in the microcirculation at every instant of time, then these high zero flow pressure intercepts could represent the downstream back pressure of a vascular waterfall (3). Critical closing pressures of this magnitude during diastole would certainly play a major role in the regulation and distribution of coronary flow. However, the assumed instantaneous equivalence of coronary inflow and intramural flow cannot be made in the presence of reactive components of the coronary system (capacitance and inertia). In particular, capacitive properties of the coronary system could provide continued intramural flow despite zero coronary inflow as measured by a flow meter. This underestimation of intramural flow can result in overestimation of the true zero flow pressure intercept.

Figure 1 illustrates the consequences of coronary capacitance on the instantaneous pressure-flow relationship. In the electrical analog representation of the coronary system during diastole PA denotes the aortic driving pressure and P0 denotes the back pressure which can represent either coronary sinus pressure or the critical closing pressure whichever is greater. Coronary capacitance, C, is in parallel to the intramural resistance,
CAPACITIVE AND RESISTIVE MODEL WITH PRESSURE OFFSET

\[ \begin{align*}
C &= \text{coronary capacitance} \\
i &= \text{coronary inflow} \\
i_c &= \text{flow from discharging capacitor} \\
i_{Rs} &= \text{intramural flow}
\end{align*} \]

\[
i_{Rs} = i + ic , \quad ic = -C \frac{dP_A}{dt} , \quad i_{Rs} = \frac{1}{Rs} \cdot (P_A - P_0)
\]

For exponentially decaying aortic pressure: \( P_A = ke^{-at} \)

\[
i = \left( \frac{1}{Rs} - aC \right) \cdot \left[ P_A - \frac{P_0}{(1 - aac)} \right]
\]

let \( ac = \frac{1}{RsC} \) 

\[
i = \frac{1}{Rs} \cdot \left(1 - a/ac\right) \cdot \left[ P_A - \frac{P_0}{(1 - a/ac)} \right]
\]

\[\text{Fig. 1}\]

\( R_s \). Large vessel resistance is ignored in this simple model since it does not affect the overall interpretation of results. Coronary inflow is represented by \( i \), intramural flow by \( i_{Rs} \), and flow from the discharging capacitor by \( ic \). Assuming an aortic pressure decay during diastole of the form \( P_A = ke^{-at} \) and a constant resistance, \( R_s \), the instantaneous pressure-flow relationship can be derived:

\[
i = \text{coronary inflow} = \left(\frac{1}{R_s}(1 - a/a_c)(P_A - P_0)/(1 - a/a_c)\right)
\]

where \( a_c \) is defined as \( 1/R_sC \). \( a_c \) represents the intrinsic coronary decay constant theoretically and practically obtained by occluding the coronary artery and measuring the peripheral coronary pressure decay rate. The instantaneous pressure-flow relationship (i versus \( P_A \)) is linear, with a slope \( = (1/R_s)(1 - a/a_c) \) and a \( P_0 = P_0/(1 - a/a_c) \). It can be seen that if \( a_c \) is comparable in magnitude to \( a \), the aortic decay rate, then the actual zero flow pressure intercept, \( P_0 \), is magnified and overestimated using instantaneous dynamic measurements. This effect is graphically depicted in figure 1. Pressure-flow relationships obtained under constant pressure...