LETTERS TO THE EDITOR

Comments on "The Cardiac and Vascular Factors That Determine Systemic Blood Flow"

The analysis of M.N. Levy (1979) of the cardiac and vascular factors that determine systemic blood flow is valuable and forces us to think again about this closed, complex conglomeration of conduits—the cardiovascular system. However, he states (p. 744, line 38) that "... any change in Pv-Pms was evoked by a change in Q, and not the converse." Dr. Levy also seemed to take issue with the concept that if the right atrial pressure is suddenly raised to equal the mean systemic pressure, then the venous return will halt if the mean systemic pressure is held constant. Those last three words are crucial. There is no question that the magnitude of the pressure gradient from the capacitance vessels to the right heart may be computed as the product of flow and venous resistance (his Equation 2), but it seems to me that we may confuse ourselves and our students a disservice by claiming that flow-related pressure gradients (in a system with no change in kinetic or gravitational levels) are caused by the flow. Flow will occur only if an energy gradient is present, for otherwise what initiates the flow? This is a conceptual, not a semantic, problem. Of course, the data presented in Figure 7 are correct, but the only way that the 3.5 1/min could have been conducted from the capacitance vessels to the mechanical pump was to reduce the central venous pressure so that the "pressure gradient for venous return" was 14 mm Hg. With the closed system, the mechanical pump did just that. The critical experiment would have been to pump the blood to the heart of his dogs from a large reservoir of blood, maintain the venous pressure at 15 mm Hg, and then measure the mean systemic pressure. As cardiac output was then increased, the mean systemic pressure would increase as the vascular blood volume increased! Drees and I (1974, 1976) investigated, in effect, the relationship by changing blood volume. We found that the mean circulatory filling pressure changed much more rapidly than central venous pressure as cardiac output was changed. A pressure gradient is needed for, not caused by, the venous return. If the central venous pressure is suddenly increased to equal the mean systemic pressure, then venous return will indeed stop until a pressure gradient is reestablished.

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References

Reply to the Preceding Letter

The Pressure Gradient for Venous Return, or the Pressure Gradient Caused by Venous Return?

In his letter to the Editor, Dr. Rothe has raised a fundamental question which, for the sake of brevity, I had not addressed adequately in my recent special article (Levy, 1979). I welcome the opportunity to elaborate on the cause-and-effect relationships between flow and pressure gradient as they pertain to the cardiovascular system.

The hydraulic equivalent of Ohm’s law is $R = \Delta P / Q$, where $R$ is the hydraulic resistance, $\Delta P$ is the pressure drop, and $Q$ is the flow. For the hydraulic system shown in Figure 1, $P_i$ and $P_o$ are the pressures at the inflow and outflow ports, respectively, and $P_x$ is the pressure at any point, $x$, between the two ends of the system. Under conditions of steady flow, the flows past each cross-section are identical; i.e., $Q = Q_x = Q_o$. Steady flow conditions will be assumed in the ensuing discussion, and so the subscript for $Q$ will usually be omitted.

Figure 1 is meant to represent any hydraulic system, including the circulatory system. If a pump, such as the heart, generates a flow, $Q$, through the system, Ohm’s law defines the relationships between $\Delta P$, $R$, and $Q$; for the system as a whole, $\Delta P = P_i - P_o$.

For the sake of convenience, we might prefer to think of the pump as a “flow-generator.” Then, for a given value of $R$, the flow, $Q$, generated by the pump, will cause a specific pressure drop, $P_i - P_o$, as defined by Ohm’s law. Conversely, it might suit our purposes to consider the pump to be a “pressure generator.” In that case, we would assert that the pump produces a certain pressure drop, $P_i - P_o$. For a given value of $R$, that pressure drop would cause a certain rate of flow. The assignment of dependent and independent variables would be entirely arbitrary, and the selection would be made to suit the requirements of the problem at hand.

The same flexibility does not apply to the relationship between $\Delta P$ and $Q$ for a component part of the system, even though Ohm’s law applies as much.
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