Is the heart a pressure or flow generator? Possible implications and suggestions for cardiovascular pedagogy

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We greatly appreciate Dr. Mitchell’s contribution concerning the educator’s difficulty of presenting a cohesive circulation model to students of cardiovascular physiology (6). As clinicians and educators, we have been aware of this paradox for many years and believe that, far from being a question of semantics, it is one of the core issues in cardiovascular physiology. The case in point is whether the heart is primarily a pressure- or flow-generating pump.

Briefly, despite the general agreement that the pressure gradient provided by the heart is the source of blood propulsion, the question over control of the cardiac output (CO) continues to be, as noted by Dr. Mitchell, the subject of a vigorous debate. Proponents of the classic pressure propulsion model of circulation maintain that in addition to impelling the blood, the heart is the principal regulator of CO (1). Adherents of Guyton’s venous return view of circulation contend, on the other hand, that the peripheral circulation performs a pivotal role in the control of CO, while the heart plays only a secondary or permissive role. Guyton’s model further assumes that right atrial pressure acts as an impedance to venous return (5, 7).

In the 1970s, Elzinga and coworkers (2) conducted a series of tightly controlled experiments on perfused isolated cat heart preparations maintained at constant heart rate, filling pressure, and contractility. They showed that when the heart operates against stepwise changes in peripheral resistance and arterial compliance, there is a reciprocal relationship between mean ventricular pressure and stroke volume. The experiments further demonstrated that under different hemodynamic conditions, the heart transfers the blood to the aorta with optimal (maximal) external power and efficiency. Thus, the heart is neither a pressure nor flow generator but, according to the authors, “a finite source resistance related to its load” (2).

A recent comprehensive review of circulation models has shown that the long-standing stalemate in the debate will only be resolved when in place of the mechanistic (pressure propulsion) model, powered by the heart, a biological, evolutionary model of the circulation is adopted (3). Numerous examples from early embryonic development demonstrate that movement of the blood is a primary phenomenon generated at the level of the microcirculation. It exists before the functional maturity of the heart and is intricately linked with metabolic demands of the tissues. Evidence for the autonomous movement of the blood is further corroborated by observations from comparative anatomy and phenomenology of the mature circulation. Accordingly, the pressure in the vessels is a derived phenomenon resulting from the rhythmic interruption of flow by the heart in combination with the dynamic response of the peripheral vasculature. The heart thus functions as an impedance pump, generating pressure, but not the flow of blood (3). The framework for the pressure propulsion paradigm rests on principles of a thermodynamically closed system. That conception, our own research has shown, fails to address the complexity of living systems in general and of the circulatory system in particular (4).

The complex, self-contradictory nature of the pressure propulsion model has been a major source of confusion for generations of instructors and students of cardiovascular physiology and needs to be revised. We therefore propose that a lucid reformulation of the circulation model is the key for understanding various clinical and experimental scenarios. It can also serve as a dependable teaching tool for educators and learners.

DISCLOSURES

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