In Defense of "Venous Return"

The recent Special Article reviewing the primary controls for the circulation of blood (Levy, 1979), together with the appended editorial note by Dr. Guyton, constitute an excellent restatement of fundamental principles of the cardiovascular system. The Levy-Guyton discussion is of particular significance in demonstrating that conceptual confusion often created by defining "dependent" and "independent" variables is the consequence of the experimental design selected by the investigator to prove his point. Levy's questioning the value of the "venous return" concept as a distinct parameter of cardiovascular control also seems to reflect investigator bias attributable to the experimental preparation he has employed.

Levy's version of the Guyton model describes the function of the circulation in the anesthetized thorocotomized dog in the supine position. This preparation suffers from an abnormally low end-diastolic cardiac volume (Rushmer, 1964) and a virtual absence of gravitational forces. Deficient cardiac filling makes this preparation quite sensitive to the Frank-Starling mechanism, which is apparently not characteristic of the unanesthetized animal or man (Glantz and Parmley, 1978; Boettcher et al., 1978). In the conscious state, the cardiac function curves of Guyton are not to any significant degree a manifestation of variations in diastolic filling, but are the consequence of reflex adjustments in cardiac rate and contractility as a function of changes in venous return. We assume that Dr. Levy would not quarrel with this refinement of his model; he explicitly excluded reflex mechanisms from his analysis for the purpose of simplification.

Ignoring the gravitation factors influencing venous return is a more worrisome simplification, especially if one is interested in extrapolating the model to upright man. Levy's statement that "Skeletal muscle contraction, including that of the respiratory muscles, may play a small role in propelling blood around the circulatory system" is applicable to the anesthetized dog, but it is clearly not descriptive of unanesthetized man. Whereas it is difficult to derive a rigorous estimate of the energy input to the circulation by the "muscle pumps," a qualitative index to this energy must be reflected by the pressure gradients created and the volume of blood flow involved. In the absence of muscle pumps, venous pressure at the ankle in upright man is approximately 90 mm Hg; with activation of the muscle pumps, ankle venous pressure drops to less than 25 mm Hg (Pollack and Wood, 1949). At the same time, blood flow to the leg muscles may increase as much as 20 fold (Grimby et al., 1967). Therefore, the muscle pumps are capable of counteracting a gravitational pressure gradient to the extent of some 65 mm Hg under conditions where total leg flow is of the order of two-thirds of the cardiac output (Donald et al., 1957). Although relating all leg flow to ankle pressure obviously overestimates the contribution of the muscle pump, restricting our flow considerations to leg flow underestimates their role. The muscle pumps are clearly capable of contributing significant energy to propel the venous blood back to the heart.

Although gravity does not play as prominent a role in quadrupedal forms as in bipedal man, it should be appreciated that the gravitational factor is not restricted to static forces. In running man or dog, the inertial component of gravity becomes important, as abrupt contact with the supporting surface arrests the fall of the body at each stride. The muscle pumps must serve a crucial role in overcoming this inertial surge of venous return away from the heart.

There can be no argument with Levy's insistence that at steady state, by definition, venous return must equal cardiac output. This is an inadequate basis, however, for questioning the conceptual value of the "venous return" as a distinct component of the system. Models of the circulation should account for the important mechanisms which act uniquely on venous return, without which the circulation of blood in erect man cannot be sustained.

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References


Reply to the Preceding Letter

The cardiovascular system is a closed circuit. Hence, under steady state conditions, the blood...
flow past any given cross-section must be equal to that past every other cross-section. The terms “cardiac output” and “venous return” refer to the total blood flow being pumped by the heart and returning to the heart, respectively. In the steady state, the cardiac output and venous return are equal to each other, and they equal the “total blood flow” around the entire circuit. The principal objective of my recent paper (Levy, 1979) in this journal was to emphasize that, at equilibrium, any factor that influences the total blood flow affects cardiac output and venous return alike; indeed, the three terms are virtually synonymous in the steady state. It would be ludicrous, therefore, to explain any steady state alteration in cardiac output by invoking a change in venous return.

Dr. Alexander, in his Letter to the Editor, argues that the concept of venous return does have utility in certain contexts and therefore it should not be denigrated. He is correct, of course. In my paper, I conceded that the concept of venous return was useful in the analysis of non-steady state conditions, such as the changes in blood flow that take place during the respiratory cycle. I also alluded to the role played by “skeletal muscle contraction, including that of the respiratory muscles ... in propelling blood around the respiratory system.” Alexander properly contends that such an ancillary mechanism may be quite important under certain conditions, such as during muscular exercise, especially in “upright man.”

Granted that skeletal muscle contraction may play an important auxiliary role in propelling blood during muscular exercise. Does this necessarily support the importance of the venous return concept? Do such contractions specifically improve venous return from the legs? Or is there not the more general action of promoting a greater blood flow through the legs? It is obvious that, except transiently, such an ancillary mechanism cannot pump more venous return out of the limb than that which is flowing through that limb!

Intermittent contractions of the skeletal muscles in the legs of an erect person do diminish the quantity of blood “pooled” in the limbs. An individual supported on a tilt table and rotated into a vertical, head-up position may soon experience cardiovascular collapse. The pooling of blood in the dependent regions of the body is analogous hemodynamically to the external loss of an equivalent volume of blood. In the steady state, should such an impaired circulatory state be ascribed to an inadequate venous return? Does not the sequestered volume of blood, whether it be pooled in distended veins or whether it lies in a puddle on the ground, result in a diminished cardiac-filling pressure? Does not this reduced filling pressure cause the heart to pump blood around the body at a diminished rate? Is there any advantage to labelling this reduced total blood flow specifically as a “diminished venous return”? Regardless of the reader’s individual preference, I do fervently hope that my recent article will encourage the reader at least to pause briefly before he ascribes the decreased cardiac output to a diminished venous return!

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References
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