Right Atrial Pressure*

Determinant or Result of Change in Venous Return?

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According to the concept of Guyton, cardiac output is largely controlled by venous return, which is determined by the difference between mean systemic venous pressure and right atrial pressure. In the analysis of the venous return curve, other authors have suggested that right atrial pressure is the dependent variable and venous return is the independent variable (right atrial pressure decreased because cardiac output increased). The present report analyzes this historical debate, which has already lasted > 50 years. (CHEST 2005; 128:3639–3640)

“One of the definitions of physiology is that it is “the science of how the body works.” The key to obtaining a full understanding of the human circulatory function is the determination of its autoregulation. In the steady state, the traditional teaching is that pulsatile BP is the result of cardiac function (output), and vascular structure and function (large vessel compliance and peripheral arterial resistance). As cardiac output must equal venous return, a decrease in cardiac output means a decrease in venous return.1 Since this has been taught to three generations of intensivists, venous return is defined as the result of a constant mean circulatory pressure (ie, pressure under the condition of no flow) and an independently variable “back pressure” right atrial pressure.2 The venous return-right atrial pressure illustration was used to argue that venous return increases because right atrial pressure decreases, given a constant mean circulatory pressure.3 Stated in this way, right atrial pressure-mean circulatory pressure is the gradient for venous return (driving force).3–5

After a theoretical analysis, with the development of a mathematical model, Levy6 questioned the statement that venous return increases because of a decrease in right atrial pressure. Using a mathematical model, he suggested that in the analysis of the venous return curve, right atrial pressure is a dependent variable and venous return is an independent variable (ie, right atrial pressure decreased because cardiac output increased).6 Experimental animal results have also come to the same conclusion.7 Even Guyton4 noted that in the animal an inverse change in right atrial pressure was observed when he induced a change in the cardiac output by use of an artificial pump, in the absence of the collapsible tube (ie, Starling resistor). In the absence of cardiac dysfunction, venous return is more essential in determining cardiac output than the pump itself. However, when venous return and cardiac output are not identical (for short periods of time), and the total vascular volume is fixed, the difference is made up by a reciprocal exchange of volume between compliant compartments.5 In this situation, the illustration of venous return-right atrial pressure that was used to argue that venous return increases because right atrial pressure decreases, given a constant mean circulatory pressure,3 could be questioned. Indeed, the switch in vascular volume between compliant...
compartments affects mean circulatory pressure, right atrial pressure, the resistance to venous return, and ultimately venous return. Stated in this way, right atrial pressure-mean circulatory pressure should be the pressure gradient caused by flow rather than the gradient for venous return.

When cardiac output increases, venous pressure decreases because the venous reservoir is depleted. As stated by Levy, the development of a mathematical model is an abstraction, and hence the assignment of dependent and independent variables may be arbitrary. Thus, right atrial pressure may be the consequence of the cardiac flow value around the circuit. In a review article, Tyberg demonstrated how changing venous tone modulates cardiac output both in physiologic conditions and in disease states. Preferring the interpretation of Levy, Tyberg has extended his concepts and developed a modified pressure-volume mode of circulation. Also, in the hope of clarifying this issue, Brengelmann reexamined this question through a review of the original experiments on venous return. He emphasized the fact that Guyton et al did not record venous return in dynamic states but that their data were all taken from steady states. In a different experimental preparation (from the one employed by Guyton et al), he maintained a fixed blood volume to illustrate the consequences of and the differences between dynamic and steady-state conditions. This experiment indicated that an increase in right atrial pressure causes increased cardiac output in the cardiac sub-division and that an increase in cardiac output causes decreased right atrial pressure in the vascular sub-di-ision.

The role of the normal heart in regulating cardiac output is to lower right atrial pressure, allowing better drainage of blood from the compliant veins and venules, which means that venous return and right atrial pressure are dependent variables. This statement is in agreement with the relatively more recent point of view given by Guyton when reviewing the article by Levy (see the editors’ note at the end of the article). For Guyton, the question “is right atrial pressure the stimulus (independent variable) and the cardiac flow the response (dependent variable) or vice versa” is not a good question. The independent variables are such factors as heart rate, contractility, and the resistance and capacitance of each segment of the circulation. Considering reflexes and hormones, even the independent variables cited above become dependent variables. Therefore, both right atrial pressure and venous return are dependent variables, and both may be displayed on the horizontal axis or the vertical axis.

When teaching, the senior lecturer has to choose a particular way of describing the relationship between two dependent variables in order to avoid confusing medical students. We may expect that the question of what would happen to cardiac output if the venous pressure value changed equals what would happen to the venous pressure if the cardiac output changed, as the two variables are dependent and interdependent. Therefore, we imagine that Guyton has not imposed plots of these open-loop relationships of two variables. He has preferred one question in regard to another. He has made the choice of a teacher.