Definition of Terms

Blood flow is the volume of blood flowing through a vessel, an or- gan, or the entire circulation in a given period (ml/min). If we consider the entire vascular system, blood flow is equivalent to cardiac output (CO), and under resting conditions, it is relatively constant. At any given moment, however, blood flow through *individual* body organs may vary widely according to their immediate needs.

Blood pressure (BP), the force per unit area exerted on a vessel wall by the contained blood, is expressed in millimeters of mercury (mm Hg). For example, a blood pressure of 120 mm Hg is equal to the pressure exerted by a column of mercury 120 mm high.

Unless stated otherwise, the term *blood pressure* means systemic arterial blood pressure in the largest arteries near the heart. The pressure gradient—the *differences* in blood pressure within the vascular system—provides the driving force that keeps blood moving, always from an area of higher pressure to an area of lower pressure, through the body.

Resistance is opposition to flow and is a measure of the amount of friction blood encounters as it passes through the vessels. Be- cause most friction is encountered in the peripheral (systemic) circulation, well away from the heart, we generally use the term **peripheral resistance**.

There are three important sources of resistance: blood viscosity, vessel length, and vessel diameter.

Blood Viscosity The internal resistance to flow that exists in all fluids is *viscosity* (vis-kos′ĭ-te) and is related to the thickness or "stickiness" of a fluid. The greater the viscosity, the less eas- ily molecules slide past one another and the more difficult it is to get and keep the fluid moving. Blood is much more viscous than water. Because it contains formed elements and plasma proteins, it flows more slowly under the same conditions.

Blood viscosity is fairly constant, but conditions such as polycythemia (excessive numbers of red blood cells) can increase blood viscosity and, hence, resistance. On the other hand, if the red blood cell count is low, as in some anemias, blood is less viscous and peripheral resistance declines.

Total Blood Vessel Length The relationship between total blood vessel length and resistance is straightforward: the longer the vessel, the greater the resistance. For example, an infant's blood vessels lengthen as he or she grows to adulthood, and so both peripheral resistance and blood pressure increase.

Blood Vessel Diameter Because blood viscosity and vessel length are normally unchanging, the influence of these factors can be considered constant in healthy people. However, blood vessel diameter changes frequently and significantly alters peripheral resistance. How so? The answer lies in principles of fluid flow. Fluid close to the wall of a tube or channel is slowed by friction as it passes along the wall, whereas fluid in the center of the tube flows more freely and faster. You can verify this by watching the flow of water in a river. Water close to the bank hardly seems to move, while that in the middle of the river flows quite rapidly.

In a tube of a given size, the relative speed and position of fluid in the different regions of the tube's cross section remain constant, a phenomenon called *laminar flow* or *streamlining*. The smaller the tube, the greater the friction, because relatively more of the fluid contacts the tube wall, where its movement is impeded.

Resistance varies *inversely* with the *fourth power* of the vessel radius (one-half the diameter). This means, for example, that if the radius of a vessel doubles, the resistance drops to one- sixteenth of its original value. For this reason, the large arteries close to the heart, which do not change dramatically in diameter, contribute little to peripheral resistance. Instead, the small-diameter arterioles, which can enlarge or constrict in response to neural and chemical controls, are the major determinants of peripheral resistance.

When blood encounters either an abrupt change in vessel diameter or rough or protruding areas of the tube wall (such as the fatty plaques of atherosclerosis), the smooth laminar blood flow is replaced by *turbulent flow*, that is, irregular fluid motion where blood from the different laminae mixes. Turbulence dramatically increases resistance.

Relationship Between Flow, Pressure, and Resistance

Now that we have defined these terms, let's summarize the relationships between them.

- Blood flow (*F*) is *directly* proportional to the difference in blood pressure (ΔP) between two points in the circulation, that is, the blood pressure, or hydrostatic pressure, gradient. Thus, when ΔP increases, blood flow speeds up, and when ΔP decreases, blood flow declines.
- Blood flow is *inversely* proportional to the peripheral resistance (*R*) in the systemic circulation; if *R* increases, blood flow decreases.

We can express these relationships by the formula

$$F = \frac{\Delta P}{R}$$

Of these two factors influencing blood flow, *R* is far more im- portant than ΔP in influencing local blood flow because *R* can easily be changed by altering blood vessel diameter. For example, when the arterioles serving a particular tissue dilate (thus decreasing the resistance), blood flow to that tissue increases, even though the systemic pressure is unchanged or may actually be falling.

Marieb, E. N., & Hoehn, K. N. (2012). Human Anatomy & Physiology (9th Edition). Pearson.
Pagina 759 en 760