arterial blood flow but augments venous flow. On a clinical note, tachycardia is particularly detrimental because coronary flow is reduced when the diastolic filling time is abbreviated, and the Mvo_2 increases with increasing HR. In order to sustain constant perfusion to the myocardium, coronary blood flow is maintained constant over a wide range of pressures in a process called autoregulation.

In response to a change in Mvo_2, the coronary arteries dilate or constrict, which changes the vascular resistance and thereby appropriately changes flow. This regulation of arterial resistance occurs at the arterioles and is mediated by several factors. Adenosine, a metabolite of ATP, is released during contraction and acts as a potent vasodilator. Other consequences of myocardial metabolism, such as decreased oxygen tension, increased carbon dioxide, acidosis, and hyperkalemia, also mediate coronary vasodilation. The endothelium produces several potent vasodilators, including nitric oxide and prostacyclin. Nitric oxide is released by the endothelium in response to acetylcholine, thrombin, adenosine diphosphate (ADP), serotonin, bradykinin, platelet aggregation, and an increase in shear stress (called *flow-dependent vasodilation*). Finally, the coronary arteries are innervated by the autonomic nervous system, and activation of sympathetic neurons mediates vasoconstriction or vasodilation through α- or β-receptors, respectively. Parasympathetic neurons from the vagus nerve secrete acetylcholine, which mediates vasodilation. Vasoconstricting factors, notably endothelin, are produced by the endothelium and may be important in conditions such as coronary vasospasm. Please refer to Chapter 53, "Cardiac Function and Circulatory Control," in *Goldman-Cecil Medicine*, 25th Edition.

Physiology of the Systemic Circulation

The normal cardiovascular system delivers appropriate blood flow to each organ of the body under a wide range of conditions. This regulation is achieved by maintaining BP through adjustments in cardiac output and tissue blood flow resistance by neural and humoral factors.

Poiseuille's law generally describes the relationship between pressure and flow in a vessel. Fluid flow (F) through a tube is proportional (proportionality constant = K) to the pressure (P) difference between the ends of the tube:

$$F = K \times \Delta P$$

K is equivalent to the inverse of resistance to flow (R); that is, K = 1/R. Resistance to flow is determined by the properties of both the fluid and the tube. In the case of a steady, streamlined flow of fluid through a rigid tube, Poiseuille found that these factors determine resistance:

$$R = 8\eta L / \pi r^4$$

Where r is the radius of the tube, L is its length, and η is the viscosity of the fluid. Notice that changes in radius have greater influence than changes in length, because resistance is inversely proportional to the fourth power of the radius. Poiseuille's law incorporates the factors influencing flow, so that:

$$F = \Delta P / R = \Delta P \pi r^4 / 8\eta L$$

Therefore, the most important determinants of blood flow in the cardiovascular system are ΔP and r^4. Small changes in arterial radius can cause large changes in flow to a tissue or organ. Practically, systemic vascular resistance (SVR) is the total resistance to flow caused by changes in the radius of resistance vessels (small arteries and arterioles) of the systemic circulation. The SVR can be calculated as the pressure drop across the peripheral capillary beds (mean arterial pressure − right atrial pressure) divided by the blood flow across the beds (i.e., SVR = BP/CO). It is normally in the range of 800 to 1500 dynes-sec/$^{cm-5}$.

The autonomic nervous system alters systemic vascular tone through sympathetic and parasympathetic innervation as well as metabolic factors (local oxygen tension, carbon dioxide levels, reactive oxygen species, pH) and endothelium-derived signaling molecules (NO, endothelin). Neural regulation of BP occurs by means of constitutive and reflex changes in autonomic efferent outflow to modulate cardiac chronotropy, inotropy, and vascular resistance.

The baroreflex loop is the primary mechanism by which BP is neurally modulated. Baroreceptors are stretch-sensitive nerve endings that are distributed throughout various regions of the cardiovascular system. Those located in the carotid artery (e.g., carotid sinus) and aorta are sometimes referred to as *high-pressure baroreceptors* and those in the cardiopulmonary areas as *low-pressure baroreceptors*. After afferent impulses are transmitted to the central nervous system, the signals are integrated, and the efferent arm of the reflex projects neural signals systemically through the sympathetic and parasympathetic branches of the autonomic nervous system. In general, an increase in systemic BP increases the firing rate of the baroreceptors. Efferent sympathetic outflow is inhibited (reducing vascular tone, chronotropy, and inotropy), and parasympathetic outflow is increased (reducing cardiac chronotropy). The opposite occurs when BP decreases. Please refer to Chapter 53, "Cardiac function and Circulatory Control," in *Goldman-Cecil Medicine*, 25th Edition.

Physiology of the Pulmonary Circulation

Like the systemic circulation, the pulmonary circulation consists of a branching network of progressively smaller arteries, arterioles, capillaries, and veins. The pulmonary capillaries are separated from the alveoli by a thin alveolar-capillary membrane through which gas exchange occurs. The partial pressure of oxygen (Po_2) is the main regulator of pulmonary blood to optimize blood flow toward well-ventilated lung segments and away from poorly ventilated segments.

SUGGESTED READINGS

Berne RM, Levy MN: Physiology: part IV. The cardiovascular system, ed 6 with Student Consult Access, St. Louis, 2010, Elsevier.

Guyton AC, Hall JE: Textbook of medical physiology, ed 12, St. Louis, 2011, Elsevier.