2- VASCULAR RESISTANCE AND VASCULAR IMPEDANCE

• Definition and general concepts.
• Estimation of vascular resistance.

• DEFINITION AND GENERAL CONCEPTS.

Vascular resistance is the impediment offered by the vascular bed to flow.

The greatest resistance occurs at the site of the greatest drop in pressure (arterioles).

The percentage of total vascular resistance (1) estimated for each region of the systemic vascular is:
- Aorta and larger arteries: 9%; Small arteries and branches: 16%; Arterioles: 41%; Capillaries: 27%; Venules: 4%; Small veins: 1%; Large veins: 2%.

However, vascular resistance is dependent on the properties of the vessel and its contained fluid, with a pattern of unidirectional and constant blood flow (microcirculation).

Vascular impedance is the impediment offered to flow at the input of a vascular bed where pulsatile flow is involved (aorta and arteries).

The concept of impedance involves the pressure-flow relations at each instantaneous timing change; impedance is a complex mathematical expression, often expressed in Fourier series form. When flow values are constant, increases in pressure cause an increase in impedance. Instead, when pressure values are constant, the increase of flow diminishes the values of impedance.

• ESTIMATION OF VASCULAR RESISTANCE.

The hemodynamic expression of Ohms’s law helps one to understand how the circulation is controlled. Similarly, the Poiseuille equation for flow of homogeneous fluids states can be simplified to determine:

Flow = pressure/resistance;
Arterial pressure = cardiac output x vascular resistance.

The resistance is a ratio, relating pressure and flow, and reflects the vasomotor tone in arterioles, terminal arterioles and precapillaries sphincter.

Vascular resistance = Arterial pressure/ cardiac output.

Knowledge of both the pressure differentials across the pulmonary and systemic circuits and the respective blood flow through them is required.

The formulae are:

Systemic Vascular Resistance (SVR) = (Ao – RA)/ Qs
Pulmonary Vascular Resistance (PVR) = (PA-LA)/ Qp

Abbreviations: Ao: mean systemic arterial pressure; RA: mean right atrial pressure; PA: mean pulmonary arterial pressure; LA: mean left atrial pressure; Qs: systemic blood flow; Qp: pulmonary blood flow.

Data in these formulae are expressed in liters per minute (blood flow), and pressures are in millimeters of mercury. These equations yield resistance in arbitrary resistance units (R units). They may be converted in dynes-seconds-cm-5 by using the conversion factor 80. The normal values of vascular resistance are shown in Table 1.

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Values are expressed as mean ± standard deviation, and are derived from 37 subjects (17 males, 20 females aged 47 ± 9 years).


3- ARTERIAL PRESSURE

• Definition and Units.
• Determinants of the arterial pressure.
• Pulse wave velocity.
• First derivate (dP/dt) of the arterial pressure.

• DEFINITION AND UNITS.

Pressure (P) is defined as the force exerted per unit cross-sectional area of surface, the force being exerted...
at right angles, or normal, to the surface.
Pressure as force per unit area is expressed in dynes per square centimeter, a unit designated as the bar. In biology and medicine one millimeter of mercury (is equal to about 1,330 dynes/cm²) it is used, as unit.

- **DETERMINANTS OF THE ARTERIAL PRESSURE.**

An analysis of the factors influencing arterial pressure (systolic, diastolic and mean) is important, because it may suggest the nature and site of hemodynamic disorders.

The primary determinants of the systolic arterial pressure are stroke volume, ejection velocity and arterial distensibility. On the other hand, the diastolic arterial pressure is influenced by the following factors: peripheral resistance, heart rate, distensibility and systolic pressure (2) (fig. 4).

An increase in stroke volume will cause an increase of the systolic pressure and a more rapid ejection will similarly increment the systolic pressure because of inadequate time for the aortic wall to distend in response to the ejection volume. The lesser distensibility or compliance in the arterial wall produces a higher systolic pressure and a lesser diastolic pressure (effect of advancing age). Contrary modifications to those primary determinants produce inverse effects on the systolic arterial pressure.

An increase of the peripheral resistance raises the diastolic pressure. An augmented heart rate will interrupt the diastolic decline at a higher point of the curve and it raises the diastolic pressure. The increment of systolic pressure results in a rise in diastolic pressure. With decreased arterial distensibility, the lack of recoil will not sustain the diastolic pressure, which will then fall off more rapidly. In such cases, contrary modifications produce inverse effects.

In arterioles and capillaries there are accentuated drops of pressure with active interchanges between tissues and blood that circulates with continuous flow.

- **PULSE WAVE VELOCITY.**

The arterial pulse created in the aorta represents the pressure wave. It precedes the flow wave and travels at a quicker velocity. Pulse wave velocity is 3 to 5 meters/sec in the aorta, 7 to 9 meters/sec in the subclavian and femoral arteries, and 15 to 40 meters/sec in small arteries (See: **Velocity of the bloodstream**).

Pulse wave velocity increases when: a) cross-sectional area of the artery decreases; b) distensibility or compliance of the artery decreases (hypertension, arteriosclerosis).

- **FIRST DERIVATIVE (dP/dt) OF THE ARTERIAL PRESSURE.**

The pressure waveforms are influenced by forward pressure and flow waves in the central aorta. However, the pressure waves and the flow waves are modified by the summation of reflected pressure waves and reflected flow waves (3).

![Figure 4: Main determinants of systolic and diastolic arterial pressures. Reproduced from Smith JJ, Kampine JP. Circulatory Physiology. Williams & Wilkins, Baltimore, 1980.](image1)

![Figure 5: Recording of the aortic pressure and its first derivative, dp/dt, in a patient with acute aortic dissection and severe augmentation of the arterial pressure. Adequate descent of the arterial pressure and dp/dt is obtained with antihypertensive drugs including β - adrenergic blockers. (del Rio M, Baglivo H, Pujadas G, Mena J. “Accésit” Prize of Clinical Investigation. Title: Hemodynamic and functional evaluation of patients with hypertension. Sociedad Argentina de Cardiología, 1978.](image2)