Let us consider the cardiovascular system as a simple hydraulic circuit, where there is a pump (heart) with a rhythmic activity (systole → diastole → systole ...) that pushes a liquid (blood) into a tube (aorta), which divides over and over again (peripheral arteries → arterioles → capillaries) to be able to reach the farthest extremes (tissues).

This hydraulic circuit is very similar to a simple electric circuit, and we have to stress that electrical models are often used to verify cardiovascular hemodynamic phenomena.

According to Ohm’s law (Fig. 2.1), the potential difference between the extreme points of an electric circuit ($\Delta V = V_1 - V_2$) is defined by multiplying the current ($I$) by the resistance of the circuit ($R$).

$$\Delta V = I \cdot R.$$ 

The cardiovascular system can be considered in a similar way (Fig. 2.2), and the law which defines blood pressure comes directly from Ohm’s law:

- The difference in blood pressure values between the extreme points of the systemic circulation ($\Delta P = P_1 - P_2$) represents the potential difference between the extreme points of an electric circuit ($\Delta V = V_1 - V_2$);
• The cardiac output (CO) represents the current (I);
• The systemic vascular resistance (SVR) represents the resistance of the circuit (R).

\[ \Delta P = CO \cdot SVR. \]

As blood pressure back to the heart is very low, let us consider the pressure value as the value of blood pressure in ascending aorta (P), therefore the formula can be simplified by writing

\[ P = CO \cdot SVR. \]

As cardiac output (CO) is given by multiplying stroke volume (SV) by heart rate (HR), the formula can be rewritten as

\[ P = SV \cdot HR \cdot SVR \]

(blood pressure = stroke volume \cdot heart rate \cdot systemic vascular resistance).

However, we must point out that blood pressure values change during the cardiac cycle, so the term “P” defined by the formula above refers to mean arterial pressure (MAP). Therefore,

\[ MAP = SV \cdot HR \cdot SVR. \]

According to this formula, blood pressure values depend on just three parameters: stroke volume, heart rate and systemic vascular resistance (Fig. 2.3). It is important to note that, for decades, both research and clinical application focused their attention on these three factors affecting mean arterial pressure.

There is no doubt that mean pressure is a very important parameter. Moreover, it has a quality which makes it even more interesting, namely its relative “stability” in the arterial tree. In other words, mean arterial pressure tends to remain unchanged in the arterial system, from ascending aorta to peripheral arteries (Fig. 2.4).
How can mean arterial pressure be calculated?

Mean arterial pressure is generally calculated from brachial systolic and diastolic blood pressure (BP), according to the following formula:

\[
\text{Mean arterial pressure} = \text{diastolic BP} + \frac{(\text{systolic BP} - \text{diastolic BP})}{3}.
\]

In other words,

\[
\text{Mean arterial pressure} = \text{diastolic BP} + 33\% \text{ of pulse pressure.}
\]

However, more recent studies have suggested using the following formula:

\[
\text{Mean arterial pressure} = \text{diastolic BP} + 40\% \text{ of pulse pressure.}
\]
For more accurate calculation of mean arterial pressure, the brachial artery pressure curve can also be recorded by means of a tonometer. Once the brachial artery pressure curve is taken, the integral of the pressure curve is calculated, corresponding to the real mean arterial pressure. Now the exact ratio between mean arterial pressure and pulse pressure can be easily obtained; this topic will be dealt with later.

Are these three parameters (SV, HR, and SVR) sufficient to explain the changes in pressure found in both physiological and pathological conditions?

Let us analyze Fig. 2.5. In this figure, we can see the condition of two subjects with very different blood pressure levels. The subject on the left (a) has 80 mmHg diastolic blood pressure and 130 mmHg systolic blood pressure. On the contrary, the subject on the right (b) has 60 mmHg diastolic blood pressure and 160 mmHg systolic blood pressure.

![Graph showing mean arterial pressure for subjects (a) and (b)](image_url)

**Fig. 2.5** Example of two subjects with the same mean arterial pressure values: a normotensive, and b with isolated systolic hypertension. Waveforms were recorded in the brachial artery.

Therefore, subject (a) has blood pressure values within the normal range, while subject (b) is characterized by a condition of true isolated systolic hypertension. However, both of these subjects present the same mean arterial pressure value (100 mmHg). They could both have the same values of heart rate, stroke volume, and systemic vascular resistance.

We can conclude that different pressure values can correspond to the same mean blood pressure value.

This example is sufficient to answer the question above.
The three parameters:
- Heart rate
- Stroke volume
- Systemic vascular resistance
define mean arterial pressure, but they are not sufficient, in themselves, to justify blood pressure values.
Let us, therefore, introduce the concept of pulse pressure.
Pulse Waves
How Vascular Hemodynamics Affects Blood Pressure
Salvi, P.
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