

Hemodynamic measurements (pediatrics)

In addition to routine methods such as CVP or IBP measurements, modern thermodilution methods and the ability to **analyze the arterial pressure pulse curve** (eg. the PiCCO method) make it possible to determine more detailed hemodynamic parameters. Thermodilution methods are proving to be more accurate than ultrasounds determination of cardiac output (EBM data). For the needs of pediatrics, the most important is the indexed values of individual parameters, which are related to the body surface and thus allow comparison between the values of patients of different age groups.

Parameters defining the preload

In addition to CVP (pressure parameter defining the right ventricular preload), which is the most commonly used preload marker, we can monitor a number of other parameters in more detailed hemodynamic measurements:

- *global end-diastolic volume* (GEDVI) indicates the volume of blood contained in all 4 cavities of the heart at the end of diastole,
- *intrathoracic blood volume* (ITBVI) indicates the volume of blood contained in all 4 heart cavities at the end of diastole + blood volume in the pulmonary vessels (ITBVI = 1.25 x GEDVI).

ITBVI and GEDVI show greater sensitivity and specificity in determining cardiac preload than standard CVP and PAWP, but also right ventricular end-diastolic volume calculated by echocardiography. Another advantage of ITBVI and GEDVI is that they do not interfere with artificial lung ventilation. Indexed values must be used for children.

In patients with UPV, we can use another parameter of hemodynamics - (*stroke volume variation*, SVV - dynamic parameter). SVV reflects changes in cardiac preload depending on UPV cycles. An increase in the SVV value predicts the need for volume expansion.

Parameters defining afterload

In practice, as a determinant of afterload, we evaluate systemic and pulmonary vascular resistance (based on Ohm's law). Knowing the cardiac output (CO) values, we can calculate the value of *systemic vascular resistance* (SVR) :

$$\text{SVR} = (\text{MAP} - \text{CVP}) \times 80 / \text{CO}$$

$$\text{PerP} = \text{MAP} - \text{CVP}$$

$$\text{SVR} = (\text{MAP} - \text{CVP}) \times 80 / \text{CO} = \text{PerP} \times 80 / \text{CO}$$

Where PerP = *perfusion pressure*, is the difference between mean arterial pressure and central venous pressure. The indexed value of SVR related to body area is SVRI:

$$\text{SVRI} = (\text{MAP} - \text{CVP}) \times 80 / \text{CI} = \text{PerP} \times 80 / \text{CI}$$

Based on these relationships, it is possible to increase cardiac output by reducing vascular resistance. At the same time, however, it follows that good blood pressure may not indicate good cardiac output (vascular resistance may increase with decreasing cardiac output).

The same applies to pulmonary vascular resistance :

$$\text{PVR} = (\text{MPAP} - \text{PAOP}) \times 80 / \text{CO}, \text{ resp. } \text{PVRI} = (\text{MPAP} - \text{PAOP}) \times 80 / \text{CI}$$

MPAP is *mean pulmonary artery pressure* and PAOP is *pulmonary artery opening pressure*; (Cave!: confused with a pressure wedge. PAWP pulmonary, Pulmonary artery wedge pressure).

Extravascular lung water

Extravascular lung water (EVLW) indicates the volume of free water in the lungs and allows bedside quantification of the severity of pulmonary edema. In addition to pulmonary edema, it correlates with the severity of ARDS or the length of UPV. It is a better indicator of pulmonary edema than a chest x-ray.

Contractility

Contractility is the intrinsic inotropic activity of the myocardium independent of preload and afterload. Its exact determination is very difficult. It is affected by ionized calcium, compliance and the supply of myocardial energy substrates. An indicator of contractility is the ability to develop pressure per unit time, in practice the following is used:

- maximum ventricular elastance index according to Sugi and Sagawi,
- heart rate values left resp. right ventricle: LVSW resp. RVSW (left / right ventriculus stroke work),

$$\text{LVSW} = 0,0136 \times \text{SV} \times (\text{MAP} - \text{PAOP})$$

$$\text{RVSW} = 0,0136 \times \text{SV} \times (\text{MPAP} - \text{CVP})$$

- global ejection fraction (GEF) and cardiac function index (CFI) derived from parameters measured by the PiCCO system
- the level of myocardial contractility can also be estimated in the simplest way from the steepness of the rise of the pulse curve during direct measurement of arterial pressure.

Cardiac output

Within the possibilities of more detailed hemodynamics, we are able to determine the stroke volume (SV). Based on this value, we can calculate **cardiac output** (CO), which is the product of stroke volume and [cardiac frequency]] (heart rate) :

$$CO = HR \times SV$$

By recalculation to the body surface, we obtain the cardiac index = CI.

CO calculation using Fick´s formula :

$$CO = [VO_2 / (C_aO_2 - C_vO_2)] \times 10$$

Pulmonary wedge blood pressure measurement (PAWP)

We measure the PAWP (pulmonary artery wedge pressure) value with a **Swan-Ganz catheter**. It is the result of pulmonary resistance and left heart function. Its values are close to the pressure in the left atrium. Used to accurately determine CI (cardiac index). It has a rare application in pediatrics.

Reference values: 6-16 cm H₂O (ideally 7-15 cm H₂O)

Selected hemodynamic parameters

	parametr	jednotka	norma
cardiac output	CI (cardiac index)	l/min/m ²	3,0-4,5 (5,5)
preload	CVP (central venous pressure)	mm Hg	3-10
lung	EVLW (extravascular lung water)	ml/kg	3,0-7,0
afterload	SVRI (systemic vascular resistance index)	dyne.s.cm/5.m/2	800-1600
contractility	EF (ejection fraction)	%	55-75

Links

Source

- HAVRÁNEK, Jiří: *Šok*. (upraveno)