Неінвазивний моніторинг серцевого викиду

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No conflicts of interest
Despite improvements in resuscitation and supportive care, **progressive organ dysfunction occurs** in a large proportion of patients with acute, life-threatening illnesses and those undergoing major surgery.


**Early aggressive resuscitation** of critically ill patients may limit and/or reverse tissue hypoxia and progression to organ failure and improve outcome.

protocol of early goal-directed therapy reduces organ failure and improves survival in patients with severe sepsis and septic shock


Optimization of cardiac output (CO) in patients undergoing major surgery has been shown to reduce postoperative complications and the length of stay.

Excessive fluid resuscitation has been associated with increased complications, increased lengths of intensive care unit and hospital stay, and increased mortality.

...only about 50% of hemodynamically unstable patients are volume responsive.

If the fluid challenge does not increase the SV, volume loading serves the patient no useful benefit and is likely to be harmful.

The measurements of SV and CO are fundamental to the hemodynamic management of critically ill and injured patients and unstable patients in the operating room.

Both fluid challenges and the use of inotrophic agents/vasopressors should be based on the response of the SV to either of these challenges.
Adolph Fick described the first method of CO estimation in 1870.

\[ \dot{Q} = \frac{V_{O_2}}{(C_{aO_2} - C_{vO_2})} \]

the reference standard of determining CO until the introduction of the PAC in the 1970s.

Swan-Ganz Catheter

gold standard for the measurement of CO and is the reference standard used to compare noninvasive technologies.
CO AS MEASURED BY CARBON DIOXIDE REBREATHEING

the modified Fick equation
NICO (Respirronics, Murraysville, PA)

A limitation of the rebreathing CO2 CO method is that it only measures pulmonary capillary blood flow (ie, the nonshunted portion of the CO)

hyperventilation
low minute ventilation,
high shunt fraction
high CO
Considering the limitations of this technology and the potential inaccuracies, the routine use of the CO2 rebreathing technique to guide fluid and vasopressor therapy cannot be recommended.

ESOPHAGEAL DOPPLER

The resulting waveform is highly dependent on correct positioning. The clinician must adjust the depth, rotate the probe, and adjust the gain to obtain an optimal signal.

A major limitation of esophageal Doppler monitoring is the assumption that a fixed percentage of the CO is directed to the head and descending aorta. In hemodynamically unstable patients, the increase in blood flow velocity in the descending aorta may not correlate well with the increase in the SV.
completely noninvasive Doppler technology, the ultrasound CO monitor (USCOM, Sydney, Australia)

limitation of this technique is that it is not conducive to continuous monitoring
PULSE CONTOUR ANALYSIS

relation among:
• blood pressure
• SV
• arterial compliance
• systemic vascular resistance (SVR)

3 categories:

(1) pulse contour analysis requiring an indicator dilution CO measurement to calibrate the pulse contour (LiDCO System; LiDCO, Cambridge, UK; and PiCCO System; Pulsion, Munich, Germany)

(2) pulse contour analysis requiring patient demographic and physical characteristics for arterial impedance estimation (ie, FloTrac System; Edwards Lifesciences, Irvine, CA)

(3) pulse contour analysis that does not require calibration or preloaded data (ie, MostCare System; Vytech Health, Padua, Italy).
LIMITS

The differences in blood pressure among different sites may be large, and in conditions of intense vasoconstriction, the radial blood pressure may underestimate the true aortic blood pressure, giving a falsely low CO value.

Furthermore, it has been shown that in volume-responsive patients there is selective redistribution of blood flow to the cerebral circulation with a significantly smaller percentage increase in blood flow in the brachial artery.

This may lead to a significant error when the radial pulse is used for pulse contour analysis.

Lithium Dilution and Pulse Contour Analysis

The LiDCO … to be at least as reliable as other thermodilution methods over a broad range of CO in a variety of patients.


Cardiac Output = (Lithium Dose x 60)/(Area x (1-PCV))

Recalibration should be performed after acute hemodynamic changes and after any intervention that alters vascular impedance.
Transpulmonary Thermodilution and Pulse Contour Analysis

PiCCO

via continuous pulse contour analysis

- Continuous pulse contour cardiac analysis (PCCO)
- Arterial blood pressure (AP)
- Heart rate (HR)
- Stroke volume (SV)
- Stroke volume variation (SVV)
- Systemic vascular resistance (SVR)
- Index of left ventricular contractility
Transpulmonary Thermodilution and Pulse Contour Analysis

PiCCO

via intermittent transpulmonary thermodilution

- Transpulmonary cardiac output (C.O.)
- Intrathoracic blood volume (ITBV)
- Extravascular lung water (EVLW)
- Cardiac function index (CFI)

In a randomized controlled trial, Mutoh et al. showed an improved clinical outcome for patients with subarachnoid hemorrhage randomized to a PiCCO-based hemodynamic algorithm as compared with the “standard of care,” which used a PAC algorithm.

Pulse Contour Requiring Patient Demographic and Physical Characteristics and No Calibration

FloTrac sensor

Vigileo monitor

The basic principle of the system is the linear relation between the pulse pressure and the SV.

\[ \text{SV} = \text{SD}_{\text{AP}} \times X \]

The factor \( X \) represents the conversion factor that depends on:
- arterial compliance
- the mean arterial pressure
- waveform characteristics

Limit

the system does not track changes in the SV accurately after a volume challenge or after the use of vasopressors
Pulse Contour Requiring No Patient Data and No Calibration

The MostCare system

the pressure recording analytic method (PRAM)

The area under the curve of the arterial waveform

The accuracy of this system:

• the patent holder’s group showing good results
• independent studies have shown mixed results

<table>
<thead>
<tr>
<th>System Characteristic</th>
<th>FloTrac System</th>
<th>PICCO System</th>
<th>LIDCO System</th>
<th>PRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial waveform analysis</td>
<td>SD of 2000 arterial waveform points</td>
<td>Area under the systolic portion of the arterial waveform</td>
<td>RMS method applied to the arterial pressure signal</td>
<td>Area under curve</td>
</tr>
<tr>
<td>Requirements</td>
<td>Peripheral or central arterial catheter</td>
<td>Central arterial catheter and subclavian or IJ CVC</td>
<td>Peripheral or central arterial catheter</td>
<td>Peripheral or central arterial catheter</td>
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<tr>
<td>Calibration</td>
<td>Uncalibrated/internal</td>
<td>Transpulmonary thermodilution</td>
<td>Lithium indicator dilution</td>
<td>Uncalibrated/internal</td>
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<tr>
<td>Recalibration Indicator</td>
<td>Automatically</td>
<td></td>
<td>Manual</td>
<td>Automatic</td>
</tr>
<tr>
<td>Additional parameters</td>
<td>None</td>
<td>Saline</td>
<td>Lithium</td>
<td>None</td>
</tr>
<tr>
<td>Advantages</td>
<td>Minimally invasive</td>
<td>Broad range of hemodynamic parameters</td>
<td>Minimally invasive</td>
<td>Minimally invasive</td>
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<tr>
<td></td>
<td>Operator independent</td>
<td>More robust during hemodynamic instability</td>
<td>More robust during hemodynamic instability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Easy to use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Inaccurate especially in vasoplegic patients</td>
<td>More invasive</td>
<td>Requires lithium</td>
<td>Few validation studies</td>
</tr>
<tr>
<td></td>
<td>Does not accurately track changes in SV</td>
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</table>

Adapted with permission. Abbreviations: CVC, central venous catheter; GEDV, global end-diastolic volume; EVLW, extravascular lung water; IJ, internal jugular; RMS, root mean square.
SV is proportional to the product of maximal rate of the change of Zo (dZo/dtmax) and ventricular ejection time (VET).
Bioimpedance has been found to be inaccurate in the intensive care unit and other settings in which significant electric noise and body motion exist and in patients with increased lung water.


...this technique is sensitive to:

- the placement of the electrodes
- variations in patient body size
- the skin temperature and humidity

BIOREACTANCE

NICOM device (Cheetah Medical, Portland, OR)

bioreactance - the phase shift in voltage across the thorax

Additional studies are required to confirm the accuracy, reliability, and versatility with this device and to show improved patient outcomes.

- in ventilated and nonventilated patients
- in patients with atrial and ventricular arrhythmias
- in the emergency room, intensive care unit, and operating room
Estimated Continuous Cardiac Output
esCCO

CO = SV x HR = K X (α x PWTT x β) x HR = esCCO
The protocol for early goal-directed resuscitation of patients with sepsis.
The protocol for hemodynamic optimization in the operating room:
Неинвазивное измерение СВ у больных старческого возраста

- Клиника хирургии ЗГМУ
- Хирург Клименко В.Н., Завгородний С.Н.
- Анестезиолог Воротынцев С.И.
- Лапаротомии
- Средний возраст 82 ± 6 лет [77 - 92]
- 12 пациентов
- 11 пациентов выписаны, 1 пациент в стационаре
<table>
<thead>
<tr>
<th>Показатель</th>
<th>Результат</th>
<th>Ед.изм.</th>
<th>Муж</th>
<th>Жен</th>
</tr>
</thead>
<tbody>
<tr>
<td>Лейкоциты (WBC)</td>
<td>5,5</td>
<td>Гл</td>
<td>4,0</td>
<td>9,0</td>
</tr>
<tr>
<td>Эритроциты (RBC)</td>
<td>2,24</td>
<td>Гл</td>
<td>4,0</td>
<td>5,7</td>
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<tr>
<td>Гемоглобин (HGB)</td>
<td>54</td>
<td>Гл</td>
<td>130</td>
<td>160</td>
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<tr>
<td>Гематокрит (HCT)</td>
<td>0,170</td>
<td>Гл</td>
<td>0,35</td>
<td>0,50</td>
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<tr>
<td>Тромбоциты (PLT)</td>
<td>287</td>
<td>Гл</td>
<td>150</td>
<td>350</td>
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<tr>
<td>Средний объем эритроцита (MCV)</td>
<td>76</td>
<td>Гл</td>
<td>80</td>
<td>100</td>
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<tr>
<td>Среднее содержание HB в эритроците (MCH)</td>
<td>23,9</td>
<td>Гл</td>
<td>27</td>
<td>31</td>
</tr>
<tr>
<td>Средняя концентрация HB в эритроците (MCHC)</td>
<td>316</td>
<td>Гл</td>
<td>330</td>
<td>370</td>
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<tr>
<td>Распределение эритроцитов по объему (RDW)</td>
<td>14,8</td>
<td>%</td>
<td>11,5</td>
<td>14,5</td>
</tr>
<tr>
<td>Плазмоциты (LYM)</td>
<td>22,2</td>
<td>%</td>
<td>17,0</td>
<td>42,0</td>
</tr>
<tr>
<td>Моноклоны (MOR)</td>
<td>5,7</td>
<td>%</td>
<td>3,0</td>
<td>11,0</td>
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<tr>
<td>Гранулоциты (GRA)</td>
<td>72,1</td>
<td>%</td>
<td>43,0</td>
<td>76,0</td>
</tr>
</tbody>
</table>

Результат исследования не является диагнозом и требует консультации лечащего врача.
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Подпись: [Сигнатура]
1. Микрорасширен возникает
2. Состояние по ул.
3. Активация 100 бр.
4. Присутствие 100 бр.
5. Присутствие 100 бр.
6. Применение анестезии

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15:30

Подпись: [подпись]

[дата подписи]
Неинвазивное измерение СВ - еще один мониторируемый параметр, обеспечивающий безопасность пациентов, путем рационального использования жидкости, инотропов и вазоактивных препаратов.

In conclusion
Дякую за увагу