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CHAPTER 6

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INTRODUCTION

In patients with cardiogenic shock, monitoring cardiac output and other measures of heart and vessel function is cornerstone of diagnostics and management. By definition, patients with cardiogenic shock have an impaired cardiac function. Hemodynamic monitoring of the macrocirculation is thought to represent the delivery of oxygen to the tissues. The heart as a pump for the circulation fails to establish a circulation sufficient enough to perfuse organs and the vessels do not compensate for the loss of cardiac function sufficiently. Interventions in patients with cardiogenic shock aim to support cardiac function and the circulation by a combination of fluids, vasopressors, inotropic agents, and eventually mechanical circulatory support. For all these interventions, the effect on clinical outcome is less established, especially regarding the question on which fluid and which inotropic agent are to be preferred. Even more, the effect of monitoring on clinical outcome in patients with cardiogenic shock is hardly known. This chapter presents an overview of basic and advanced hemodynamic monitoring in patients with cardiogenic shock and aims to elucidate the current evidence of monitoring on clinical outcome.

DIAGNOSTIC VALUE OF MONITORING

In patients with cardiogenic shock, monitoring devices are primarily used for defining the current function of the heart and the circulation (static measurement) and to observe the effect over time as part of monitoring the effect of interventions and the disease course of individual patients (dynamic measurement). In general, it can be concluded that monitoring devices have a greater accuracy in individual patients, i.e. to indicate trends after certain interventions such as fluid administration or vasoactive medication, than to set an absolute value of a certain measure. In other words, a change in cardiac output or systemic vascular resistance in an individual patient is more likely to resemble a real change than that a measurement of a cardiac output in one patient of 2.5 L/min is equal to a cardiac output of 2.5 L/min in another patient. Not for all devices, the static and dynamic accuracy are equal. Some devices

can measure, for instance, cardiac output more accurately but lack the technical capacity to be considered a continuous monitoring (like critical care echocardiography), while other are less accurate in measuring the exact cardiac output but are a continuous monitoring device [like the Pulse Contour Cardiac Output (PiCCO) device]. For most measures, thermodilution via the pulmonary artery catheter is considered the gold standard method although the differences in techniques might drive differences in outcomes of measures more than the lack of accuracy of an individual device, i.e. the difference between a cardiac output measured by a pulmonary artery catheter, a PiCCO and critical care echocardiography might be due to invasive versus minimal invasive and ultrasound differences and not by a lack of diagnostic accuracy of an individual device. For daily practice, two main conclusions can be set: first, physicians should be aware that the absolute values obtained by hemodynamic monitoring differ by devices. Second, physicians should know that monitoring trends in individual patients has a greater implication on management that the absolute value of a single measure while using the same device.

Value of Monitoring on Outcome

Monitoring devices are usually divided based on invasiveness into basic monitoring devices and (more) advanced monitoring devices. For decades, the pulmonary artery catheter (PAC) was used to monitor cardiovascular function in patients with shock, with thermodilution as the clinical gold standard for cardiac output measurements. More recently, a growing number of less invasive (e.g. transpulmonary thermodilution) and even noninvasive monitoring techniques (e.g. uncalibrated pulse contour analysis) have been introduced and suggested to serve as alternatives for monitoring these patients.[1,2] However, these noninvasive or less invasive monitoring techniques are less accurate,[3] and the measured variables not interchangeable with those from invasive "gold standards" in terms of absolute values.[4] Therefore, their value for guiding therapy might be limited, although it has repeatedly been shown that changes in cardiac output (e.g. after volume expansion or vasoactive medication) can be tracked with sufficient accuracy also by less invasive monitoring devices. Hence, pulmonary artery catheterization might be preferred in a critically ill patient with circulatory shock and right ventricular failure or pulmonary artery hypertension but not in a less severely ill patient. For a patient with circulatory shock and acute respiratory failure, however, transpulmonary thermodilution could be a better choice, since it additionally allows the assessment of extravascular lung water. For indications like assessing fluid responsiveness with dynamic tests (e.g. passive leg raising of fluid challenge), less invasive pulse contour analysis is suitable to guide further (goal-directed fluid) management.

A single concluding statement on the value of hemodynamic monitoring cannot be made. In order to extrapolate the findings to patients with cardiogenic shock, the most interesting group to consider for hemodynamic monitoring are hemodynamic unstable patients. Various studies investigated the accuracy of different devices.[5] In general, one should consider the value of devices to establish a diagnosis and the value to guide treatment.

Value to Establish a Diagnosis and Underlying Cause

Hemodynamic monitoring devices are of utmost importance to study the function of the heart and vessels. With several monitoring devices, one can set the diagnosis cardiogenic shock and define the underlying mechanism among all patients with shock, i.e. regional wall motion disturbances in myocardial infarction, diffuse wall motion dysfunction in myocarditis, severe valve dysfunction caused by endocarditis, or papillary muscle rupture. No one will argue against the importance of setting the exact diagnosis cardiogenic shock (and its underlying causes) over hypovolemic shock or septic shock. Setting a correct diagnosis has great impact on outcome, as it guides treatment like percutaneous coronary intervention, cardiac surgery, or systemic antibiotics. These considerations are in line with recent recommendations on invasive hemodynamic monitoring in patients with cardiogenic shock.[6]

Value to Guide Treatment

If the diagnosis of cardiogenic shock and the underlying cause is set, it is less clear, if the use of hemodynamic monitoring devices will have an impact on outcome within this group of patients. The main reason for lack of effect of hemodynamic monitoring on outcome is that a monitoring device will never affect outcome solely unless associated with a treatment algorithm. An impact on outcome is to be expected only if monitoring is followed by adequate interventions, i.e. starting fluids, vasopressors or inotropic agents, or even mechanical circulatory support. If these interventions lack effect the monitoring device cannot be blamed for it. Studies in cardiogenic shock patients mostly fail and evidence should come from mixed populations, such as patients after major (cardiac) surgery, and from patients on mechanical circulatory support.

There is not enough evidence from randomized trials to support the role of pulmonary artery catheter monitoring to guide treatment, partly due to the above-mentioned limitations. Still some results should be considered. For instance, in a prospective study (n = 112) in medical intensive care unit patients without myocardial infarction, pulmonary artery catheter-derived hemodynamic profiles lead to therapy changes (63%) in shock patients unresponsive to standard treatment, which in turn was associated with an improved prognosis.[7] However, the nonrandomized study design hampers extrapolation of these results to a greater population. In a two-center randomized trial (n = 120), fluid resuscitation was guided either by transpulmonary thermodilution or by pulmonary artery catheter-derived hemodynamic variables during the 72 hours after inclusion.[8] Patient important outcomes like 28-day mortality were equal in both groups. In nonseptic patients (including 17 nonsurgical and 13 after cardiac surgery), there were less ventilator and hospital days in patients assigned to a pulmonary artery catheter-guided treatment.

A major limitation of the pulmonary artery catheter is its invasiveness. For less or noninvasive monitoring some data is available. In a multicenter randomized trial of hemodynamic unstable patients (n = 388), treatment based on noninvasive cardiac output monitoring (FlowTrac®) for 24 hours compared to usual care had no effect on fluids given for volume resuscitation (total amount, type of fluids, and their timing), vasopressor or inotropic agents, and use of a

pulmonary artery catheter.[9,10] Only vasodilators were given more frequently in patients in the usual care group. This trial included various patients of which approximately one out of five patients had a primary cardiovascular diagnosis and the external validity for patients with cardiogenic shock is therefore limited. In both the trials of Trof and Takala, the number of patients with a cardiovascular disease is limited and the external validity for patients with cardiogenic shock is therefore limited.

A recent meta-analysis on goal-directed hemodynamic resuscitation combining previously available data with new data of a trial concluded that hemodynamic monitoring is beneficial.[11] The original trial randomized patients (n = 126) to a target of cardiac index of greater than 3 L/min/m with intravenous (IV) fluids, inotropic agents (>95% dobutamine), and red blood cell transfusion starting from cardiopulmonary bypass versus usual care for 8 hours after arrival to the intensive care unit. In the goal-directed fluid therapy (using LiDCOrapid®) versus the usual care group the volume of fluids was greater (1,000 mL vs 500 mL) and the primary endpoint of 30-day mortality (4.8% vs 9.4%) and major postoperative complications was lower (28% vs 45%), with infections as the main driver for the difference. The meta-analysis on all types of goal-directed trials (n = 825), including various types of monitoring (FlowTrac®, esophageal Doppler, PiCOplus, pulmonary artery catheter) showed a difference in postoperative complications (11% vs 22%). The number of cardiogenic shock patients included were, however small again, limiting the external validity.

Some evidence exists for use of monitoring in patients with mechanical circulatory support. Two trials (n = 51 and n = 22) of the same group of researchers showed a beneficial effect of hemodynamic monitoring with critical care echocardiography for guiding treatment like during weaning.[12,13] Their observations were confirmed by another cohort (n = 23) using transesophageal echocardiography.[14]

CONCLUSION

Evidence to support the use for hemodynamic monitoring for guiding treatment in patients with cardiogenic shock is sparse. Some promising results from patient populations with cardiac dysfunction urge for further investigation. The large number of different devices available has potential to optimize monitoring depending on the individual patient, i.e. to prevent invasive monitoring in low-risk patients and to apply more invasive monitoring in high-risk patients in order to better weigh the risk–benefit ratio for both diagnosis and guiding treatment.

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