

Introduction to “Hemodynamic Monitoring”

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The primary goal of intensive care medicine is the prevention, reduction, and removal of temporary risk of death in acutely ill patients, including patients exposed to risk of death due to surgery and other therapeutic interventions. Cardiovascular organ dysfunction or failure is, after respiratory failure, the most common organ function problem in intensive care unit (ICU) patients [1]. The central role of hemodynamic monitoring in the ICU armamentarium is therefore self-evident. In this context monitoring implies observing continuously or continually changes in physiologic variables over time to reveal changes in organ function, to prompt therapeutic interventions, and to evaluate response to therapeutic interventions. Monitoring per se cannot be expected to improve patient outcomes – only timely applied right interventions can do so [2].

Hemodynamic monitoring and diagnostics are different entities, sharing common features and overlapping, if diagnostics are frequently repeated. Monitoring tools, such as cardiac output monitors or pulmonary artery catheter, may help to establish diagnosis, and diagnostic tools, such as echocardiography, can be used repeatedly to monitor cardiovascular function and response to treatment at least over short periods of time. Measurements and diagnostic evaluations that were intermittently done in the past (e.g., cardiac output, venous oximetry) can now be performed continually or continuously. Echocardiography, traditionally a diagnostic tool, has an established role in perioperative monitoring of cardiac surgery patients. Barriers for its use for monitoring ICU patients are disappearing with increased availability of equipment and trained operators, although operator dependence and the need for frequent repetitions remain limitations. The introduction of miniature transesophageal echocardiography probes is likely to facilitate echocardiography-based continual monitoring also in the ICU [3].

The use of dynamic assessment of circulation is a fundamental component of hemodynamic monitoring. The principle of observing the physiology, inducing a perturbation, and observing the response was emphasized by Max Harry Weil in 1965, when he described the use of fluid challenge in shock: “The effect of fluid replacement on the clinical status of the patient in shock is gauged by objective changes in circulation, such as blood pressure, mental alertness, urine flow, peripheral venous filling, and appearance and texture of the skin” [4]. In this elegant paper, the today well-known limitations of static values of hemodynamic variables are discussed with great insight. In the last decades, the physiology underlying dynamic hemodynamic assessments and their limitations in monitoring the circulation have been established. Instead of using the fluid challenge to perturb the circulation, many of the current approaches try to predict the response to a fluid challenge in order to avoid unnecessary fluid loading. All these dynamic approaches are based on the principle of assessing “preload dependence.” This can be done by observing respiratory cycle-dependent variations in intravascular pressures, vascular diameters, and stroke volume or its surrogates or by directly observing the effect of a volume shift induced by passive leg raising on these variables. The practical aspects of these methods as well as their limitations are discussed elsewhere in this book. Two major issues deserve to be mentioned already here: first, to be preload or volume responsive is normal and does not indicate the need for volume; second, hypovolemia and right heart failure may both manifest as left heart preload dependence.

The quest for less invasive hemodynamic monitoring has been driven by the goal to reduce the risks of invasive techniques, to reduce the need of special skills and resources, and to make hemodynamic monitoring more widely available. This has been facilitated by major evolution in signal processing, transducer and imaging technology, and in understanding physiology. Wireless transducers and biosensors, and body area networks make

remote monitoring technically possible, although their routine clinical application is still confronted with technical and logistic problems [5].

Another trend in hemodynamic monitoring has been the focus on microcirculation. Research tools used for studying pathophysiology of microcirculation and peripheral tissue perfusion have so far failed to break through into clinical monitoring. In order to monitor peripheral tissue perfusion in the clinical setting, traditional clinical variables to monitor circulation have had a renaissance. These include skin temperature, central to peripheral skin temperature difference, capillary refill time, and evaluation of skin mottling [6]. These simple measurements can be used for monitoring hemodynamics without any special equipment, and at same time, they are amenable for new sensor technologies.

Integration of hemodynamic monitoring data to provide relevant information for therapeutic decisions becomes a major challenge, when the amount of available data increases. At the moment, such integration can be achieved using clinical information systems to display pathophysiologically relevant combinations of data. The development of intelligent alarms is the next step and can help to apply hemodynamic monitoring outside the ICU [7].

Despite all the exciting new developments in technology, the variety of available monitoring devices, and the improved understanding of pathophysiology, the most important challenge remains: What should be the hemodynamic targets? Hemodynamic monitoring can only reveal changes in cardiovascular function, and the interpretation of such changes may prompt therapeutic interventions. What are the right interventions and what should be their targets remain disappointingly unclear. The application of fixed hemodynamic targets in large-scale randomized controlled trials has given little if any definitive answers [8]. The risks of overzealous hemodynamic support with fluids and vasoactive drugs have also been demonstrated. Given the complexity of hemodynamic pathophysiology, it is very unlikely that any fixed numeric targets for all patients are appropriate. Rather, assessing response to treatment should consider changes in the individual patient's clinical status and signs of tissue perfusion, such as mental alertness, skin temperature and capillary refill, and urine flow, and objective changes in hemodynamic variables provided by hemodynamic monitoring and imaging.

References

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