Hemodynamic Assessment in the Contemporary Intensive Care Unit

A Review of Circulatory Monitoring Devices

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KEYWORDS

• Hemodynamic • Circulatory • Monitoring • Critically ill • Intensive care unit

KEY POINTS

- The ideal circulatory monitoring system would be noninvasive, cost-effective and easy to use.
- As understanding of hemodynamics and critical illness has evolved, more sophisticated circulatory monitoring technologies have been developed.
- The primary hemodynamic goal in the management of critically ill patients includes the assessment and manipulation of the circulatory system to ensure adequate tissue delivery of oxygen and essential metabolic substrates.
- Current monitoring devices should continue to be selected on a patient-specific basis, either alone or in combination with other hemodynamic monitors, until the gold standard hemodynamic monitoring tool is developed.

INTRODUCTION

The primary hemodynamic goal in the management of critically ill patients includes the assessment and manipulation of the circulatory system to ensure adequate tissue delivery of oxygen and essential metabolic substrates. Goals of optimization of the circulatory system in the ICU have met with mixed results. Traditional methods to assess the circulatory system can sometimes be inadequate, particularly in the early stages of shock when compensatory mechanisms may cloud the presentation.[1,2]

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As the understanding of hemodynamics and critical illness has evolved, more sophisticated circulatory monitoring technologies have been developed, including pulmonary artery catheterization (PAC). The introduction of PAC was accompanied with great optimism; unfortunately, clinical studies have failed to show a consistent benefit with routine use of PAC in the ICU. Because of the belief that PAC was inadequate because of technical problems in interpretation and complications associated with its use, a new wave of noninvasive modalities were developed. Traditional methods continue to have a role in assessing critically ill patients but newer technologies have greatly expanded circulatory monitoring systems.

The ideal circulatory monitoring system would be noninvasive, cost-effective, and easy to use. Although such a system remains elusive, several circulatory monitors possess a combination of these characteristics. This article reviews the most commonly available technologies and their underlying physiologic principles as well as their strengths and limitations in the assessment of critically ill patients.

CLINICAL METHODS FOR HEMODYNAMIC ASSESSMENT

Detailed physical examination along with other clinical data provide a framework for assessment of the underlying pathophysiology of the patient against which all information obtained from hemodynamic monitors can be interpreted. These methods are used to infer data about the two major parameters of the circulatory system: intravascular volume and tissue perfusion.

Invasive Blood Pressure Monitoring

Given the unreliability of sphygmomanometers at blood pressure extremes, invasive arterial blood pressure monitoring is often needed in hemodynamically unstable patients. Literature is starting to emerge questioning the use of arterial catheters in critically ill patients. Lakhal and colleagues[3] demonstrated that noninvasive blood pressure monitoring is accurate and reliable compared with invasive monitors. This is particularly when assessing mean arterial blood pressure at the arm level, although limitations at extremes of blood pressure or body mass index were still noted.

Regardless of the method, a mean arterial pressure (MAP) of 60 to 65 mm Hg is the normally accepted target for resuscitative efforts. It is necessary to understand that normalization of blood pressure does not always indicate microcirculatory sufficiency and adequate tissue perfusion. This goal should also be adjusted according to the clinical scenario. For example, a higher MAP may be necessary with untreated critical coronary artery stenosis or elevated intracranial pressure, whereas a lower MAP in the absence of significant tissue hypoperfusion may be tolerated in conditions such as severe aortic insufficiency.

Assessment of filling pressures and left ventricular function using arterial pressure variation

Physiologic variation of arterial blood pressure during the respiratory cycle is driven by the effect of lung inflation and changes in thoracic or abdominal pressure on ventricular loading conditions in the setting of ventricular interdependence. During spontaneous inspiration, the reduction in left ventricular (LV) stroke volume (SV) causes a decrease in systemic blood pressure and pulse pressure (PP) at end-inspiration (**Fig. 1**). During positive pressure ventilation, the right ventricular (RV) preload usually decreases at end-inspiration, shifting the ventricular septum to the right and improving LV compliance. LV preload also increases as the alveolar inflation enhances venous return to the left atrium (LA). This, coupled with the decrease in LV afterload, produces an increase in systemic blood pressure at end-inspiration. A few heart beats later and