Using What You Get

Dynamic Physiologic Signatures of Critical Illness

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KEYWORDS

• Data hierarchy • Fused parameter • Physiologic signature
• Cardiopulmonary instability • Machine learning

KEY POINTS

- Physiologic monitoring of dynamic changes is more useful than static variables for the early detection of critical illness, and the guidance and appropriate cessation of therapeutic interventions.
- Physiologic monitoring techniques that take advantage of complex organ-organ interaction (eg, heart rate variability, arterial pressure variation, and secondary variables from hemodynamic waveforms) are valuable but are an underused resource for identifying critical illness.
- Using new tools to analyze available physiologic variables, it is possible to construct the physiologic signatures at every point in a disease process to identify and treat critical illness as early as possible.
- Tools that integrate large amounts of physiologic data are complex to develop; their use requires collaboration with information technology experts.
- The integration of physiologic predictors and applications in critical illness is an area of research still under intense investigation.

INTRODUCTION

Cardiopulmonary instability can occur in any disease process when the metabolic needs of the body are not being met with adequate supply. Cardiopulmonary equilibrium is achieved in the presence of adequate oxygenation, preload, contractility, and vasomotor tone. Although the body may be able to compensate for a significant change in any one of these components from baseline, any change may still lead to

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significant morbidity and mortality. Each component can contribute to cardiopulmonary instability. In the setting of trauma, there is a loss of adequate preload because of hemorrhage. Hemorrhage accounts for 50% of deaths within the first 24 hours of hospitalization for a traumatic injury.[1] Vasomotor tone is the most prominent derangement in sepsis, although these patients can also experience hypovolemia with reduced preload and decreased contractility because of myocardial suppression. Inflammatory and apoptotic mediators contribute significantly to the pathophysiology of all 3 components in sepsis.[2] For patients with global tissue hypoxia, as shown by increased lactate levels or hypotension, mortality can range from 36% to 46.5%.[3–6] In addition to global circulatory function, organ and microcirculatory function should also be addressed.[7] Early identification and management of threats to physiologic equilibrium, preferably before instability is clinically apparent, may prevent untoward patient outcomes.

In recent years, advances in hemodynamic monitoring have ushered the concept of physiologic signatures, specific physiologic profiles describing a disease process through time. Such profiles are constructed using an expanded set of physiologic variables and can be used to identify and manage critical illness in a timely manner. In this article, many of the physiologic variables available in current clinical practice, the successes and challenges of protocolized care that use many of these physiologic variables (goal-oriented therapy), as well as ways to address some of those challenges by building physiologic signatures are summarized. The substrate for these signatures is created through the use of a data hierarchy (**Table 1**), or the idea that new variables can be created from existing clinical variables collected at different frequencies. The goal of signature creation would be to identify a patient's location on the spectrum of critical illness and continuously assess the response to therapy.

DIAGNOSIS AND MANAGEMENT OF CRITICAL ILLNESS THROUGH CONTEMPORARY MONITORING IS GOOD, BUT CAN BE IMPROVED

Cardiopulmonary Parameters Used in Clinical Practice

Many simple variables are available to assess cardiopulmonary function and the balance between global oxygen supply and demand, but they may be nonspecific or late markers of cardiopulmonary compromise. Blood pressure is a primary determinant of

Table 1
Levels of data hierarchy

Data Hierarchy	Examples	Notes
Primary variables	HR, MAP, CVP, $Scvo_2$, SV, Spo_2	Used most frequently in goal-oriented therapy protocols
Secondary (derived) variables	HRV measures,[a] PPV, SVV	Requires high-frequency data collection Increasingly being integrated into goal-oriented therapy protocols
Advanced waveform analyses	Morphologic changes,[b] harmonic analyses[b]	Requires data collection via waveforms ($\geq$100 Hz) Can be performed on any variable derived from a waveform (eg, CVP, ABP)

Abbreviations: ABP, arterial blood pressure; CVP, central venous pressure; HR, heart rate; HRV, heart rate variability; MAP, mean arterial pressure; PPV, pulse pressure variability; $Scvo_2$, central venous oxygen saturation; Spo_2, arterial oxygen saturation measured by pulse oximetry; SV, stroke volume; SVV, stroke volume variation.

[a] The term HRV measures represents dozens of independent variables.

[b] Represent potentially hundreds of variables.