Data integration and biological dynamics in the ICU: a step towards real-time computational support

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Patients admitted to an intensive care unit (ICU) often present with some form of organ failure, usually defined as Multiple Organ Dysfunction Syndrome (MODS). While standards of care continue to improve, successful treatment is heavily reliant on early identification of at-risk patients. Currently, this task falls to the intensivist who has to juggle clinical data from a variety of sources that are mostly vertically siloed. Even very basic trend information is not routinely accessible. Consequently, treatment decisions and risk stratification are based on snapshot observations, rather than real-time diagnostic tools and biomarkers that reflect the overall state of the patient.

Similar to many physical, economic and sociological systems, biological organisms at the molecular and physiologic level are characterized by self-organization and emergence. Therefore, higher order information can be analyzed using the common principles of power-law behavior, fractal scaling and chaotic attractors, among others. Physiologic time series specifically, are characterized by **variability pattern dynamics**, i.e. rhythmic changes in the timing, shape and interconnectedness of physiologic variables that occur over multiple temporal and spatial scales. Intuitively, these patterns reflect the homeodynamic regulation by the underlying neural circuits and sensory feedback loops. In the context of critical care, quantifying **multivariate complexity** can pinpoint the position of a patient in "**physiologic space**", which is especially important to track the progression of syndromes such as MODS that are characterized by progressive and systemic failure, unattributable to a single variable.

To that end, we are running a data mining project in the ICU, focused on associating fluctuations in the dynamic state of the patient with later changes in clinical status, in order to develop **early-warning biomarkers** for clinical decompensation. In the current phase, the study is focused on identifying **nonlinear dynamical patterns** in physiologic waveform data (electrocardiogram, invasive blood pressure, and capnography), as well as the **coupling** (shared information) within multiple time series. In later stages, promising leads from the data mining phase will be developed into real-time biomarkers at the bedside, both in mock and real ICU settings. Ultimately, these steps are necessary to develop a heads-up display with relevant, sensitive, and condensed clinical information that is continuously streamed to the treating physician for each individual patient.