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Measures of Cardiac Index and Autonomic Function Non-invasively Describe Cardiac Function

Joseph Colombo PhD, Charles CJ Wo, BS, Elif Aysin, MS, Ben Aysin, PhD, Kevan Iffrig, BS, Adam Colombo, DO, William C. Shoemaker MD

ABSTRACT

Introduction: Cardiac index (by the bio-impedance method, CIbi) and autonomic nervous system (ANS) function testing (by spectral analysis of respiratory activity and spectral analysis of heart rate variability) are non-invasive indicies of cardiac function. ANS function provides independent, simultaneous, quantitative measures of neural input controlling the heart and CIbi quantifies bolus blood flow from the heart. The two measures have been correlated with survival. Changes in both indicies, individually, have been associated with early detection of changes in critically ill and injured patients, including patients with sepsis or septic shock. Improvements in both indicies, individually, have been associated with improved outcomes. Together, CIbi and ANS function may fully describe heart dysfunction in ill or injured patients, non-invasively and possibly earlier than current invasive methods. This study presents preliminary evidence of the association of non-invasive CIbi and ANS function indicies with outcomes in severely ill or injured patients.

Methods: We noninvasively monitored concurrent autonomic and hemodynamic patterns in 208 consecutive severely ill septic and septic shock patients. Simultaneous respiratory rate (RR) variability and heart rate (HR) variability (HRV) spectral patterns were collected. We used two types of ANS monitoring: a) HRV *without* respiratory analysis, and b) HRV *with* respiratory analysis. The former calculates the SNS and PSNS, Low Frequency (LF) and High Frequency (HF) parameters, respectively, according to the standard spectral analysis of HRV methodology. The latter adds spectral analysis of RR variability to compute more sensitive SNS and PSNS measures (the Low Frequency areas (LFa) and Respiratory Frequency area (RFa), respectively) according to the MIT technique. Noninvasive hemodynamic monitoring included: a) cardiac index (CI) by bioimpedance, HR, and mean arterial pressure (MAP) to reflect cardiac function, b) pulse oximetry ($SapO_2$) to reflect changes in pulmonary function, and c) transcutaneous oxygen ($PtcO_2$) indexed to the FiO_2 as a marker of tissue perfusion.

Results: The ANS measurement techniques were correlated. ANS measures from HRV *with* respiratory analysis were associated with outcomes and corresponding hemodynamic patterns, including CI. In all patients autonomic balance (the ratio of sympathetic activity, as measured by LFa, to parasympathetic activity, as measured by RFa) was markedly abnormal. Autonomic balance was not well-correlated with HR or BP. Increased autonomic activity in patients shortly after admission to ED was associated with immediate increases in HR, MAP, and CI, and a tendency toward reduced

tissue perfusion/oxygenation ($PtcO_2/FiO_2$). Patients with high RFa values, indicative of excess PSNS activation, were more associated with mortality and morbidity than patients with normal RFa values. These patients also presented with, hypotension, low flow, and decreased tissue perfusion. Survivors had relatively normal hemodynamic patterns and autonomic balance, and moderately increased autonomic activity initially. Patients whose RFa and CI levels were normalized tended to survive. Patient's whose LFa, HR and BP only were normalize were associated with poor outcomes.

Conclusions: Patients that first presented with poor ANS balance and had balance improved or restored due to therapy early in their ED stay, all survived. Patients with improved or restored CI tended to survive. Nonsurvivors were associated with abnormal autonomic balance and CI throughout their ED stay, even when other hemodynamic parameters were normalized.