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Invited Commentary for: Predicting clinical physiology: A Markov chain model of heart rate recovery after spontaneous breathing trials in mechanically ventilated patients

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This study proposes a Markov chain model study to assess heart rate recovery (HRR) in mechanically ventilated patients upon attempted weaning (spontaneous breathing trial, or SBT). It is known that postexercise HRR data can be plotted as an exponentially decreasing HR vs time curve, with an initial rapid decline (in the first 30 seconds), which can be curve fitted as a first-order decay curve with an exponential time constant. This initial rapid decline has been previously attributed to parasympathetic blockade, with minimal dependence on the sympathetic system and exercise intensity. The second slow HR decay phase supposedly reflects sympathetic activity withdrawal and the clearance of stress metabolites [1]. In fact, the interactions are quite complex, and it has been difficult to establish a clear correlation between HRR and HRV.

What is established is that attenuated HRR after exercise is a reflection of the parasympathetic tone and is an independent predictor of mortality among patients undergoing stress testing [2]. The presence of autonomic dysfunction, as assessed by HRV or baroreceptor insensitivity, is likewise predictive of increased mortality. Can these alterations be extended to patients with pulmonary abnormalities? Seshadri et al [3] have similarly shown that during stress testing, in patients with a worsening FEV1 and FEV/FVC, these spirometry abnormalities are associated with abnormal HRR. Finally, it has been demonstrated in healthy children and adolescents that there is an inverse correlation between HRR and metabolic risks (waist circumference, systolic blood pressure, C-reactive protein) [4]. This suggests that impaired HRR in the post-stress setting may be a generic indicator of underlying early or established pathology of a cardiac, pulmonary, or metabolic nature.

The authors hypothesize that a SBT, in the absence of the usual treadmill stress test, is a stressor in itself and has comparable effects on HRR. These early results are promising, with development of an analytical solution that successfully connects the post-SBT HRR time constant with an HRV index (correlation coefficient of the HR Poincare plot) during a "steady state" prediction in 17 of 20 data sets. The best results were obtained in well-sedated long-term tracheostomy patients, where supratentorial input has been reduced, with linearization of the HRR. However, there are significant model failures—missed spike detection, the need to accommodate a second order exponential fit, and negative correlations—that need to be better addressed in follow-up investigations. If the quantitative measure of the time constant is all that is needed for clinical inference, a linear model approach should suffice, although there are still some concerns about the validity of the working assumptions (data stationarity, fluctuation-dissipation analogy, and assumption of the SBT as stressor).

A limitation of this study is that, during patient selection, there is no mention of patients being excluded because of potential interfering factors, such as the presence of atrial fibrillation, or the use of β-blockers or sympathomimetic drugs. No apparent use was made of spirometry indices (FEV1, FEV/FVC) that might have been helpful in assessing the patient's pre-SBT pulmonary status and

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respiratory muscle strength. Finally, there were no independent measures of autonomic dysfunction used, such as a Valsalva maneuver, deep breathing, acetylcholine sweat-spot test, and so on.

The existence of a heart rate with a relatively stable frequency range (60-100 beats per minute) indicates oscillatory behavior. It should be noted that system oscillatory behavior cannot be achieved with a single-order linear differential equation (although possibly with a first-order nonlinear differential equation). For oscillatory behavior to occur, a linear differential equation must be at least second-order or higher. Perhaps consideration can be given to developing a model based on a nonlinear limit cycle oscillator that, when perturbed from its equilibrium point, exhibits alterations in its frequency. When the stressor is removed, the oscillating system ultimately reverts back to its baseline frequency. For example, a Van der Pol equation limit cycle, for all nonzero parameter ε, exhibits a variable frequency during a single closed periodic trajectory.

References

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