A Human Cardio-Respiratory Model: Applications in Critical Care Medicine

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We present an overview of a composite human cardio-respiratory (C-R) model, integrating hemodynamics, whole-body and cerebral gas exchange, and baro- and chemoreceptor reflexes, and simulating the complex cardio-respiratory interactions occurring during the Valsalva maneuver, thigh-cuff deflation and apnea. Parameters of the modeled systemic and pulmonary circulatory subsystems have been adjusted to fit input impedance data. This provides an excellent description of the output loading conditions for the ejecting ventricles. The model can mimic inlet tricuspid and mitral flow velocity waveforms often used in diagnosing congestive heart failure using echocardiography. We describe an application in critical care medicine, namely left ventricular diastolic dysfunction (LVDD). Diagnosis of LVDD customarily uses a combination of invasive pressure recordings and non-invasive Doppler flow velocity recordings from the inlet valves of the heart. Three flow velocity patterns are of interest in LVDD: Incomplete Relaxation (IR) (evident during early rapid filling of the LV); the Restrictive (R) pattern (evident in late diastole particularly with atrial contraction); and the Pseudonormal (P-N) pattern (putatively a mixed pattern). The C-R model allows study of the inlet flow patterns of both normal and diseased left ventricles (LVDD), giving insight into the mechanisms underlying these differences. Our normal human C-R model serves as control, and simple changes in two parameters of the LV mechanics subsystem can mimic many features of LVDD. Assessing the effect of these changes within the context of the larger C-R model allows prediction of their more global effects manifested in the major symptoms of congestive heart failure: lowered cardiac output and mean arterial blood pressure, elevated heart rate, increased left atrial blood volume and pressure, pulmonary hypertension and altered A-V O_2 and CO_2 differences across different vascular beds (lung, brain, skeletal muscle).