From Space to Iraq: Optimizing the Respiratory Pump for Treatment of Hypovolemic Hypotension

Hypotension secondary to reduced circulating blood volume (hypovolemia) can compromise the health and wellbeing of individuals, from fainting astronauts to patients in cardiac arrest to bleeding combat casualties. In these clinical scenarios, effective resuscitation can be lifesaving. Recent animal and clinical studies demonstrated that one of the body's natural response mechanisms to hypotension is to harness the respiratory pump to increase circulation. That finding is consistent with observations in the 1960s about the effect of lowering intrathoracic pressure on key physiological and hemodynamic variables. This seminar will focus on the fundamental relationship between the generation of negative intrathoracic pressure during inspiration through a low level of resistance and the physiologic sequelae of a respiratory pump. A decrease in intrathoracic pressure during inspiration through a fixed resistance resulting in a pressure difference of ~7 cm H_2O has multiple physiological benefits, including: enhanced venous return and cardiac stroke volume, lower intracranial pressure, elevated cerebral blood flow oscillations, increased tissue blood flow/pressure gradient, and maintenance of the integrity of the baroreflex-mediated coherence between arterial pressure and sympathetic nerve activity. While breathing has traditionally been thought primarily to provide gas exchange, studies of the mechanisms involved in animals and humans provide the physiological underpinnings for "the other side of breathing": to increase circulation to the heart and brain, especially in the setting of physiological stress. The existing results support the use of the intrathoracic pump as an effective therapy to treat clinical conditions associated with hypotension, including orthostatic hypotension, hemorrhagic shock, heat stroke, septic shock, and cardiac arrest. Harnessing these fundamental mechanisms through engineering of an impedance threshold device that controls cardiopulmonary physiology provides new opportunities for biomedical engineers to improve the capabilities of respiratory therapists and others who help treat serious and often life-threatening circulatory disorders.

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