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MICROGRAVITY-INDUCED REDUCED JUGULAR VEIN FLOW IS MORE PRONOUNCED ON THE NON-DOMINANT SIDE

Abstract

Recently, an astronaut developed a left-sided internal jugular vein (IJV) thrombosis while in orbit, likely due to reduced IJV blood flow. We hypothesized that microgravity-induced flow reductions would be greatest on the non-dominant (usually left) side thereby increasing thrombosis risk. In a novel analysis, a Simulink®-based lumped parameter model (LPM), was used to explore causes of jugular flow reduction and asymmetric thrombosis risk. The model includes the cardiovascular, cerebrospinal fluid, and aqueous humor fluid systems. Vessel behavior is described by combinations of four discrete components: hydrostatic gradients, vessel compliance, flow resistance, and flow inertia. The cranial venous system features drainage pathways through the right IJV, the left IJV and the vertebral plexus. The right jugular vein was modeled as the dominant jugular pathway (60% of total unconstrained jugular cross-sectional area). The left side accounted for the remaining 40%. Multiple variables were adjustable in the LPM: body position (supine, prone, head-down tilt), lower body chamber pressure (atmospheric pressure, negative pressure, positive pressure), and gravity. A key feature of this LPM is the incorporation of compressive forces exerted on the vessels by the weight of tissues and the subsequent release of those forces in microgravity. These forces change vessel volume through effects on vessel transmural pressure.

Relative to a supine baseline, simulated total IJV flow dropped from an average of 11.0 to 2.0 mL/s in weightlessness. The left and right IJV flow in microgravity was 0.6 and 1.4 mL/s, respectively (30% and 70% of total jugular venous flow, respectively). Not only was average flow reduced, but the flow pulsatility in the left IJV matched the observations made by Marshall-Goebel et al. in microgravity, where blood flowed forward, but with periodic zero-velocity flow. In the LPM, each IJV cross-sectional area—and therefore flow resistance— depends on transmural pressure. A larger transmural pressure reduces flow resistance and results in greater blood flow. In microgravity, with tissue weight removed, external vascular pressure is relieved and vascular volume redistributes, dropping pressure throughout, greatly reducing IJV transmural pressure and blood flow. We hypothesize that this mechanism may explain the findings from spaceflight. In microgravity, simulated left IJV was reduced to 30% from 40% of total jugular flow because the reduction in vein diameter in response to the transmural pressure changes is non-linear.

Due to the computational nature of LPM, further experimental validation is necessary to ensure the results and inferred mechanism is representative of true spaceflight physiological changes.