VESsel GENeration Analysis (VESGEN): Innovative Vascular Mappings for Astronaut Exploration Health Risks and Human Terrestrial Medicine

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Currently, astronauts face significant health risks in future long-duration exploration missions such as colonizing the Moon and traveling to Mars. Numerous risks include greatly increased radiation exposures beyond the low earth orbit (LEO) of the ISS, and visual and ocular impairments in response to microgravity environments. The cardiovascular system is a key mediator in human physiological responses to radiation and microgravity. Moreover, blood vessels are necessarily involved in the progression and treatment of vascular-dependant terrestrial diseases such as cancer, coronary vessel disease, wound-healing, reproductive disorders, and diabetes.

NASA developed an innovative, globally requested beta-level software, VESSEL GENeration Analysis (VESGEN) to map and quantify vascular remodeling for application to astronaut and terrestrial health challenges. VESGEN mappings of branching vascular trees and networks are based on a weighted multi-parametric analysis derived from vascular physiological branching rules. Complex vascular branching patterns are determined by biological signaling mechanisms together with the fluid mechanics of multi-phase laminar blood flow.

Branching vascular trees and networks by VESGEN vascular mappings. Branching generations of vessels recorded for 20 model vascular networks were automatically mapped by VESGEN according to vascular physiological branching rules (top left image, legend for branching generations). The VESGEN analysis of vascular networks is illustrated for the mouse retina (top, right image). Lower illustration is a fluorescence confocal image of the developing lymphatic vascular network in an avian experimental model from Gravitational and Space Biology, confocal images of progressive inflammation in the mouse GI are displayed together with the VESGEN vascular network mappings (bottom two rows).

By 'anti-stovepipe' multi-disciplinary, multi-directorate and external collaborations among biomedical, computer and physicist scientists and engineers, NASA continues to develop the VESGEN vascular analysis resulting from technology development awards by the Center Innovation Fund (CIF), IRAD and Vascular Centennial Challenge (VTC). Consequently, biomedical research discoveries continue to be supported by peer-reviewed research awards from NASA and the US National Institutes of Health, and disclosed as new technology inventions (patent application in progress). For the current CIF award, we are developing: (1) 3D vascular mappings beyond current 2D capabilities, and (2) the automated binarization of vascular maps as black/white vascular patterns from experimental and clinical grayscale vascular images.

Ongoing Development of VESGEN 3D. Algorithms for 2D vascular mapping have been extended to 3D (David Kao). In addition, retrospective 3D visualizations of the complex 3D vascular structures are being developed. 3D confocal image of the mouse intestinal (upper left) and mouse retina (lower right) provided by Hans Christian Niemeyer MD, Massachusetts General Hospital, Vivien Mao PhD, Loma Linda University.

Advances in Vascular Image Binarization by Machine Learning. Unsupervised and supervised methods are being applied to grayscale vascular images (Hamed Vallazdegan) for significant advances in the automated extraction of binary (black/white) vascular patterns from experimental or clinical grayscale images.


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