Innovative Research & Discovery Tool

NASA’s VESSEL GENeration Analysis (VESGEN) Software

Vascular Patterning Analysis by VESGEN 2D/3D with Bioinformatics: Updates for Rodent Tissues

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VESGEN Patent Pending
NASA’s VESGEN Vascular Analysis

- Astronaut health risks
- Terrestrial medicine
- Rodent and other vertebrate vascular studies
VESGEN
Translational Mapping and Quantification of Fractal-Based Vascular Pattern

Vascular Trees
Human Retinal Disease, Mouse/Avian Coronary Vessels, CAM, Yolksac

Vascular Networks
Mouse Intestinal Inflammation, CAM Lymphatic Vessels, Abnormal Mouse Corneal Angiogenesis, Drosophila (Fruitfly) Wing

Vascular Tree-Network Composites
Mouse Postnatal Retina, Early Embryonic Coronary Vessels, Arabidopsis Leaf Venation
Long-Term Research Hypothesis

‘Fingerprint’ vascular patterns offer integrative read-outs of dominant molecular signaling pathways important for astronaut, terrestrial health

Vascular Physiological Branching Rules

Vascular fluid mechanics, molecular/cell biology (angiogenesis), experimental observations

Mapping and Quantification by Multiparametric Weighted Analysis

Fractal Dimension, $D_f$
Vessel Number Density, $N_v$
Vessel Length Density, $L_v$
Vessel Diameter, $D_v$
Branchpoint + Endpoint Densities, $Br_v + E_v$
Vascular Patterning Research

Biomedical Translation from Experimental Models to Terrestrial Human and Astronaut Studies

1. Molecules \textit{in Vitro} 
2. Avian CAM 
3. Rodents 
4. Humans

NASA to NIH to NASA

\textbf{in Vivo}
**Fundamental Hypothesis**

‘Fingerprint’ or ‘Signature’ Vascular Pattern as Useful Integrative Readout of Complex Molecular Signaling Pathways

- **bFGF as Simple Stimulator**

- **VEGF as Vascular Complexity Factor: Phenotypic Readout with eNOS Signaling**

- **TGF-β1 as Simple Inhibitor but Complex Potentiator**
  - *Microvascular Research* 59 (2000)

*The form of an object is a 'diagram of forces'

Physiologist
D’ Arcy Thompson*
Clinical Steroid TA Inhibits and Thins Vessels in Vascular Tree

Translational Research Tool for ROS, oxidative stress, persistent radiation damage

VESGEN mapping of progressive GI inflammation in mice with probiotic protection

Parsons, Reinecker Gravitational Space Biology 25(1):69 2012
Collaborative Study of Probiotic Inhibition of VEGF

VESGEN mapping of progressive GI inflammation in mice with probiotic protection

Chen, Reinecker, Parsons, Kelly et al PlosONE 2013
Vascular Networks in Transgenic Mouse Retina

Heart, Brain

- Superficial, other branching trees
- Small laminar networks

Cerebral Vascular System


Pial Arterial Network

**FIGURE 3**

Ventral (top left), dorsal (top right), and lateral (bottom) views of the superficial cerebral arteries of a rat brain treated by selective arterial injection with a neoprene latex-black ink mixture.
Main panel
• Image specification
• Algorithm selection
• Process initiation

Panel to specify vessel type

Mature, Beta-Level VESGEN
Vascular 2D Image Binarization  Hamed Valizadegan, PhD

- **Involves:** (1) Preprocessing, (2) Segmentation, and (3) Postprocessing
- It reduces time for semi-automated manual extraction, a worldwide technical challenge for biomedical grayscale images
  - But very small vessels are still very difficult to extract
  - Sensitive the the setting of parameters in preprocessing, segmentation and post-processing

- **Deep Neural Network (DNN)**
  - Given the existing manually labeled images, we can utilize the state of the arts supervised learning techniques for binarization.
  - Each pixel and its class label (foreground or background) is the training example
  - Our preliminary results with DNN shows that this is the right direction to pursue
  - This is an ongoing work

Semi-automated binarization: requires 2-15 hours per image

Automation result of CIF efforts (Unsupervised binarization)

Automation Ongoing work: Supervised Binarization
VESGEN 3D Development

- 3D visualization
- 38 slices
- 1024x1024 resolution

Mouse retina,
Xiao-Wen Mao PhD
VESGEN Bioinformatics XD Analysis
Structure-Function Relationships for Omic Correlations
Mapping of Progressive Diabetic Retinopathy by VESGEN

Surprising, Innovative Paradigm Shift by VESGEN

Alternation [Homeostatic Oscillation] of Vascular Dropout with Vascular Growth (Angiogenesis) during Progression of Diabetic Retinopathy

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How can we work together for future space exploration and colonization?