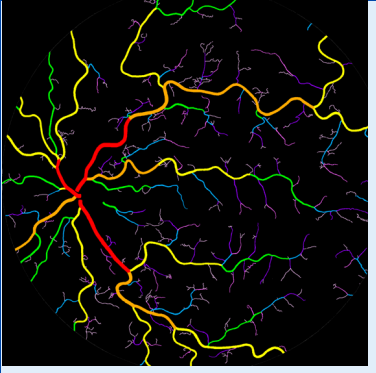
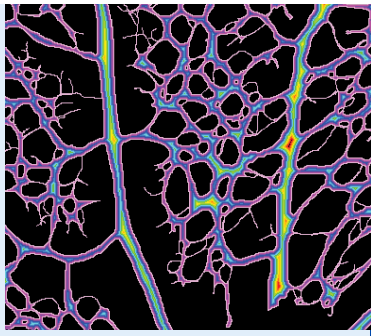
# NASA's VESsel GENeration Analysis (VESGEN) Software



Human Retina



Mouse Retina

# Mapping by VESGEN of Blood Vessels in Astronaut Retinas Pre- and Post-Flight to the ISS

P. Parsons-Wingerter[1], R. J. Vyas[1], M. C. Murray[1], M. Predovic[1], S. Lim[1], G. Vizzeri[2], G. Taibbi[2], S. S. Mason[3], S. B. Zanello[4], M. Young[5]

[1]NASA Ames Research Center, NASA, Mountain View CA,
[2]Department of Ophthalmology and Visual Sciences, University of Texas Medical Branch, Galveston TX, [3]MEI Technologies, [4]Universities Space Research Association and [5]Human Health and Countermeasures, NASA Johnson Space Center, Houston TX

Supported by NRA from NASA's Human Health & Countermeasures

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*Primary Risk* Spaceflight-Induced Intracranial Hypertension/Vision Alterations
*Primary Gap VIIP1* We do not know the etiological mechanisms and contributing risk factors

VESGEN Hypothesis & Background

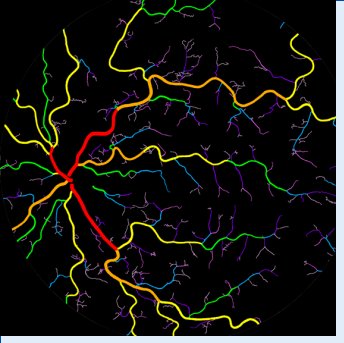
VIIP VESGEN Studies for 2 NRA Awards

Preliminary Results for Crew Members

Study Completion April 2017

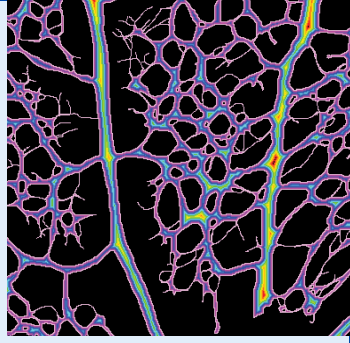
## *Hypothesis*

The retinal microvasculature withinnecessarily remodels during long-duration microgravityto accommodate ocular fluid shifts



# VESGEN

## Translational Mapping and Quantification of Fractal-Based Vascular Branching Patterns From Physiological Rules



Human Retina

Mouse Retina

## Vascular Trees

Retinal Vascular 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, Juvenile and Adult Leaf Venation

## 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, $Br_v$+$E_v$

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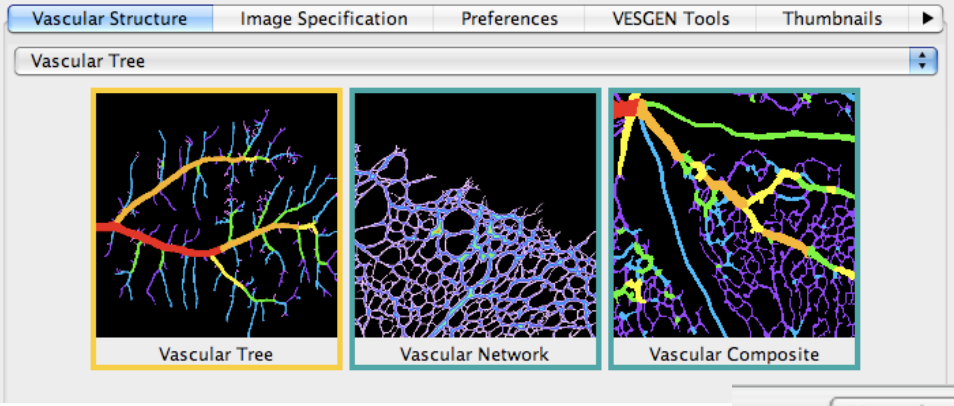
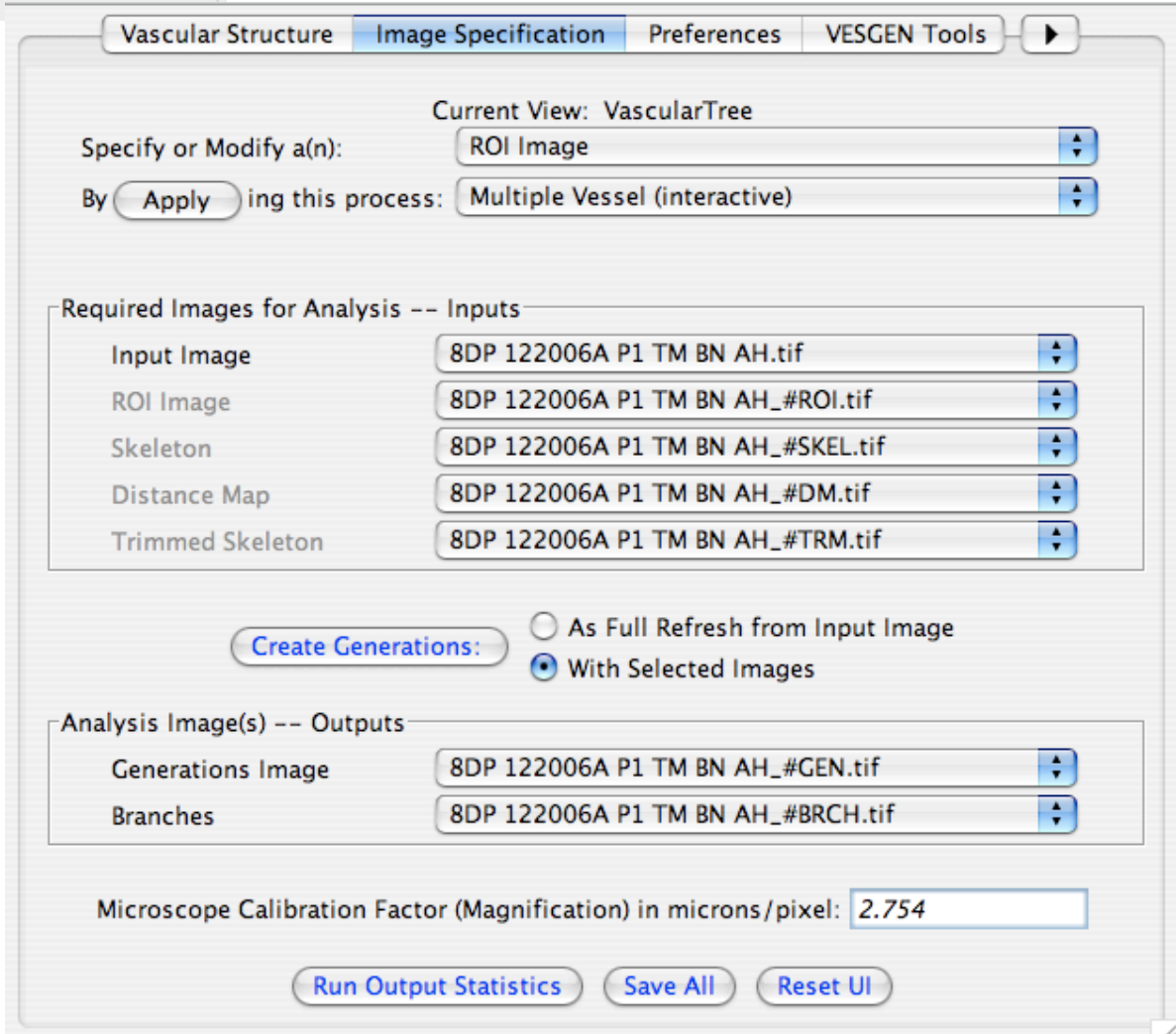
# Mature, Beta-Level VESGEN




**Panel to specify vessel type**

## Main panel

- Image specification
- Algorithm selection
- Process initiation

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# Common VESGEN Study Design for ISS Crew Members, 70-Day HDT Bed Rest, and 90-Day HS Rodents

- Retrospective Human Subject Studies approved by NASA's HHC, LSAH and IRB
- **Phase 1** Masked VESGEN analysis of retinal images
- **Phase 2** Unmasking of subject status and correlation with other ocular, vision and cardiovascular parameters
- **Crew Members and Bed Rest** Retinal imaging by Heidelberg Spectralis 30° Infrared (IR)
- 8 Crew Members by 32 Spectralis IR images

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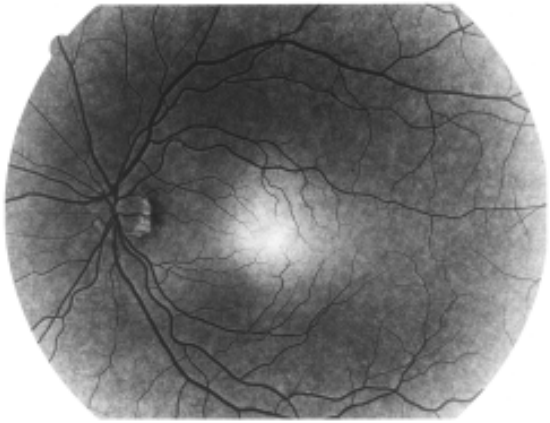
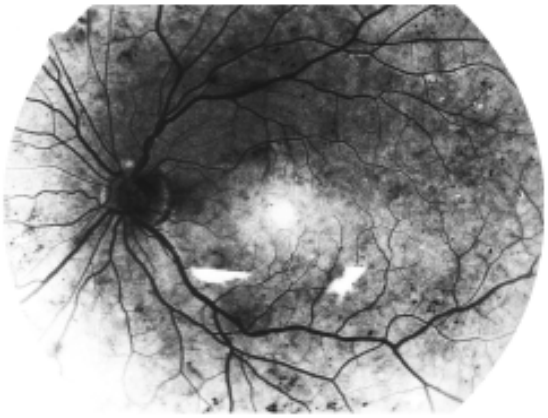
# Diabetic Retinopathy

**Previous grading by secondary, indirect consequences, not primary, indirect vascular changes**

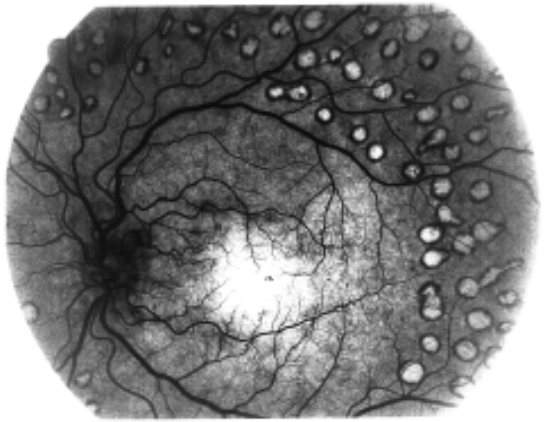
Normal



NPDR

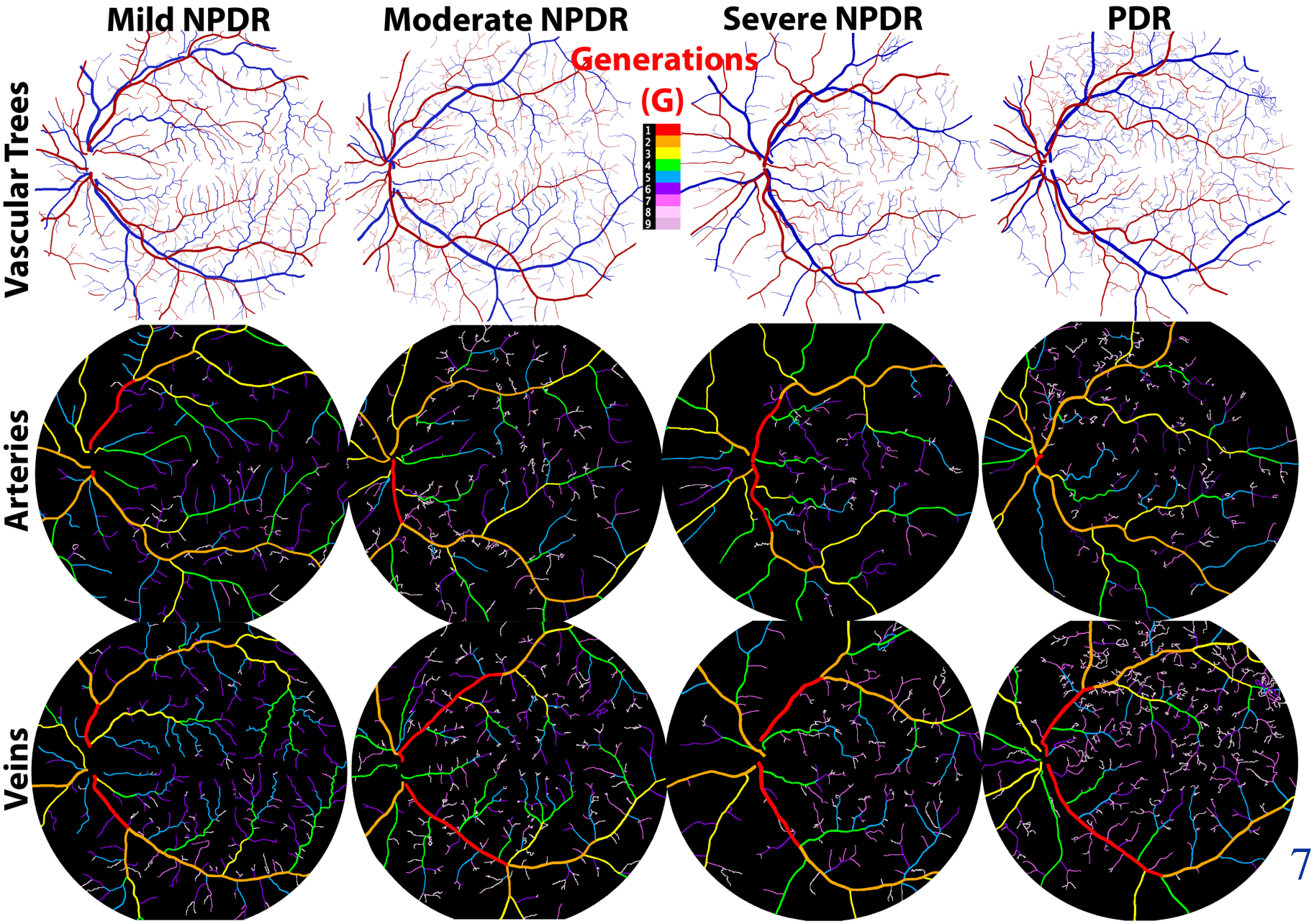


after Laser Ablation



**EARLY** ***Vascular*** Nonproliferative DR (NPDR)
**LATE** ***Vascular*** Proliferative DR (PDR)

# Mapping of Progressive Diabetic Retinopathy by VESGEN





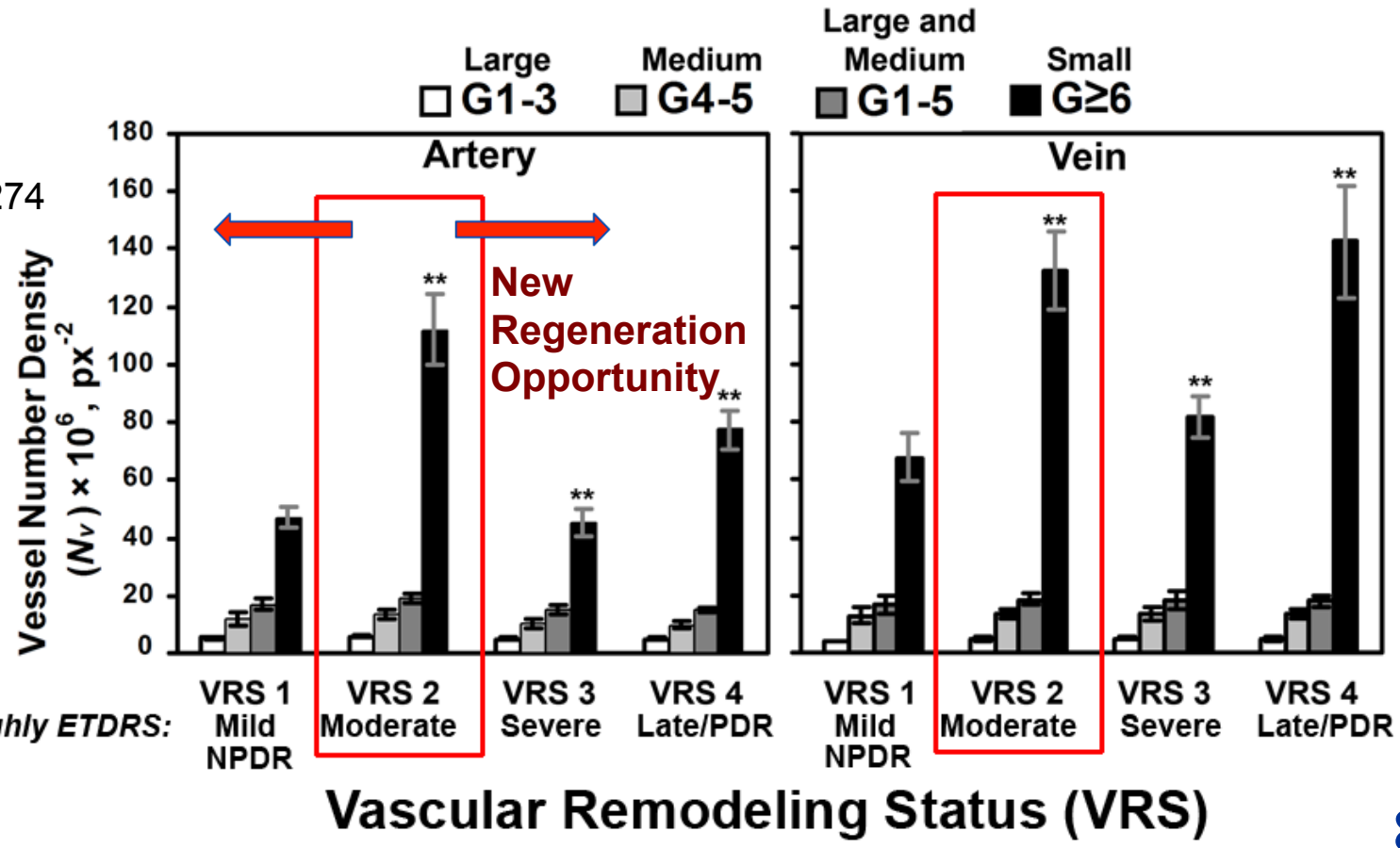

P Parsons-Wingerter, K Radhakrishnan, M B Vickerman, P K Kaiser, *IOVS* 51(1):498-507 (2010), in progress

# Surprising, Innovative Paradigm Shift by VESGEN

## Alternation of Vascular Dropout with Vascular Growth (Angiogenesis) during Progression of Diabetic Retinopathy

**Normal Retina**

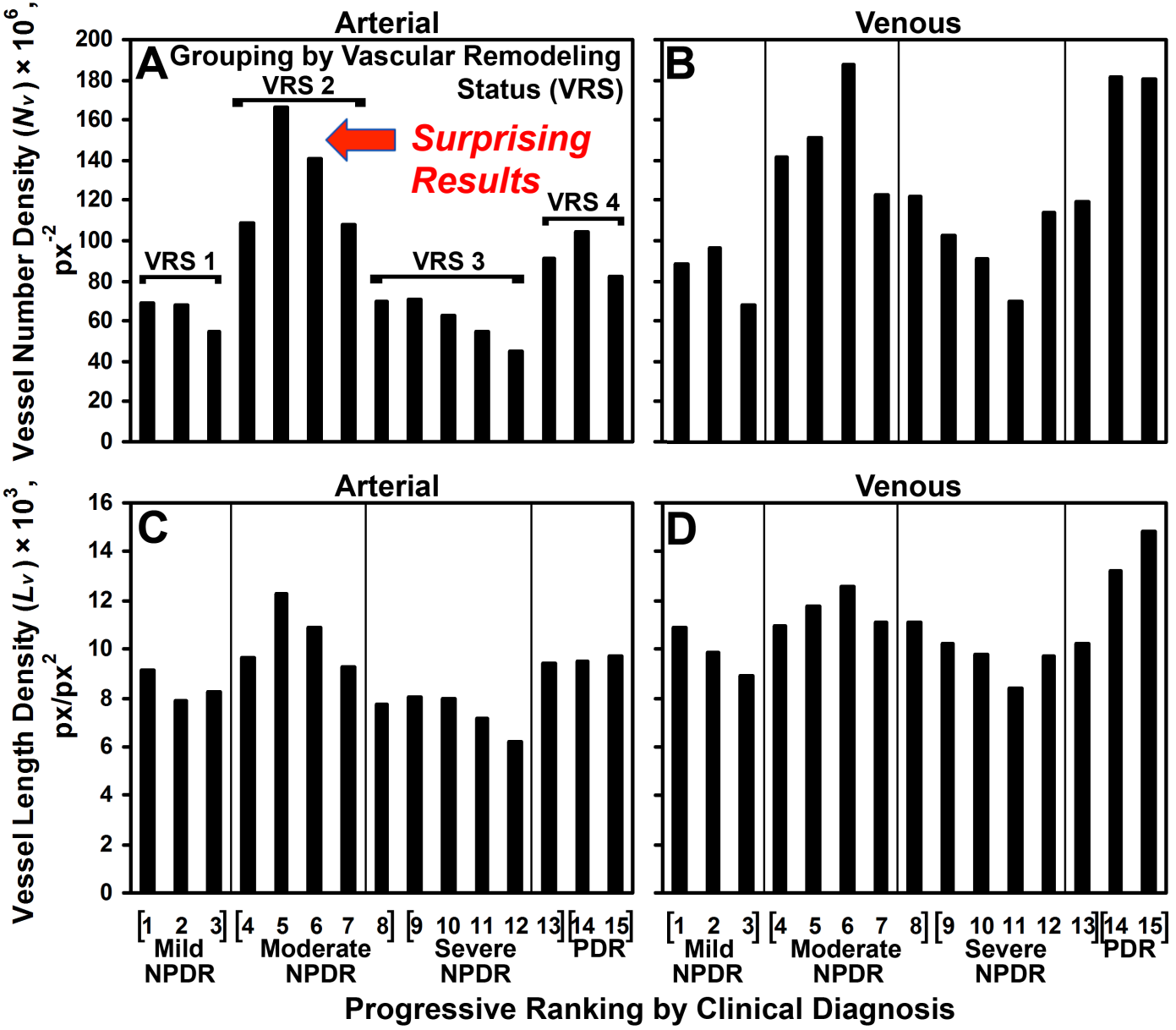
*Curr Eye Res* 24(4):274






P Parsons-Wingerter, K Radhakrishnan, M B Vickerman, P K Kaiser, *IOVS* 51(1):498-507 (2010) and in progress

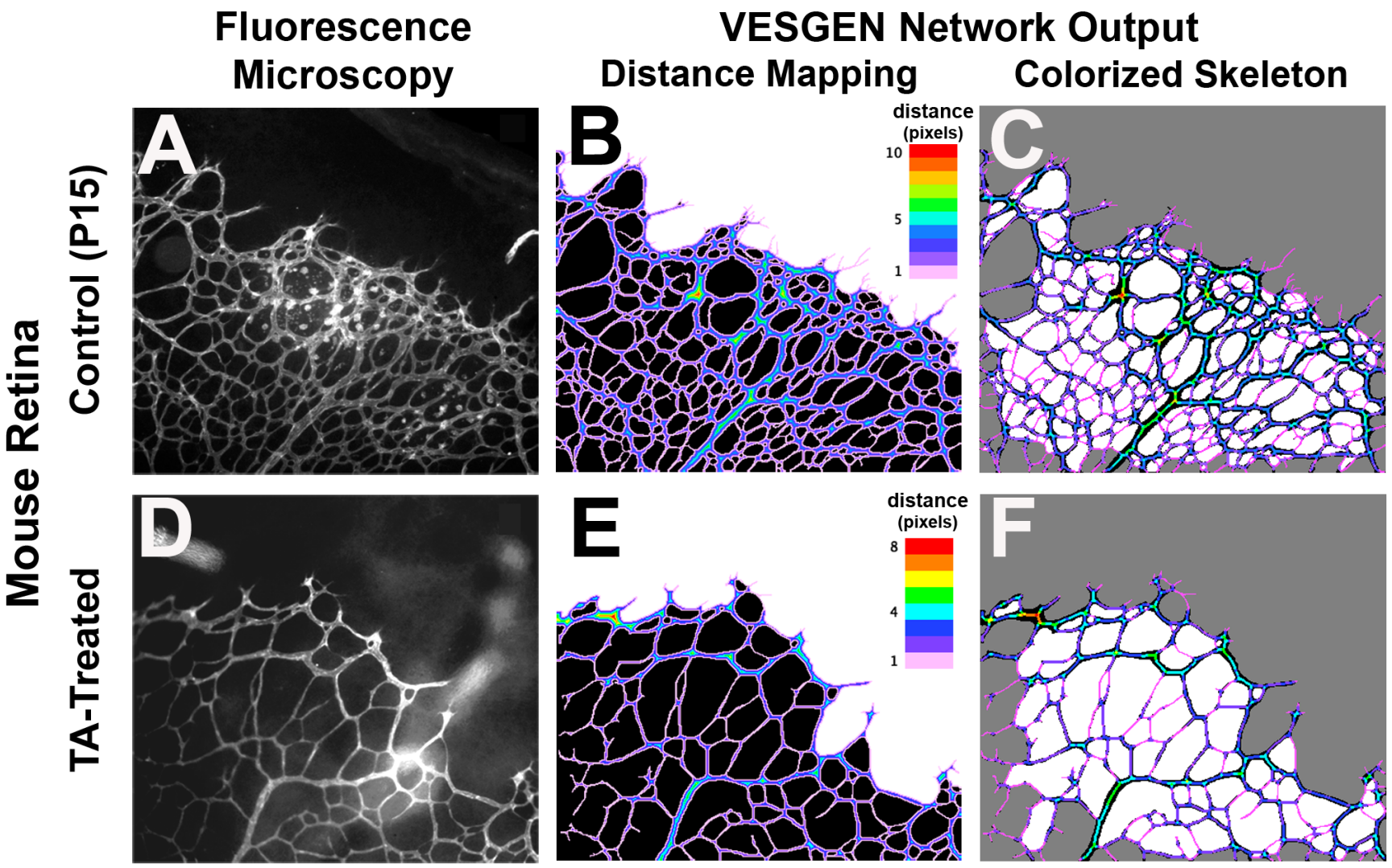
# Grouping by Vascular Remodeling Status (VRS)






P Parsons-Wingerter, K Radhakrishnan, M B Vickerman, P K Kaiser, *IOVS* 51(1):498-507 (2010), in progress

# Vascular Networks in Transgenic Mouse Retina




with J Sears & Q Ebrahem (Cole Eye Institute), from Vickerman et al, *Anatomical Record A* 292(3), 2009

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# Differences in Spectralis IR Image Background between April 2014 Study and Current Crew Members, HDT

Dr N Patel March 2014

Crew Member

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# Preliminary Phase 1 VESGEN Results for Crew Members Pre- and Post-Flight to the ISS

- 8 Crew Members by 32 Spectralis IR images
- Phase 1, Phase 2, Final Report complete by mid April 2017
- **Phase 1** Masked VESGEN analysis of retinal images
- **Phase 2** Unmasking of subject status and correlation with other ocular, vision and cardiovascular parameters
- **Crew Members and Bed Rest** Retinal imaging by Heidelberg Spectralis 30° Infrared (IR)

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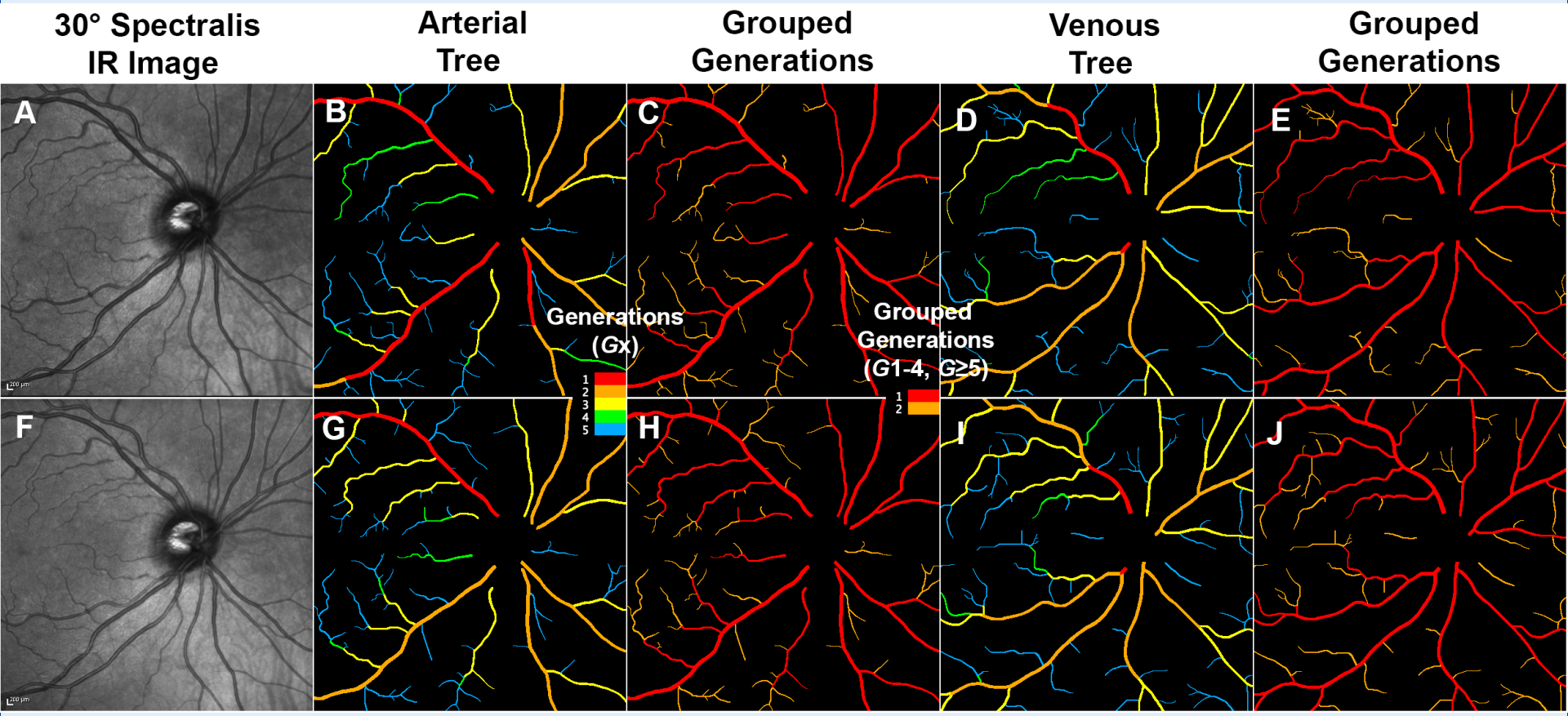
# Comparison of VESGEN Analysis for Arterial and Venous Trees In the Retina of ISS Crew Member Pre- and Post-Flight to ISS

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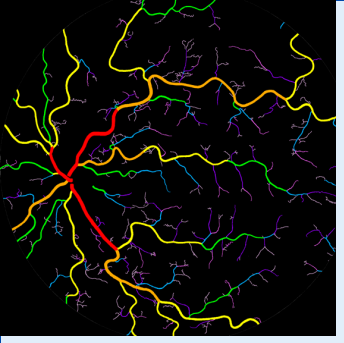
## *VESGEN Example* Companion images of identical Crew Member retina
## 30° IR image resolution of vessels matched by vessel diameter

*Grouped by Branching Generation ($G_x$)*

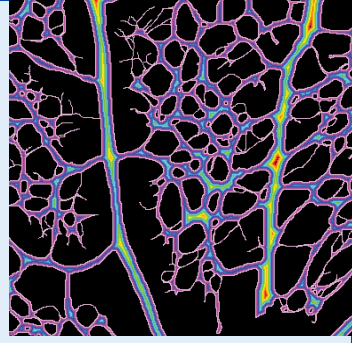
Large Vessels ($G_{1-4}$), Small Vessels ($G_{\geq 5}$)

| Crew Member | Vessel Number | | Vessel Length Density (E+3, μm/μm²) | | Fractal Dimension | Vessel Diameter (μm) | |
|---|---|---|---|---|---|---|---|
| | $N_{1-4}$ | $N_{\geq 5}$ | $L_{v1-4}$ | $L_{v\geq 5}$ | $D_f$ | $D_{v1-4}$ | $D_{v\geq 5}$ |
| Arteries | 31 | 48 | 2.65 | 1.26 | 1.35 | 25 | 12 |
| | **37** | **64** | **2.74** | **1.71** | **1.38** | 26 | 11 |
| Veins | 29 | 63 | 2.35 | 1.48 | 1.35 | 28 | 12 |
| | **32** | **69** | **2.52** | 1.49 | 1.36 | 27 | 11 |



Human Retina

# Conclusions



Mouse Retina

- Phase 1 nearing completion: VESGEN analysis of vascular patterning in the retinas of 8 Crew Members by 32 Spectralis IR images
- Phase 1, Phase 2, Final Report complete by mid April 2017
- VESGEN Results for Crew Members will be compared with 70-Day HDT Bed Rest study and 90-Day Rodent Hindlimb Suspension (in progress)
- Definitive testing of our hypothesis requires more advanced imaging of blood vessels in the retina and choroid by newer technologies such as OCT-A and AOSLO

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