Stanford

Paul George, MD, PhD

Associate Professor of Neurology (Adult Neurology) and, by courtesy, of Neurosurgery

Neurology & Neurological Sciences

CLINICAL OFFICE (PRIMARY)

- **Stanford Neuroscience Health Center**

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Bio

BIO

Stroke is the leading cause of disability in the United States, drastically disrupting the lives of stroke survivors and their caretakers. Unfortunately, because of tight therapeutic time requirements, the majority of stroke patients are not eligible for the current medicines or interventions. The George Lab's research focuses on improving stroke diagnostics as well as engineering new methods to enhance stroke recovery. Our lab's primary focus is applying novel bioengineering techniques to understand the mechanisms of neural recovery (primarily in stroke) and discovering methods to improve patient recovery. We use rodent models of stroke combined with biomaterial techniques, stem cell transplants, and microfabrication to achieve these aims and evaluate our methods with behavior testing and various imaging techniques. Our ultimate goal is to translate these findings into clinical trials to help stroke patients.

CLINICAL FOCUS

- Vascular Neurology

ACADEMIC APPOINTMENTS

- Associate Professor - University Medical Line, Neurology & Neurological Sciences
- Associate Professor - University Medical Line (By courtesy), Neurosurgery
- Member, Bio-X
- Member, Cardiovascular Institute
- Member, SPARK at Stanford
- Member, Wu Tsai Neurosciences Institute

ADMINISTRATIVE APPOINTMENTS

- Co-Director, Neurology Faculty Mentorship & Sponsorship Program, Department of Neurology, (2023- present)
- Member, Neuroscience Graduate IDP Faculty Program Committee, (2023- present)
- Member, Neuroscience PhD Program DEIB Committee, (2022- present)
- Neuroscience PhD Program Representative, Committee on Graduate Admissions and Policy, (2017- present)

BOARDS, ADVISORY COMMITTEES, PROFESSIONAL ORGANIZATIONS

- Chair, Science Committee, American Academy of Neurology (2023 - present)
- Ex-Officio Director, Board of Directors, American Academy of Neurology Institute (2023 - present)
- Science Committee, American Academy of Neurology (2013 - present)

PROFESSIONAL EDUCATION

- Residency: Stanford University Dept of Neurology (2012) CA
- Internship: Stanford University Internal Medicine Residency (2009) CA
- Fellowship: Stanford University Vascular Neurology Fellowship (2013) CA
- Board Certification: Vascular Neurology, American Board of Psychiatry and Neurology (2014)
- Board Certification: Neurology, American Board of Psychiatry and Neurology (2012)
- Medical Education: Harvard Medical School (2008) MA
- PhD, Massachussetts Institute of Technology , Electrical and Medical Engineering (2005)
- BSE, Tulane University of Louisiana (1999)

LINKS

- George Lab Site: http://med.stanford.edu/george-lab.html
- Get a Second Opinion: https://stanfordhealthcare.org/second-opinion/overview.html

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

CONDUCTIVE POLYMER SCAFFOLDS FOR STEM CELL-ENHANCED STROKE RECOVERY:

We focus on developing conductive polymers for stem cell applications. We have created a microfabricated, polymeric system that can continuously interact with its biological environment. This interactive polymer platform allows modifications of the recovery environment to determine essential repair mechanisms. Recent work studies the effect of electrical stimulation on neural stem cells seeded on the conductive scaffold and the pathways by which it enhances stroke recovery Further understanding the combined effect of electrical stimulation and stem cells in augmenting neural repair for clinical translational is a major focus of this research going forward.

BIOPOLYMER SYSTEMS FOR NEURAL RECOVERY AND STEM CELL MODULATION:

The George lab develops biomaterials to improve neural recovery in the peripheral and central nervous systems. By controlled release of drugs and molecules through biomaterials we can study the temporal effect of these neurotrophic factors on neural recovery and engineer drug delivery systems to enhance regenerative effects. By identifying the critical mechanisms for stroke and neural recovery, we are able to develop polymeric technologies for clinical translation in nerve regeneration and stroke recovery. Recent work utilizing these novel conductive polymers to differentiate stem cells for therapeutic and drug discovery applications.

APPLYING ENGINEERING TECHNIQUES TO DETERMINE BIOMARKERS FOR STROKE DIAGNOSTICS:

The ability to create diagnostic assays and techniques enables us to understand biological systems more completely and improve clinical management. Previous work utilized mass spectroscopy proteomics to find a simple serum biomarker for TIAs (a warning sign of stroke). Our study discovered a novel candidate marker, platelet basic protein. Current studies are underway to identify further candidate biomarkers using transcriptome analysis. More accurate diagnosis will allow for aggressive therapies to prevent subsequent strokes.

CLINICAL TRIALS

- Imaging Collaterals in Acute Stroke (iCAS), Not Recruiting
- Transient Ischemic Attack (TIA) Triage and Evaluation of Stroke Risk, Not Recruiting

Teaching

COURSES

2023-24

- Responsible Conduct of Neuroscience Research: NEPR 212 (Aut)

2022-23

- Responsible Conduct of Neuroscience Research: NEPR 212 (Aut)

2021-22

- Responsible Conduct of Neuroscience Research: NEPR 212 (Aut)

2020-21

- Responsible Conduct of Neuroscience Research: NEPR 212 (Aut)

STANFORD ADVISEES

Postdoctoral Faculty Sponsor

Sepideh Kiani Shabestari, Dingying Shan

Doctoral Dissertation Co-Advisor (NonAC)

Matine Azadian

GRADUATE AND FELLOWSHIP PROGRAM AFFILIATIONS

- Neurosciences (Phd Program)
- Vascular Neurology (Fellowship Program)

Publications

PUBLICATIONS

- **Eye Toward Stroke Prevention: Central Retinal Artery Occlusion and Tandem Internal Carotid Artery Occlusion.** *Stroke*
  Cheronis, C., Silverman, A., George, P. M.
  2024
- **Conductive gradient hydrogels allow spatial control of adult stem cell fate.** *Journal of materials chemistry. B*
  Song, S., McConnell, K. W., Shan, D., Chen, C., Oh, B., Sun, J., Poon, A. S., George, P. M.
  2024
- **Intravenous Tenecteplase and Carotid Artery Stenting in a Young Adult With Fibromuscular Dysplasia and Carotid Dissection.** *Stroke*
  Alfandy, F., Dugue, R., Pulli, B., George, P. M.
  2023
- **Clinical Problem Solving: A 38-year-Old Woman With Systemic Lupus Erythematosus Presenting With Headache, Nausea, and Vomiting.** *The Neurohospitalist*
  Silverman, A., Dugue, R., George, P. M.
  2023; 13 (4): 394-398
- **Wirelessly Powered-Electrically Conductive Polymer System for Stem Cell Enhanced Stroke Recovery.** *Advanced electronic materials*
  Santhanam, S., Chen, C., Oh, B., McConnell, K. W., Azadian, M. M., Patel, J. J., Gardner, E. E., Tanabe, Y., Poon, A. S., George, P. M.

2023; 9 (10)

- **Controlling the Stem Cell Environment Via Conducting Polymer Hydrogels to Enhance Therapeutic Potential** *ADVANCED MATERIALS TECHNOLOGIES*
  Santhanam, S., Feig, V. R., McConnell, K. W., Song, S., Gardner, E. E., Patel, J. J., Shan, D., Bao, Z., George, P. M.
  2023
- **Strategic Planning at NINDS: Translating Plans into Action and Outcomes.** *Neurology*
  Jones, L. K., George, P.
  2022
- **Electrical modulation of transplanted stem cells improves functional recovery in a rodent model of stroke.** *Nature communications*
  Oh, B., Santhanam, S., Azadian, M., Swaminathan, V., Lee, A. G., McConnell, K. W., Levinson, A., Song, S., Patel, J. J., Gardner, E. E., George, P. M.
  2022; 13 (1): 1366
- **Elastin-like Proteins to Support Peripheral Nerve Regeneration in Guidance Conduits.** *ACS biomaterials science & engineering*
  Suhar, R. A., Marquardt, L. M., Song, S., Buabbas, H., Doulames, V. M., Johansson, P. K., Klett, K. C., Dewi, R. E., Enejder, A. M., Plant, G. W., George, P. M., Heilshorn, S. C.
  2021; 7 (9): 4209-4220
- **Electrical stimulation of human neural stem cells via conductive polymer nerve guides enhances peripheral nerve recovery.** *Biomaterials*
  Song, S., McConnell, K. W., Amores, D., Levinson, A., Vogel, H., Quarta, M., Rando, T. A., George, P. M.
  2021; 275: 120982
- **Conducting polymer-based granular hydrogels for injectable 3D cell scaffolds.** *Advanced materials technologies*
  Feig, V. R., Santhanam, S., McConnell, K. W., Liu, K., Azadian, M., Brunel, L. G., Huang, Z., Tran, H., George, P. M., Bao, Z.
  2021; 6 (6)
- **Modulating the Electrical and Mechanical Microenvironment to Guide Neuronal Stem Cell Differentiation.** *Advanced science (Weinheim, Baden-Wurttemberg, Germany)*
  Oh, B., Wu, Y. W., Swaminathan, V., Lam, V., Ding, J., George, P. M.
  2021; 8 (7): 2002112
- **Morphing electronics enable neuromodulation in growing tissue.** *Nature biotechnology*
  Liu, Y. n., Li, J. n., Song, S. n., Kang, J. n., Tsao, Y. n., Chen, S. n., Mottni, V. n., McConnell, K. n., Xu, W. n., Zheng, Y. Q., Tok, J. B., George, P. M., Bao, et al
  2020
- **Single-Cell Encapsulation via Click-Chemistry Alters Production of Paracrine Factors from Neural Progenitor Cells.** *Advanced science (Weinheim, Baden-Wurttemberg, Germany)*
  Oh, B. n., Swaminathan, V. n., Malkovskiy, A. n., Santhanam, S. n., McConnell, K. n., George, P. M.
  2020; 7 (8): 1902573
- **Controlling properties of human neural progenitor cells using 2D and 3D conductive polymer scaffolds.** *Scientific reports*
  Song, S., Amores, D., Chen, C., McConnell, K., Oh, B., Poon, A., George, P. M.
  2019; 9 (1): 19565
- **Regulating Stem Cell Function with Electrical Stimulation**
  Oh, B., Song, S., Lam, V., George, P.
  WILEY.2019: S277–S278
- **Conductive polymers to modulate the post-stroke neural environment** *BRAIN RESEARCH BULLETIN*
  Oh, B., George, P.
  2019; 148: 10–17
- **Utilizing Single Cell Immune Profiling to Identify Serum-based Biomarkers for Transient Ischemic Attacks**
  Therkelsen, K., Tsai, A., Mlynash, M., Oh, B., Eyngorn, I., Gaudilliere, B., George, P.
  LIPPINCOTT WILLIAMS & WILKINS.2019
- **Identification of New Therapeutic Pathways by Transcriptome Analysis of Electrically Stimulated-Neural Progenitor Cells After Stroke.**
  Oh, B., Swaminathan, V., Lam, V., Levinson, A., George, P.
  LIPPINCOTT WILLIAMS & WILKINS.2019

- **Engineered stem cell mimics to enhance stroke recovery** *BIOMATERIALS*
  George, P. M., Oh, B., Dewi, R., Hua, T., Cai, L., Levinson, A., Liang, X., Krajina, B. A., Bliss, T. M., Heilshorn, S. C., Steinberg, G. K.
  2018; 178: 63–72

- **In vivo Electrical Stimulation of Neural Stem Cells via Conductive Polymer Scaffold Improves Endogenous Repair Mechanisms of Stroke Recovery**
  Oh, B., Song, S., Lam, V., Levinson, A., George, P.
  LIPPINCOTT WILLIAMS & WILKINS.2018

- **Electrically Conductive Scaffold to Modulate and Deliver Stem Cells** *JOVE-JOURNAL OF VISUALIZED EXPERIMENTS*
  Oh, B., Levinson, A., Lam, V., Song, S., George, P.
  2018

- **Electrically Conductive Scaffold to Modulate and Deliver Stem Cells.** *Journal of visualized experiments : JoVE*
  Oh, B., Levinson, A., Lam, V., Song, S., George, P.
  2018

- **Electrical preconditioning of stem cells with a conductive polymer scaffold enhances stroke recovery.** *Biomaterials*
  George, P. M., Bliss, T. M., Hua, T. n., Lee, A. n., Oh, B. n., Levinson, A. n., Mehta, S. n., Sun, G. n., Steinberg, G. K.
  2017; 142: 31–40

- **Conductive polymer scaffolds to improve neural recovery.** *Neural regeneration research*
  Song, S. n., George, P. M.
  2017; 12 (12): 1976–78

- **Validation and comparison of imaging-based scores for prediction of early stroke risk after transient ischaemic attack: a pooled analysis of individual-patient data from cohort studies** *LANCET NEUROLOGY*
  Kelly, P. J., Albers, G. W., Chatzikonstantinou, A., De Marchis, G. M., Ferrari, J., George, P., Katan, M., Knoflach, M., Kim, J. S., Li, L., Lee, E., Olivot, J., Purroy, et al
  2016; 15 (12): 1236-1245

- **Inter-rater agreement analysis of the Precise Diagnostic Score for suspected transient ischemic attack.** *International journal of stroke*
  Cereda, C. W., George, P. M., Inoue, M., Vora, N., Olivot, J., Schwartz, N., Lansberg, M. G., Kemp, S., Mlynash, M., Albers, G. W.
  2016; 11 (1): 85-92

- **Novel TIA biomarkers identified by mass spectrometry-based proteomics** *INTERNATIONAL JOURNAL OF STROKE*
  George, P. M., Mlynash, M., Adams, C. M., Kuo, C. J., Albers, G. W., Olivot, J.
  2015; 10 (8): 1204-1211

- **Novel TIA biomarkers identified by mass spectrometry-based proteomics.** *International journal of stroke : official journal of the International Stroke Society*
  George, P. M., Mlynash, M., Adams, C. M., Kuo, C. J., Albers, G. W., Olivot, J. M.
  2015; 10 (8): 1204-11

- **Novel Stroke Therapeutics: Unraveling Stroke Pathophysiology and Its Impact on Clinical Treatments.** *Neuron*
  George, P. M., Steinberg, G. K.
  2015; 87 (2): 297-309

- **Beneficial effects of a semi-intensive stroke unit are beyond the monitor.** *Cerebrovascular diseases*
  Cereda, C. W., George, P. M., Pelloni, L. S., Gandolfi-Decristophoris, P., Mlynash, M., Biancon Montaperto, L., Limoni, C., Stojanova, V., Malacrida, R., Städler, C., Bassetti, C. L.
  2015; 39 (2): 102-109

- **Aortic arch atheroma: a plaque of a different color or more of the same?** *Stroke; a journal of cerebral circulation*
  George, P. M., Albers, G. W.
  2014; 45 (5): 1239-1240

- **Three-dimensional conductive constructs for nerve regeneration.** *Journal of biomedical materials research. Part A*
  George, P. M., Saigal, R., Lawlor, M. W., Moore, M. J., LaVan, D. A., Marini, R. P., Selig, M., Makhni, M., Burdick, J. A., Langer, R., Kohane, D. S.
  2009; 91 (2): 519-527

- **Electrically controlled drug delivery from biotin-doped conductive polypyrrole** *ADVANCED MATERIALS*

George, P. M., LaVan, D. A., Burdick, J. A., Chen, C. Y., Liang, E., Langer, R.
2006; 18 (5): 577-+

- **Electrically Controlled Drug Delivery from Biotin-Doped Conductive Polymer** *Advanced Materials*
  George, P. M., LaVan, D., Burdick, J., Chen, C. Y., Liang, E., Langer, R.
  2006; 18 (5)
- **Fabrication and biocompatibility of polypyrrole implants suitable for neural prosthetics** *BIOMATERIALS*
  George, P. M., Lyckman, A. W., LaVan, D. A., Hegde, A., Leung, Y., Avasare, R., Testa, C., Alexander, P. M., Langer, R., Sur, M.
  2005; 26 (17): 3511-3519
- **Simple, three-dimensional microfabrication of electrodeposited structures** *ANGEWANDTE CHEMIE-INTERNATIONAL EDITION*
  LaVan, D. A., George, P. M., Langer, R.
  2003; 42 (11): 1262-1265
- **Fabrication of Screen-Printed Carbon Electrode Arrays for Sensing Neuronal Messengers** *BIOMEDICAL MICRODEVICES*
  George, P. M., Muthuswamy, J., Currie, J., Thakor, N. V., Paranjape, M.
  2001; 3 (4): 307-313