Stanford



Raag Airan

Associate Professor of Radiology (Neuroimaging and Neurointervention) and, by courtesy, of Materials Science & Engineering and of Psychiatry and Behavioral Sciences

CLINICAL OFFICE (PRIMARY)

- **Radiology Department**

  300 Pasteur Dr Rm S062B

  Grant Bldg MC 5105

  Stanford, CA 94305

  Tel (650) 736-6172 **Fax** (650) 498-5374

Bio

CLINICAL FOCUS

- Neuroradiology
- Diagnostic Neuroimaging

ACADEMIC APPOINTMENTS

- Associate Professor, Radiology
- Associate Professor (By courtesy), Materials Science and Engineering
- Associate Professor (By courtesy), Psychiatry and Behavioral Sciences
- Member, Bio-X
- Member, Maternal & Child Health Research Institute (MCHRI)
- Faculty Fellow, Sarafan ChEM-H
- Member, Wu Tsai Neurosciences Institute

PROFESSIONAL EDUCATION

- Fellowship: Johns Hopkins University Neuroradiology Fellowship (2016) MD
- Medical Education: Stanford University School of Medicine (2010) CA
- Board Certification: Diagnostic Radiology, American Board of Radiology (2016)
- Residency: Johns Hopkins University Dept of Radiology (2015) MD
- Board Certification: Neuroradiology, American Board of Radiology (2018)
- Internship: Medstar Washington Hospital Center Internal Medicine Residency (2011) DC
- PhD, Stanford University , Bioengineering (2010)

LINKS

- Airan Lab: http://airan-lab.stanford.edu

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

Our goal is to develop and clinically implement new technologies for high-precision and noninvasive intervention upon the nervous system. Every few millimeters of the brain is functionally distinct, and different parts of the brain may have counteracting responses to therapy. To better match our therapies to neuroscience, we develop techniques that allow intervention upon only the right part of the nervous system at the right time, using technologies like focused ultrasound and nanotechnology.

CLINICAL TRIALS

- Ultrasonic Debris Clearance to Promote Brain Resilience, Recruiting

Teaching

COURSES

2026-27

- Introduction to Imaging and Image-based Human Anatomy: BIOE 220, BMP 220, RAD 220 (Win)

2025-26

- Introduction to Imaging and Image-based Human Anatomy: BIOE 220, BMP 220, RAD 220 (Win)

2024-25

- Introduction to Imaging and Image-based Human Anatomy: BIOE 220, BMP 220, RAD 220 (Win)

2023-24

- Introduction to Imaging and Image-based Human Anatomy: BIOE 220, BMP 220, RAD 220 (Win)

STANFORD ADVISEES

Med Scholar Project Advisor

John Layton

Doctoral Dissertation Reader (AC)

Charlotte Herber

Orals Chair

Goldie Roth

Postdoctoral Faculty Sponsor

Payton Martinez

GRADUATE AND FELLOWSHIP PROGRAM AFFILIATIONS

- Biophysics (PhD Program)
- Medicine (Masters Program)
- Neuroradiology (Fellowship Program)
- Neurosciences (PhD Program)

Publications

PUBLICATIONS

- **Transient blood-brain barrier opening by focused ultrasound enhances ferumoxytol accumulation in glioblastoma.** *Materials today. Bio*
  Saladino, G. M., Martinez, P. J., Wang, J., Roudi, R., Annio, G., Airan, R. D., Daldrup-Link, H. E.
  2026; 38: 103280

- **Ethological profiling defines pain behaviors and parses analgesia from drug side effects in a mouse model of complex regional pain syndrome.** *Pain*
  Muwanga, G. P., Tena, A. C., Pang, A., Ewbank, S. N., Siliezar-Doyle, J., Nippert, A. R., Airan, R. D., Tawfik, V. L.
  2026; 167 (6): 1453-1469

- **How Common Are Incidental Brain MRI Findings in Psychiatric Populations? Insights From Patients Seeking Accelerated TMS**
  Austelle, C., Struckmann, W., Jones, R., Buchanan, D., Lissemore, J., Geoly, A., Feyder, M., Stimpson, K., Ford, T. J., Ehrie, J., Airan, R., Rolle, C., Bentzley, et al
  ELSEVIER SCIENCE INC.2026

- **Is Ketamine an Opioid?** *Biological psychiatry*
  Heifets, B. D., Airan, R. D.
  2026; 99 (4): 266-268

- **From Microstructure to Molecules: Mechanisms of Stem Cell-Driven White Matter Repair After Chronic Stroke**
  Habib, P., Ewbank, S., Liang, X., Noristani, R., Johnston, N., Kim, J., Airan, R., Bliss, T., Steinberg, G.
  LIPPINCOTT WILLIAMS & WILKINS.2026

- **Open Letter on Intervention Regimes and Adverse Events in Focused Ultrasound for Neuromodulation.** *Brain stimulation*
  Klein-Flugge, M. C., Airan, R. D., Attali, D., Aubry, J. F., Bubrick, E. J., Caskey, C. F., Cleveland, R. O., Fouragnan, E. F., Jones, R. M., Khokhlova, T. D., Kubanek, J., Lea-Banks, H., Legon, et al
  2025: 102994

- **Combination of Neuronavigation-Guided Focused Ultrasound and Bevacizumab for Patients With Recurrent Glioblastoma: A Pilot Study.** *Neurosurgery*
  Chen, K. T., Tsai, H. C., Huang, C. Y., Liau, C. T., Ho, K. C., Toh, C. H., Chuang, C. C., Hsu, P. W., Huang, Y. C., Chang, T. W., Yeap, M. C., Chen, P. Y., Lee, et al
  2025

- **Clearance of intracranial debris by ultrasound reduces inflammation and improves outcomes in hemorrhagic stroke models.** *Nature biotechnology*
  Azadian, M. M., Kiani Shabestari, S., Rajan, A., Martinez, P. J., Macedo, N., Markarian, E., Xiang, Y., Yu, B. J., George, P. M., Fame, R. M., Airan, R. D.
  2025

- **Acoustically activatable liposomes as a translational nanotechnology for site-targeted drug delivery and noninvasive neuromodulation.** *Nature nanotechnology*
  Purohit, M. P., Yu, B. J., Roy, K. S., Xiang, Y., Ewbank, S. N., Azadian, M. M., Hart, A. R., Muwanga, G. P., Martinez, P. J., Wang, J. B., Taoube, A. K., Markarian, E., Macedo, et al
  2025

- **Developing algorithmic psychiatry via multi-level spanning computational models.** *Cell reports. Medicine*
  Halassa, M. M., Frank, M. J., Garety, P., Ongur, D., Airan, R. D., Sanacora, G., Dzirasa, K., Suresh, S., Fitzpatrick, S. M., Rothman, D. L.
  2025: 102094

- **Ketamine-induced static and dynamic functional connectivity changes are modulated by opioid receptors and biological sex in rats.** *Neuropsychopharmacology : official publication of the American College of Neuropsychopharmacology*
  Grasso, V., Tennyson, J., Airan, R. D., Di Ianni, T.
  2025

- **Quantitative Profiling of the Effects of Subanesthetic Ketamine on Naturalistic Behavior and Brain Microstructure**
  Ewbank, S., Hart, A., Muwanga, G., Gopal, D., Roy, K., Yu, B., Laurent, R., Tawfik, V., Rodriguez, C., Mcnab, J., Airan, R.

SPRINGERNATURE.2024: 104

- **SELECTIVELY ACTIVATING THE AFFECTIVE EFFICACY OF KETAMINE VIA REGIONALLY-TARGETED NONINVASIVE ULTRASONIC DRUG UNCAGING**
  Yu, B., Roy, K., Ewbank, S., Purohit, M., Azadian, M., Xiang, Y., Wang, J., Airan, R.
  SPRINGERNATURE.2024: 411-412

- **Optimized ultrasound neuromodulation for non-invasive control of behavior and physiology.** *Neuron*
  Murphy, K. R., Farrell, J. S., Bendig, J., Mitra, A., Luff, C., Stelzer, I. A., Yamaguchi, H., Angelakos, C. C., Choi, M., Bian, W., Dilanni, T., Pujol, E. M., Matosevich, et al
  2024

- **Ultrasonic cerebrospinal fluid clearance improves outcomes in hemorrhagic brain injury models.** *bioRxiv : the preprint server for biology*
  Azadian, M. M., Macedo, N., Yu, B. J., Fame, R. M., Airan, R. D.
  2024

- **Sex dependence of opioid-mediated responses to subanesthetic ketamine in rats.** *Nature communications*
  Di Ianni, T., Ewbank, S. N., Levinstein, M. R., Azadian, M. M., Budinich, R. C., Michaelides, M., Airan, R. D.
  2024; 15 (1): 893

- **High-throughput ultrasound neuromodulation in awake and freely behaving rats.** *Brain stimulation*
  Di Ianni, T., Morrison, K. P., Yu, B., Murphy, K. R., de Lecea, L., Airan, R. D.
  2023; 16 (6): 1743-1752

- **Pharmacokinetics-Pharmacodynamics Dissociation Indicative of Ketamine-Induced Plasticity as Revealed by Ultrasonic Ketamine Uncaging in Rat Medial Prefrontal Cortex**
  Yu, B., Roy, K., Purohit, M., Xiang, Y., Azadian, M., Taoube, A., Kwan, A., Lopez, D., Airan, R.
  SPRINGERNATURE.2023: 277-278

- **Acoustomechanically activatable liposomes for ultrasonic drug uncaging.** *bioRxiv : the preprint server for biology*
  Purohit, M. P., Roy, K. S., Xiang, Y., Yu, B. J., Azadian, M. M., Muwanga, G., Hart, A. R., Taoube, A. K., Lopez, D. G., Airan, R. D.
  2023

- **Oscillatory effects of ketamine using focused ultrasound sensitive liposomes**
  Yu, B., Taoube, A. K., Airan, R. D.
  CELL PRESS.2023: 540A

- **Oscillatory effects of ketamine using focused ultrasound sensitive liposomes.** *Biophysical journal*
  Yu, B., Taoube, A. K., Airan, R. D.
  2023; 122 (3S1): 540a

- **Noninvasive ultrasonic induction of cerebrospinal fluid flow enhances intrathecal drug delivery.** *Journal of controlled release : official journal of the Controlled Release Society*
  Aryal, M., Azadian, M. M., Hart, A. R., Macedo, N., Zhou, Q., Rosenthal, E. L., Airan, R. D.
  2022

- **Changes In The Cerebello-thalamo-cortical Network After MR-guided Focused Ultrasound Thalamotomy.** *Brain connectivity*
  Thaler, C., Tian, Q., WIntermark, M., Ghanouni, P., Halpern, C., Henderson, J., Airan, R., Zeineh, M., Goubran, M., Leuze, C., Fiehler, J., Butts Pauly, K., McNab, et al
  2022

- **Deep-fUS: A deep learning platform for functional ultrasound imaging of the brain using sparse data.** *IEEE transactions on medical imaging*
  Di Ianni, T., Airan, R. D.
  2022; PP

- **Mu opioid receptor activation mediates (S)-ketamine reinforcement in rats: implications for abuse liability** *Biological Psychiatry*
  Levinstein, M. R., Carlton, M. L., Di Ianni, T., Ventriglia, E. N., Rizzo, A., Gomez, J. L., Budinich, R. C., Shaham, Y., Airan, R. D., Zarate Jr, C. A., Bonaventura, J., Michaelides, M.
  2022

- **Using Passively Detected Acoustic Signals to Characterize Ultrasound Gated Nanoparticles**

Singh, A., Xiang, Y., Sigona, M., Purohit, M., Hart, A., Hosseini-Nassab, N., Airan, R., Caskey, C., IEEE
IEEE.2021

- **Ultrasonic Drug Uncaging for Noninvasive Targeted Neuropsychopharmacology**
  Airan, R.
  SPRINGERNATURE.2020: 22

- **Histologic evaluation of activation of acute inflammatory response in a mouse model following ultrasound-mediated blood-brain barrier using different acoustic pressures and microbubble doses.** *Nanotheranostics*
  Pascal, A. n., Li, N. n., Lechtenberg, K. J., Rosenberg, J. n., Airan, R. D., James, M. L., Bouley, D. M., Pauly, K. B.
  2020; 4 (4): 210–23

- **Focused Ultrasound for Noninvasive, Focal Pharmacologic Neurointervention.** *Frontiers in neuroscience*
  Wang, J. B., Di Ianni, T. n., Vyas, D. B., Huang, Z. n., Park, S. n., Hosseini-Nassab, N. n., Aryal, M. n., Airan, R. D.
  2020; 14: 675

- **CT and CEST MRI bimodal imaging of the intratumoral distribution of iodinated liposomes** *QUANTITATIVE IMAGING IN MEDICINE AND SURGERY*
  Chen, Z., Li, Y., Airan, R., Han, Z., Xu, J., Chan, K. W. Y., Xu, Y., Bulte, J. W. M., van Zijl, P. C. M., McMahon, M. T., Zhou, S., Liu, G.
  2019; 9 (9): 1579-+

- **CT and CEST MRI bimodal imaging of the intratumoral distribution of iodinated liposomes.** *Quantitative imaging in medicine and surgery*
  Chen, Z., Li, Y., Airan, R., Han, Z., Xu, J., Chan, K. W., Xu, Y., Bulte, J. W., van Zijl, P. C., McMahon, M. T., Zhou, S., Liu, G.
  2019; 9 (9): 1579-1591

- **Polymeric perfluorocarbon nanoemulsions are ultrasound-activated wireless drug infusion catheters.** *Biomaterials*
  Zhong, Q., Yoon, B. C., Aryal, M., Wang, J. B., Ilovitsh, T., Baikoghli, M. A., Hosseini-Nassab, N., Karthik, A., Cheng, R. H., Ferrara, K. W., Airan, R. D.
  2019; 206: 73–86

- **Noninvasive Ultrasonic Drug Uncaging Maps Whole-Brain Functional Networks.** *Neuron*
  Wang, J. B., Aryal, M., Zhong, Q., Vyas, D. B., Airan, R. D.
  2018; 100 (3): 728

- **Hearing out Ultrasound Neuromodulation.** *Neuron*
  Airan, R. D., Butts Pauly, K.
  2018; 98 (5): 875–77

- **Optogenetic Control of Intracellular Signaling: Class II Opsins** *OPTOGENETICS: A ROADMAP*
  Ellwardt, E., Airan, R. D.
  edited by Stroh, A.
  2018; 133: 63–73

- **Diffusion MRI tractography for improved transcranial MRI-guided focused ultrasound thalamotomy targeting for essential tremor.** *NeuroImage. Clinical*
  Tian, Q., Wintermark, M., Jeffrey Elias, W., Ghanouni, P., Halpern, C. H., Henderson, J. M., Huss, D. S., Goubran, M., Thaler, C., Airan, R., Zeineh, M., Pauly, K. B., McNab, et al
  2018; 19: 572–80

- **Neuromodulation with nanoparticles** *SCIENCE*
  Airan, R.
  2017; 357 (6350): 465

- **Noninvasive Targeted Transcranial Neuromodulation via Focused Ultrasound Gated Drug Release from Nanoemulsions.** *Nano letters*
  Airan, R. D., Meyer, R. A., Ellens, N. P., Rhodes, K. R., Farahani, K., Pomper, M. G., Kadam, S. D., Green, J. J.
  2017; 17 (2): 652-659

- **MR-Guided Delivery of Hydrophilic Molecular Imaging Agents Across the Blood-Brain Barrier Through Focused Ultrasound.** *Molecular imaging and biology : MIB : the official publication of the Academy of Molecular Imaging*
  Airan, R. D., Foss, C. A., Ellens, N. P., Wang, Y., Mease, R. C., Farahani, K., Pomper, M. G.
  2017; 19 (1): 24-30

- **Factors affecting characterization and localization of interindividual differences in functional connectivity using MRI** *HUMAN BRAIN MAPPING*
  Airan, R. D., Vogelstein, J. T., Pillai, J. J., Caffo, B., Pekar, J. J., Sair, H. I.
  2016; 37 (5): 1986-1997

- **Presurgical brain mapping of the language network in patients with brain tumors using resting-state fMRI: Comparison with task fMRI** *HUMAN BRAIN MAPPING*
  Sair, H. I., Yahyavi-Firouz-Abadi, N., Calhoun, V. D., Airan, R. D., Agarwal, S., Intrapiromkul, J., Choe, A. S., Gujar, S. K., Caffo, B., Lindquist, M. A., Pillai, J. J.
  2016; 37 (3): 913-923

- **Neurovascular Uncoupling in Resting State fMRI Demonstrated in Patients With Primary Brain Gliomas** *JOURNAL OF MAGNETIC RESONANCE IMAGING*
  Agarwal, S., Sair, H. I., Yahyavi-Firouz-Abadi, N., Airan, R., Pillai, J. J.
  2016; 43 (3): 620-626

- **Estimating a graphical intra-class correlation coefficient (GICC) using multivariate probit-linear mixed models** *COMPUTATIONAL STATISTICS & DATA ANALYSIS*
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  2015; 89: 126-133

- **Label-free in vivo molecular imaging of underglycosylated mucin-1 expression in tumour cells** *NATURE COMMUNICATIONS*
  Song, X., Airan, R. D., Arifin, D. R., Bar-Shir, A., Kadayakkara, D. K., Liu, G., Gilad, A. A., van Zijl, P. C., McMahon, M. T., Bulte, J. W.
  2015; 6

- **Neuroinflammation and brain atrophy in former NFL players: An in vivo multimodal imaging pilot study** *NEUROBIOLOGY OF DISEASE*
  Coughlin, J. M., Wang, Y., Munro, C. A., Ma, S., Yue, C., Chen, S., Airan, R., Kim, P. K., Adams, A. V., Garcia, C., Higgs, C., Sair, H. I., Sawa, et al
  2015; 74: 58-65

- **Optogenetics in Freely Moving Mammals: Dopamine and Reward.** *Cold Spring Harbor protocols*
  Zhang, F., Tsai, H., Airan, R. D., Stuber, G. D., Adamantidis, A. R., de Lecea, L., Bonci, A., Deisseroth, K.
  2015; 2015 (8): pdb top086330-?

- **Natural neural projection dynamics underlying social behavior.** *Cell*
  Gunaydin, L. A., Grosenick, L., Finkelstein, J. C., Kauvar, I. V., Fenno, L. E., Adhikari, A., Lammel, S., Mirzabekov, J. J., Airan, R. D., Zalocusky, K. A., Tye, K. M., Anikeeva, P., Malenka, et al
  2014; 157 (7): 1535-1551

- **Human brain atlas for automated region of interest selection in quantitative susceptibility mapping: application to determine iron content in deep gray matter structures.** *NeuroImage*
  Lim, I. A., Faria, A. V., Li, X., Hsu, J. T., Airan, R. D., Mori, S., van Zijl, P. C.
  2013; 82: 449-469

- **Genetic tools to manipulate MRI contrast** *NMR IN BIOMEDICINE*
  Airan, R. D., Li, N., Gilad, A. A., Pelled, G.
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- **MRI biosensor for protein kinase A encoded by a single synthetic gene** *MAGNETIC RESONANCE IN MEDICINE*
  Airan, R. D., Bar-Shir, A., Liu, G., Pelled, G., McMahon, M. T., van Zijl, P. C., Bulte, J. W., Gilad, A. A.
  2012; 68 (6): 1919-1923

- **Optogenetic interrogation of neural circuits: technology for probing mammalian brain structures** *NATURE PROTOCOLS*
  Zhang, F., Gradinaru, V., Adamantidis, A. R., Durand, R., Airan, R. D., de Lecea, L., Deisseroth, K.
  2010; 5 (3): 439-456

- **Temporally precise in vivo control of intracellular signalling** *NATURE*
  Airan, R. D., Thompson, K. R., Fenno, L. E., Bernstein, H., Deisseroth, K.
  2009; 458 (7241): 1025-1029

- **Brain circuit dynamics** *AMERICAN JOURNAL OF PSYCHIATRY*
  Hu, E. S., Airan, R. D., Vijaykumar, R., Deisseroth, K.

2008; 165 (7): 800-800

- **Integration of light-controlled neuronal firing and fast circuit imaging** *CURRENT OPINION IN NEUROBIOLOGY*
  Airan, R. D., Hu, E. S., Vijaykumar, R., Roy, M., Meltzer, L. A., Deisseroth, K.
  2007; 17 (5): 587-592
- **High-speed Imaging reveals neurophysiological links to behavior in an animal model of depression** *SCIENCE*
  Airan, R. D., Meltzer, L. A., Roy, M., Gong, Y., Chen, H., Deisseroth, K.
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