

Kai Zhao, Ph.D.

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A. EDUCATION AND APPOINTMENTS

Education

2004	Ph.D.	University of Pennsylvania, Philadelphia, PA. (Bioengineering)
1999	M.S.E	University of Pennsylvania, Philadelphia, PA. (Bioengineering)
1996	B.S.	Zhejiang University, Hangzhou, China. (Biomedical Engineering)

Appointments

2015-	Associate Professor, Department of Otolaryngology - Head&Neck Surgery, the Ohio State University, Columbus, OH
2008-2015	Adjunct Assistant Professor of Otolaryngology, Thomas Jefferson University Medical College, Philadelphia, PA
2007-2014	Assistant Member, Monell Chemical Senses Center, Philadelphia, PA
2004-2007	Postdoctoral Fellow, Monell Chemical Senses Center, Philadelphia, PA

B. RESEARCH SUPPORT

Current research support

“Objective evaluation of conductive olfactory losses & nasal obstruction symptoms”,
Agency: **NIH-NIDCD, R01 DC013626, PI: Kai Zhao** (12/01/2014-11/31/2018, 4 year total cost \$1,523,000)

This project aims to objectively evaluate the conductive mechanisms contributing to nasal obstruction symptoms, including smell losses, by combining novel computational models with existing sensory measurements.

“A Prospective, Non-Randomized Study to Evaluate Treatment Outcome of Nasal Airway Obstruction Using the Aerin Medical Vivaer Stylus”,

Agency: Industry Sponsor, Otto (PI) (5/19/17-5/19/18) Budget: \$152,250.53,
Role: Co-Investigator

Pending research support

“Optimizing surgical outcomes to olfactory losses through endoscopic sinus surgery simulator”
Agency: **NIH-NIDCD, PI: Kai Zhao** (12/01/2017-11/31/2019, 2 year direct cost \$275,000)

Completed research support

“Modulation of Olfactory Cilia” (05/01/2012-04/30/2016)

Agency: **NIH NIDCD, R01 DC011554, PI: Minghong Ma** (Neuroscience, UPENN)

Subcontract PI: Kai Zhao (20%). This project investigates modulation of the structure and function of olfactory cilia, by the stimulus input properties in the nasal cavity

“VOC Odor Signature Modeling for Portable Sensing Platforms” (10/01/2013-04/30/2014)
Agency: **US Air Force** (SBIR FA8650-13-M-6448, phase I), PI: Applied Nanotech, Inc.,
Subcontract PI: Kai Zhao (\$23,000, 6 months)

“Airborne Human Odorants: detection, dispersion and characterization”, **US Air Force, PIs: George Preti, Kai Zhao** (total \$130,000), 06/01/2011 – 08/31/2012.

“Nasal airflow and odorant transport: a prerequisite for normal olfaction” (12/01/2006-12/01/2010)

Agency: **NIH/NIDCD R03** DC008187-01 **PI: Kai Zhao** (3 Yrs total direct cost \$150,000)
This project uses computational fluid dynamic (CFD) modeling techniques to quantify the anatomy-dependent nasal airflow and odorant mucosal deposition patterns among healthy human subjects and to characterize their potential functional impact on human olfactory function.

“The left-right asymmetry in Parkinson disease development” (2011, 1 year), Agency: private source, **PI: Kai Zhao** \$20,000 total cost.

“Nasal airflow and odorant transport in healthy adult domestic cat” (10/01/2007-09/30/2008)
Industry funding: Mars, Inc. - Petcare. **PI: Kai Zhao** (total \$104,000)

“Occupational exposure, inflammatory process and chemosensory function” (1/01/2005-12/31/2010). Agency: **NIH/NIDCD P50** DC 006760 PI: Pamela Dalton
Role in this project: **Co-investigator** Using computational models to evaluate the degree to which occupational exposure-induced deviations in nasal airflow patterns are predictive of alternations in olfactory sensitivity.

“Temporal integration in nasal lateralization” (10/01/06-10/01/10)

Agency: **NIH/NIEHS R03** Principal Investigator: Paul Wise
Role in this project: **Consultant**. To develop a mathematical model that characterizes the tradeoff between stimulus-duration and concentration in the detection of chemical irritation in the human nose based on transport of molecules through the mucosa.

C. HONORS, AWARDS AND PROFESSIONAL EXPERIENCES

Honors and Awards

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| 2004 | Best Poster Presentation, 1st Place Award , American Rhinology Society annual meeting |
| 2004 | Frances Davidson Award for best oral presentation , American Academy of Otolaryngology-- Head and Neck Surgery, Pennsylvania annual meeting |
| 2003 | Feature Presentation , highlighted for press release, Association for chemoreception sciences (<i>AchemS</i>) annual meeting |

Professional Experiences and Organization

Ad hoc reviewer for NIH study section (BMIT-A), 2017
Ad hoc reviewer for NIH study section (Communication Disorders Review Committee), 2016
Ad hoc reviewer for NIH study section (ZDC1 X-61), 2016
Ad hoc reviewer for NIH study section (ZDC1 SRB-K(20)), 2015

Program committee for *Beijing international meeting on research in taste and smell*, 2009

Journal Reviewers: *PNAS, Journal of the Royal Society Interface, Laryngoscope, American Journal of Rhinology, International Forum of Rhinology and Allergy, Acta Oto-laryngologica, Journal of Rhinology, Laryngoscope Investigative Otolaryngology, Medical Engineering & Physics, Chemical Senses, Chemoperception, Inhalation Toxicology, Medical & Biological Engineering & Computing, Journal of Aerosol Science, Journal of Biomechanical Engineering, Journal of biomechanics, Journal of Experimental Biology, Anatomical Record, Computer Methods in Biomechanics and Biomedical Engineering, Surgery Research and Practice, Computers in Biology and Medicine, Current Medical Imaging Reviews, Scientific Reports.*

Memberships: *Association for Chemoreception Sciences (AchemS), Biomedical Engineering Society (BMES)*

D. LECTURES AND PUBLICATIONS

Invited Reviews and Book Chapters

Zhao K., Frye R. (2015), "Nasal Patency and the Aerodynamics of Nasal Airflow - in Relation to Olfactory Function", *the Handbook of Olfaction and Gustation*, 3rd ed, Ed: Richard L. Doty, Wiley-Blackwell, Hoboken, USA.

Scherer P.W., Huang J.W., and **Zhao K.** (2011). Capnography and the SPM Applied to Cardiac Output Recovery and Airway Structure and Function. In: *Capnogram: Clinical aspects, 2nd ed*", Cambridge University Press, Cambridge, UK.

Zhao K., and Dalton P. (2007) The way the wind blows - implications of modeling nasal airflow, *Current Allergy/Asthma Reports*, 7:117–125 (Citations: 15)

Scherer P.W. and **Zhao K.** (2004). Anatomic and physiological basis of volume capnography studied by the single path model. In: *Clinical aspects of volumetric capnogram*", Ed: Gravenstein J. S., Jaffe M.B., and Paulus D.A., Cambridge University Press, 321-336, Cambridge, UK.

Peer-reviewed Publications

Li C., Farag A.A., Maza G., McGheel S., Ciccone M.A., Deshpande B., Pribitkin E.A., Otto B.A., **Zhao K.** (2017) Investigation of the abnormal nasal aerodynamics and trigeminal

- functions among empty nose syndrome patients, *International Forum of Allergy Rhinol* doi: 10.1002/alr.22045.
- Lee TS., Goyal P., Li C., **Zhao K.**, (2017) Inferior turbinate reduction: on which portion should surgery focus? A CFD study, *JAMA Facial Plastic Surgery* (in press)
- Li C., Jiang J., Dong H. and **Zhao K.** (2017) Computational modeling and validation of human nasal airflow under various breathing conditions, *Journal of Biomechanics* Nov 7;64:59-68. doi: 10.1016/j.jbiomech.2017.08.031
- Shen J., Hur K., Li C., **Zhao K.**, Leopold D.A., Wrobel B.B. (2017) Determinants and Evaluation of Nasal Airflow Perception, *Facial Plast Surg.* Aug;33(4):372-377
- Otto B.A., Li C., Farag A.A, Bush B., Krebs J., Hutcheson R., Kim K, and **Zhao K.** (2017) Computational fluid dynamics evidence of posterior septectomy as viable treatment option for large septal perforation, *International Forum of Allergy and Rhinology*, Jul;7(7):718-725.
- Craig J., Palmer J. and **Zhao K.** (2017) Computational fluid dynamic modeling of nose-to-ceiling head positioning for sphenoid sinus irrigation, *International Forum of Allergy Rhinol*, May;7(5):474-479. doi: 10.1002/alr.21908 PMID: PMC5426973
- Li C., Farag A.A., Leach J., Deshpande B., Jacobowitz A., Kim K., Otto B.A., **Zhao K.** (2017) Computational fluid dynamics and trigeminal sensory examinations of empty nose syndrome patients, *Laryngoscope*, Mar 9. doi: 10.1002/lary.26530
- Craig J., **Zhao K.**, Doan N., Khalili S., John LYK, Adappa ND and Palmer J. (2016) Cadaveric validation study of computational fluid dynamics model of sinus irrigations before and after sinus surgery, *International Forum of Allergy Rhinol* Apr;6(4):423-8. doi: 10.1002/alr.21677. PMID: PMC5145305
- Zhao K.**, Craig J., Cohen NA., Adappa ND, Khalili S. and Palmer J. (2016) Sinus irrigations before and after surgery – visualization through computational fluid dynamics simulations, *Laryngoscope* Mar;126(3):E90-6. doi: 10.1002/lary.25666. PMID: PMC5084453
- Lewis R., Tian HK., Wang J., He JW., Jiang J., Chen XM., Yin WB., Connelly T., Ma LM., Yu CR., Pluznick, JP., Storm DR., Huang LQ., **Zhao K.**, and Ma M. (2015) An Olfactory Cilia Pattern in the Mammalian Nose Ensures High Sensitivity to Odors, *Current Biology*, Oct; 25(19):2503-12. PMID: 2596779
- Zhao K.**, Malhotra P., Rosen D., Dalton P. and Pribitkin EA. (2014) Computational Fluid Dynamics (CFD) as surgical planning tool: a pilot study on middle turbinate partial resection, *Anatomical Record*. Nov;297(11):2187-95. doi: 10.1002/ar.23033. (Cited: 2)

Zhao K., Jiang J. (2014) What is Normal Nasal Airflow? – A Computational Study of 22 Healthy Adults, *International Forum of Allergy Rhinol.* Jun;4(6):435-46. doi: 10.1002/alr.21319 (Cited: 2)

Scott JW*, Sherrilla L., Jiang J., **Zhao K.*** (2014) Tuning to Odor Solubility and Sorption Pattern in Olfactory Epithelial Responses, *Journal of Neuroscience*, 34(6):2025-36 * co-first author. (Cited: 5)

Zhao K., Dalton P., Cowart BJ., Pribitkin EA.(2014) Re: In Reference to Regional Peak Mucosal Cooling Predicts the Perception of Nasal Patency. *Laryngoscope.* May;124(5):E211-2

Zhao K., Jiang J., Pribitkin EA., Dalton P., Rosen D. Lyman B., Yee KK., Rawson NE., Cowart, BJ. (2014) Conductive olfactory losses in chronic rhinosinusitis? – A computational fluid dynamics study of 29 patients, *International Forum of Allergy Rhinol.* Apr; 4(4):298-308. (Cited: 1)

Zhao K., Jiang J., Blacker K., Lyman B., Dalton P., Cowart BJ., Pribitkin EA. (2014) Regional Peak Mucosal Cooling Predicts the Perception of Nasal Patency, *Laryngoscope*, 124(3):589-95 (Cited: 11)

Zhao K., Blaker K., Luo Y. Bryant B., Jiang J. (2011) Perceiving nasal patency through mucosal cooling rather than air temperature or nasal resistance, *Plos One* 6: pp. e24618(Cited: 10)

Dalton PH., Opiekun RE., Gould M., McDermott R., Wilson T., Maute C., Ozdener MH., **Zhao K.**, Emmett E., Lees PSJ., Herbert R., Moline J. (2010) Chemosensory Loss: Functional Consequences of the World Trade Center Disaster. *Environ Health Perspect* 118(9): 1251-1256. (Citations: 8)

Wise P.M., **Zhao K.**, and Wysocki C.J. (2010) Dynamics of nasal irritation from pulsed homologous alcohols. *Chem Senses.* 35(9): 823-9 PMID: PMC2980991

Jiang J.B., and **Zhao K.** (2010) Airflow and nanoparticle deposition in rat nose under various breathing and sniffing conditions —A computational evaluation of the unsteady and turbulent effect. *Journal of Aerosol Science.* 41: 1030–1043 PMID: PMC2976565 (Citations: 21)

Wise P.M., **Zhao K.**, and Wysocki C.J. (2009) Dynamics of nasal chemesthesis, *Ann N Y Acad Sci.* 1170:206-14 (Citations: 9)

Wise P.M., Toczydlowski, S.E., **Zhao K.**, and Wysocki C.J. (2009) Temporal integration in nasal lateralization of homologous propionates. *Inhalation Toxicology*, 21(10):819-27

Yang C.C., Scherer P.W., **Zhao K.** and Mozell M.M. (2007) Numerical modeling of odorant uptake in the rat nasal cavity, *Chem. Sense.* 32: 273–284. (Citations: 29)

Zhao K., Dalton P., Yang G.C., and Scherer P.W. (2006) Numerical modeling of turbulent and laminar airflow and odorant transport during sniffing in the human and rat nose, *Chemical Senses*, 31: 107-118. (Citations: 66)

Zhao K., Pribitkin E.D., Scherer P.W., Cowart B.J., Rosen D. and Dalton P. (2006) Numerical modeling of nasal obstruction and endoscopic surgical intervention: outcome to airflow and olfaction, *American Journal of Rhinology*, 20: 308–316,. (Citations: 32)

Zhao K., Scherer P.W., Hajiloo A., and Dalton P. (2004). Effect of anatomy on human nasal air flow and odorant transport patterns: implications for olfaction, *Chemical Senses* 29: 365-379. (Citations: 121)

Kurtz D.B., **Zhao K.**, Hornung D.E., Scherer P.W. (2004). Experimental and numerical determination of odorant solubility in nasal and olfactory mucosa, *Chemical Senses*, 29, 763-773. (Citation: 40)

Ma Z.M., **Zhao K.** Qian W.J., and Zheng X.X. (1997) Ion Selective Microelectrode for Histamine and Application, *Chinese J. of Analytical chemistry*, 25(7), 750-754.

Publications (submitted, in progress)

Patel T., Li C., Krebs J., **Zhao K.**, Malhotra P. (2017) Modeling Congenital Nasal Pyriform Aperture Stenosis Using Computational Fluid Dynamics, *International Journal of Pediatric Otorhinolaryngology* (submitted)

Li C., Jiang J., Kim K., Otto B.A., Farag A.A., Cowart B.J., Pribitkin E.A. Dalton P., **Zhao K.**,(2017) Nasal structural and aerodynamic features that may benefit normal olfactory sensitivity, *Chemical Senses* (submitted).

Oral presentations

Oct. 23rd, 2017 “The untold truth about nasal obstruction – from a bioengineer’s perspective”, Grand Rounds, Department of Otolaryngology, Kansas University.

Sep. 22th, 2016 “Computational fluid dynamics (CFD) and trigeminal sensory examinations of empty nose syndrome patients: pre and post turbinate surgery”, American Rhinology Society (ARS) Annual Meeting.

Mar. 19th, 2015 “The way the wind blows: investigating the impediments in nasal airway”, Grand Rounds, Department of Otolaryngology, Vanderbilt University.

Mar. 17th, 2015 “From nostril to receptors: nasal aerodynamics and its implications in mammalian nasal functions and diseases”, Grand Rounds, Department of Otolaryngology, Northwestern University.

Feb. 25th, 2015 “Anosmia: A Sense of Hope”, Panelist, Lecture for continuing medical education (CME) for physicians, Jefferson University.

- Jan. 29th, 2015 “The way the wind blows: investigating the impediments of nasal airflow”, Grand Rounds, Department of Otolaryngology, University of Miami.
- Sep. 27th, 2013 “What is Normal Nasal Airflow? – A Computational Study of 22 Healthy Adults”, American Academy of Otolaryngic Allergy (AAOA) Annual Meeting.
- Sep. 28th, 2013 “Conductive olfactory losses in chronic rhinosinusitis? – A computational fluid dynamics study of 29 patients”, American Rhinology Society (ARS) Annual Meeting.
- Nov. 17th, 2009 “The history and future of computational nasal airflow modeling – the clinical and functional relevance?”, Beijing International Meeting on Research in Taste and Smell.
- Apr. 16th, 2009 “Sensation of nasal patency through mucosal heat loss rather than air temperature”, Rhinology World 2009 - *the combined meeting of four major Societies: The International Rhinological society (IRS), The International Symposium on Infection and Allergy of the Nose (ISIAN), The American Rhinological Society (ARS) and The American Academy of Otolaryngic Allergy (AAOA).*
- Apr. 18th, 2009 “Objective assessment of the impact of chronic rhinosinusitis (CRS) on olfactory function”, Rhinology World 2009.
- Apr. 18th, 2009 “Computational modeling of nasal airflow and odorant transport in patients with chronic rhinosinusitis”, Rhinology world 2009.
- Oct. 15th, 2006 “Modeling of nasal airflow and odorant transport in patients with chronic rhinosinusitis”, Biomedical engineering society (BMES) annual conference.
- May. 19th, 2006 “Numerical nasal airflow simulation in patients pre- & post- middle turbinate resection”, American Rhinology Society (ARS) COSM Meeting.
- Apr. 29th, 2006 “Computational modeling of nasal airflow and odorant transport in patients with chronic rhinosinusitis”, AchemS Annual Conference.
- Jun. 11th, 2004 “Modeling of airflow and odorant delivery pattern in a pre- & post-operative nasal cavity: a quantitative evaluation of surgical intervention”, American Academy of Otolaryngology-- Head and Neck Surgery (AAO-HNS), Pennsylvania annual meeting, Philadelphia, PA.
- Apr. 12th, 2003 “Nasal airflow and odorant transport patterns: implications for odor perception”, *AchemS* Annual Conference.

Conferences Abstracts (selected)

1. **Chengyu Li**, Haibo Dong, and Kai Zhao, “*Effect of induced airflow on odor plume transportation in a fruit fly in forward flight*,” AChemS Annual Meeting, Bonita Springs, Florida, April 2017.
2. Bradley Hittle, **Chengyu Li**, Hector J Medina-Fetterman, Brad A Otto, Alexander A Farag, Gregory J. Wiet, Don Stredney, Kai Zhao, “*Use virtual reality to optimize sinus surgery treatment of olfactory losses due to nasal obstruction*,” AChemS Annual Meeting, Bonita Springs, Florida, April 2017.
3. Nakesha King, Victoria Pepper, Cameron Best, Ekene Onwuka, Chengyu Li, Eric Heuer, Jed Johnson, Kai Zhao, Jonathan Grischkan, Christopher Breuer, and Tendy Chiang, “*A pilot study: Using computational fluid dynamics to model physiologic airflow through an ovine tissue engineered tracheal graft*,” Association for Clinical and Translational Science (ACTS), Washington, D.C., April 2017.

Sniffing and nasal aerodynamics: pre-processing of odorant information?, Form and Function of the Olfactory System, HHMI Janelia farm 2010

Jiang J.B., Luo Y.H., Dishowitz M., Wright A.C., and Zhao K., The first quantitative model of the nasal aerodynamics in mouse, AchemS 2010

Jiang J.B. and **Zhao K.**, Deposition of inhaled particles in the olfactory region in rat and human nasal cavities during breathing, AchemS 2009.

Zhao K., and Jiang J.B. Spatial and temporal odorant transport patterns in rat nose: a computational study, ISOT 2008.

Jiang J.B., and **Zhao K.** Quantifying mechanical stimuli in rat and human nasal models during breathing, ISOT 2008.

E. TEACHING AND MENTORING

Lecture to residents Feb, 2016

Contributing as guest lecturer to UPENN Bioengineering Department BE 350, “Biomedical applications of fluid mechanics” (spring 2008).

Served as advisor for independent study UPENN Bioengineering Department BE 499 2008 - Dhinakaran Chinappen, “*Algorithms to determine minimum cross-sectional area in the human nasal cavity based on CT imaging*”

Advised students in the Monell research apprentice program:
2007 - Tao Yang (Master students in Computer Science, Clarkson University), “*The repeatability of image segmentation methods*”

- 2008 - Jenifer Shusterman (Psychology undergrad, Tufts), *“The effect of air temperature and humidity on nasal patency”*
- 2009 - Lisa Pretoria (Bioengineering Undergrad, U of Pennsylvania), *“Modeling the effect of nasal dilator on nasal airflow”*
- 2010 - Elizabeth Cushing (Chemistry Undergrad, Swarthmore U), *“An Improved Partition Model for Odor Detection Thresholds”*.
- 2011 - Dianna Feng (Senior in high school, placed 1st in the final poster presentation). *“3D image analysis and reconstruction for rat nasal cavity”*.
- 2012 - Lesenia Santiago (Senior in high school), *“Is anterior turbinate reduction better than posterior?”*
- 2013 - Lesenia Santiago (Biomedical Engineering Undergrad, Carnegie Mellon), *“Odor Propagation in a Room”*.
- 2014 – Ngoc Doan (Chemical Engineering, Drexel U), *“CFD simulation of sinus irrigation”*.

Advised mentee in the Ohio State University:

Postdoctoral fellows: Dr. Jianbo Jiang (2008-2012),
Dr. Chengyu Li (2016-)

Resident: Bush, Benjamin,

Ph.D. candidate: Kanghyun Kim

Undergrad: James Leach, Adam Jacobowitz, Jillian Krebs, Ryan Hutcheson, Samuel McGheel, Michael Ciccone