BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Fan, Zhaoyang

eRA COMMONS USER NAME (credential, e.g., agency login): zhaoyang

POSITION TITLE: Associate Professor, Radiology and Radiation Oncology, University of Southern California.
Director, MR Imaging Research of Department of Radiology

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Tsinghua University, Beijing, China	B.S.	07/2002	Engineering Physics
McMaster University, Hamilton, ON, Canada	M.S.	11/2006	Medical Physics
Northwestern University, Evanston, IL	Ph.D.	12/2010	Biomedical Engineering
Cedars-Sinai Medical Center, Los Angeles, CA	Postdoctoral	06/2012	Advanced MR Imaging

A. Personal Statement

I am currently an Associate Professor at the Departments of Radiology and Radiation Oncology, University of Southern California. My career as an MR physicist has been focused primarily on the development and applications of novel magnetic resonance (MR) methods for fast and precise assessment of atherosclerosis disease. While MR is a powerful imaging modality for detection and severity evaluation of atherosclerotic plaques, its clinical adoption has been hindered by a series of technical limitations. Over the past 10 years, I have developed or optimized many three-dimensional (3D) high-resolution MR techniques (such as noncontrast FSD MRA of peripheral arteries, FSD SPACE imaging of carotid plaque, self-gated SPACE for swallowing motion compensation, 3D MATCH for carotid composition characterization, cDIG imaging for calcified coronary plaque) that allow for higher spatial resolution and SNR, more efficient spatial coverage, and flexibility in image visualization in comparison to conventional 2D imaging methods. Through these projects, I have gained extensive training and outstanding scientific abilities in conducting research, as evidenced by near 100 peer-reviewed journal articles and successful competition for federal and society's funds.

a. Yang W, **Fan Z**, Tuli R, Deng Z, Pang J, Wachsman A, Reznik R, Sandler H, Li D, Fraass BA. Four-dimensional magnetic resonance imaging with 3-dimensional radial sampling and self-gating-based K-space sorting: early clinical experience on pancreatic cancer patients. *International Journal of Radiation Oncology, Biology, Physics.* 2015;93:1136-1143. PMID: 26452571.

b. Deng Z, Pang J, Lao Y, Bi X, Wang G, Chen Y, Fenchel M, Tuli R, Li D, Yang W, **Fan Z**. A post-processing method based on inter-phase motion correction and averaging to improve image quality of 4D magnetic resonance imaging: a clinical feasibility study. *British Journal of Radiology* 2019;92:20180424. PMID: 30604622.

c. Yang W, **Fan Z**, Deng Z, Pang J, Bi X, Fraass BA, Sandler H, Li D, Tuli R. Novel 4D-MRI of tumor infiltrating vasculature: characterizing tumor and vessel volume motion for selective boost volume definition in pancreatic radiotherapy. *Radiation Oncology* 2018;13:191. PMID: 30285889.

d. Wang N, Gaddam S, Wang L, Xie Y, **Fan Z**, Yang W, Tuli R, Lo S, Hendifar A, Pandol S, Christodoulou AG, Li D. Six-dimensional quantitative DCE MR multitasking of the entire abdomen: method and application to pancreatic ductal adenocarcinoma. *Magnetic Resonance in Medicine* 2020;84:928-948. PMID: 31961967.

B. Positions and Honors

Positions and Employment

01/11-06/12	Postdoctoral Fellow, Department of Biomedical Sciences, Cedars-Sinai Medical Center
01/11-	3T MRI Technical Director, Research Imaging Core, Cedars-Sinai Medical Center
07/12-06/13	Project Scientist, Department of Biomedical Sciences, Cedars-Sinai Medical Center
07/13-12/18	Scientist I, Cedars-Sinai Medical Center
07/13-	Assistant Professor, Biomedical Sciences, Cedars-Sinai Medical Center
05/17-	Assistant Professor, Medicine, University of California, Los Angeles
05/18-	Assistant Professor, Bioengineering, University of California, Los Angeles
01/19-	Scientist II, Cedars-Sinai Medical Center
01/20-10/20	Associate Professor, Biomedical Sciences, Cedars-Sinai Medical Center
11/20-	Associate Professor, Radiology and Radiation Oncology, University of Southern California
11/20-	Director, MR Imaging Research, Radiology, University of Southern California

Other Experience and Professional Memberships

2007-	Member, International Society for Magnetic Resonance in Medicine (ISMRM)
2008-	Member, Society for Cardiovascular Magnetic Resonance (SCMR)
2013-	Member, American Heart Association (AHA)
2014-	Member, Overseas Chinese Society for Magnetic Resonance in Medicine (OCSMRM)
2018-	Member, American Association of Physicists in Medicine (AAPM)
2010-	Member, Cedars-Sinai Research Imaging Core Operations Committee
2013-2014	Member, ISMRM Workshop & Study Group
2015	Organizing Committee Member, ISMRM Non-contrast-enhanced Cardiovascular MRI Workshop
2015-2017	Member, American Society of Neuroradiology Vessel Wall Imaging Study Group
2017-	Member, Cedars-Sinai Master Program Committee for Magnetic Resonance in Medicine
2018-	Member, AHA Career Development Award Scientific Review Committee
2018-	Member, Samuel Oschin Cancer Center at Cedars-Sinai Medical Center
2019-	RSNA Quantitative Imaging Biomarkers Alliance (QIBA) DSC Biomarker Committee
2020-	Cedars CTSI Core Voucher Review Committee
2018	*Ad-hoc* Reviewer, Science and Technology Facilities: 21st Century Challenge Networks, UK
2018	*Ad-hoc* Reviewer, The Netherlands Organisation for Scientific Research
2019/2020	*Ad-hoc* Reviewer, EITA Study Section, National Institutes of Health (NIH)

Honors

2006-2008	ISMRM Annual Meeting Educational Stipend
2012	ISMRM Magna Cum Laude Merit Award
2012-2018	Distinguished Reviewer, Magnetic Resonance in Medicine
2013	ISMRM Conference Abstract Summa Cum Laude Merit Award
2013	ISMRM Conference Abstract Magna Cum Laude Merit Award
2013	Junior Fellow, ISMRM
2013	ISMRM Annual Meeting Educational Stipend
2013	Presentation Award Best in Session, International MR Angiography Workshop 2013
2015, 2016	Distinguished Reviewer, Journal of Magnetic Resonance Imaging
2018	Fellow, SCMR
2018	Finalist in the Science Council Session of AAPM Annual Meeting

C. Contributions to Science

1. **Technical development in cancer imaging.** In free-breathing radiotherapy treatment planning, respiration-induced motion in abdominal organs poses significant challenges to accurate determination of treatment margins for target tumors. The clinically standard approach to treatment planning is 4D computed tomography (CT). 4D-MR is recently gaining more interests due to its excellent soft-tissue contrast and the lack of ionizing radiation. My team developed a continuous spoiled gradient echo sequence with 3D radial trajectory for image acquisition and self-gating for respiratory motion detection. Data were retrospectively sorted into different respiratory phases based on their temporal locations within a respiratory cycle or amplitudes, and each phase was reconstructed by means of self-calibrating CG-SENSE that can well handle undersampling problems. This technique eliminates the need for external motion surrogate set up, allows for the exclusion of irregular breathing cycles after scanning, and facilitates the reconstruction of an averaged phase-resolved isotropic-spatial-resolution volumetric image series with

consistent image quality throughout all respiratory phases and subjects. We later made continuous improvement on this technique in both acquisition and post-processing aspects.

a. Deng Z, Pang J, Yang W, Yue Y, Sharif B, Tuli R, Li D, Fraass B, **Fan Z**. Four-dimensional MRI using three-dimensional radial sampling with respiratory self-gating to characterize temporal phase-resolved respiratory motion in the abdomen. *Magnetic Resonance in Medicine* 2016;75:1574-1585. PMID: 25981762.
b. Yue Y, **Fan Z**, Yang W, Pang J, Deng Z, McKenzie E, Tuli R, Wallace R, Li D, Fraass B. Geometric validation of self-gating k-space-sorted 4D-MRI vs 4D-CT using a respiratory motion phantom. *Medical Physics* 2015;42:5787-5797. PMID: 26429253.
c. Jin J, McKenzie E, **Fan Z**, Tuli R, Deng Z, Pang J, Fraass B, Li D, Sandler H, Yang G, Sheng K, Gou S, Yang W. "Non-local means denoising of SG-KS-4D-MRI using block matching 3D: Implications for pancreatic tumor registration and segmentation", *International Journal of Radiation Oncology, Biology, Physics* 2016;95:1058-1066. PMID: 27302516.
d. Deng Z, Yang W, Pang J, Bi X, Tuli R, Li D, **Fan Z**. Improved vessel-tissue contrast and image quality in 3D radial sampling-based 4D-MRI. *Journal of Applied Clinical Medical Physics*. 2017;18:250-257. PMID: 28980395.

2. **Development of free-breathing cardiac imaging methods.** Abnormality in myocardium or coronary arteries are common reason for cardiovascular events. Imaging of these structures are highly challenged by cardiac motion and respiratory motion. I have invested efforts on developing high-resolution motion-compensated MR sequences for imaging morphology and functions in the myocardium and coronary arteries.

a. Xie G, Bi X, Liu J, Yang Q, Natsuaki Y, Conte A.H., Liu X, Li K, Li D, **Fan Z**. Three-dimensional coronary dark-blood interleaved with gray-blood (cDIG) magnetic resonance imaging at 3Tesla. *Magnetic Resonance in Medicine* 2016;75:997-1007. PMID: 25858528.
b. Nguyen C, **Fan Z**, Xie Y, Pang J, Speier P, Bi X, Kobashigawa J, Li D. In vivo diffusion-tensor MRI of the human heart on a 3 tesla clinical scanner: An optimized second order (M2) motion compensated diffusion-preparation approach. *Magnetic Resonance in Medicine* 2016;76:1354-1363. PMID: 27550078.
c. Pang J, Chen Y, **Fan Z**, Nguyen C, Yang Q, Xie Y, Li D. High efficiency coronary MR angiography with nonrigid cardiac motion correction. *Magnetic Resonance in Medicine* 2016;76:1345-1353. PMID: 27455164.
d. Zhang X, Xie G, Zhu Y, Wei Z, Su S, Shi C, Yan F, Liu X, Qiu B, **Fan Z**. 3D self-gated cardiac cine imaging at 3 Tesla using stack-of-stars bSSFP with tiny golden angles and compressed sensing. *Magnetic Resonance in Medicine*. 2019;81:3234-3244. PMID: 30474151.

3. **Development of novel MR methods for cerebrovascular imaging.** Cerebrovascular disease is one of the major causes of morbidity and mortality worldwide and is the number one cause of adult disability. One of my research interests has been focused on the development of 3D black-blood MR techniques for better diagnosis or risk stratification of various cerebrovascular diseases. We developed a CSF-suppressed whole-brain vessel wall imaging technique that allows for improved spatial coverage and vessel wall contrast to CSF. Imaging time, by using a parameter tune-up strategy, was reduced to a clinically acceptable time. Due to superior spatial resolution and enhanced T1-weighting, this technique is particularly suitable for the detection of intraplaque hemorrhage and inflammation-related contrast enhancement. This technique is currently being assessed in a multi-center registry ("WISP") for its clinical utility in stroke etiology determination. I am one of Co-PIs on this project.

a. **Fan Z**, Yang Q, Deng Z, Li Y, Bi X, Song S, Li D. Whole-brain intracranial vessel wall imaging at 3 Tesla using cerebrospinal fluid-attenuated T1-weighted 3D turbo spin echo. *Magnetic Resonance in Medicine* 2017;77:1142-1150. PMID: 26923198.
b. Yang Q, Deng Z, Bi X, Song SS, Schlick KH, Gonzalez NR, Li D, **Fan Z**. Whole-brain vessel wall MRI: A parameter tune-up solution to improve the scan efficiency of three-dimensional variable flip-angle turbo spin-echo. *Journal of Magnetic Resonance Imaging* 2017;46:751-757. PMID: 28106936.
c. Wu F, Song H, Ma Q, Xiao J, Jiang T, Huang X, Bi X, Guo X, Li D, Yang Q, Ji X, **Fan Z**. Hyperintense plaque on intracranial vessel wall magnetic resonance imaging as a predictor of artery-to-artery embolic infarction. *Stroke* 2018;49:905-911. PMID: 29540606.
d. Wu F, Ma Q, Song H, Guo X, Diniz M, Song S, Gonzalez N, Bi X, Ji X, Li D, Yang Q, **Fan Z**. Differential features of culprit intracranial atherosclerotic lesions: a whole-brain vessel wall imaging study in acute

ischemic stroke patients. *Journal of the American Heart Association* 2018;7:e009705. PMID: 30033434.

4. **Development of novel MR techniques for carotid atherosclerosis imaging.** Carotid atherosclerosis is a degenerative disease of the arterial wall which can result in predisposition to cerebral thrombo-embolic stroke, the leading cause of mortality and morbidity worldwide. We were one of the first groups proposing 3D black-blood MR, i.e. FSD-prepared SPACE, for carotid arterial wall evaluation at 3.0 Tesla. To mitigate image artifacts owing to swallowing and/or breathing motion at the carotid bifurcations, I developed a real-time motion monitoring scheme using a self-gating method. More recently, I developed a multi-contrast atherosclerosis characterization (MATCH) technique (United States Patent US9554727B2), the first 3D technique that provides comprehensive plaque composition analysis in 5 minutes. This work allows for expedite carotid plaque assessment for treatment guidance and surgical planning. I was invited to contribute to a White Paper (c.) on carotid vessel wall imaging from the American Society of Neuroradiology.
    a. **Fan Z**, Zhang Z, Chung Y-C, Weale P, Zuehlsdorff S, Carr JC, Li D. Carotid arterial wall MRI at 3T using 3D variable-flip-angle TSE with flow-sensitive dephasing. *Journal of Magnetic Resonance Imaging* 2010;31:645-654. PMID: 20187208.
    b. **Fan Z**, Zuehlsdorff S, Li D. Prospective self-gating for swallowing motion compensation in 3D carotid artery wall imaging. *Magnetic Resonance in Medicine* 2012;67:490-498. PMID: 22161627.
    c. **Fan Z**, Yu W, Xie Y, Dong L, Yang L, Wang Z, Conte A.H., Bi X, An J, Zhang T, Laub G, Shah P.K., Zhang Z, Li D. Multi-contrast atherosclerosis characterization (MATCH) of carotid plaque with a single 5-min scan: technical development and clinical feasibility. *Journal of Cardiovascular Magnetic Resonance* 2014;16:53. PMID: 25184808.
    d. Saba J, Yuan C, Hatsukami TS, Balu N, Qiao Y, DeMarco JK, Saam T, Moody AR, Li D, Matouk CC, Johnson MH, Jager HR, Mossa-Basha M, Kooi ME, **Fan Z**, Saloner D, Wintermark M, Mikulis DJ, Wasserman BA. Carotid artery wall imaging: perspective and guidelines from the ASNR vessel wall imaging study group and expert consensus recommendations of the American Society of Neuroradiology. *American Journal of Neuroradiology* 2018;39:E9-E31. PMID: 29326139.

5. **Development of multi-contrast imaging techniques of peripheral vessels.** Peripheral artery disease is a major cause of diminished functional capacity and quality of life in a large portion of western populations (~ 8 million Americans) and is also involved with a 4-5 times higher risk of heart attack or stroke. I developed a novel technique named FSD-SSFP 3D MRA and several 3D black-blood MR technique to assess the severity of PAD. These techniques can cover both lower legs within 4-6 min and may potentially serve as a fast screening method for PAD.
    a. **Fan Z**, Sheehan J, Bi X, Liu X, Carr JC, Li D. 3D Noncontrast MR angiography of the distal lower extremities using flow-sensitive dephasing (FSD)-prepared balanced SSFP. *Magnetic Resonance in Medicine* 2009;62:1523-1532. PMID: 19877278.
    b. Lim RP, **Fan Z**, Chatterji M, Baadh A, Atanasova IP, Storey P, Kim DC, Kim S, Hodnett PA, Ahmad A, Stoffel D, Babb JS, Adelman MA, Xu J, Li D, Lee VS. Comparison of nonenhanced MR angiographic subtraction techniques for infragenual arteries at 1.5 T: a preliminary study. *Radiology* 2013;267:293-304. PMID: 23297320.
    c. Xie G, Zhang N, Xie Y, Nguyen C, Deng Z, Bi X, Fan Z, Liu X, Li D, **Fan Z.** DANTE-prepared three-dimensional FLASH: a fast isotropic-resolution MR approach to morphological evaluation of the peripheral arterial wall at 3 Tesla. *Journal of Magnetic Resonance Imaging* 2016;43:343-351. PMID: 26139414.
    d. Xie G, Chen H, He X, Liang J, Deng W, He Z, Ye Y, Yang Q, Bi X, Liu X, Li D, **Fan Z**. Black-blood thrombus imaging (BTI): a contrast-free cardiovascular magnetic resonance approach for the diagnosis of non-acute deep vein thrombosis*. Journal of Cardiovascular Magnetic Resonance* 2017;19:4. PMID: 28095878.

Complete List of Published Work in NCBI MyBibliography:

https://www.ncbi.nlm.nih.gov/myncbi/1NimbPHJfjeQa/bibliography/public/

D. Research Support

Ongoing Research Support

NIH/NIBIB R01 EB029088 (MPI: Fan, Yang) 07/01/2020-03/31/2024

“Multi-task MR simulation for abdominal radiation treatment planning”
This project aims to develop an MR technique for motion-resolved multi-contrast abdominal imaging in abdominal radiation therapy planning.
Role: Contact PI

NIH/NCI R21 CA234637 (MPI: Fan, Yang) 07/17/2019-06/30/2021
“Novel four dimensional magnetic resonance imaging to monitor pancreatic tumor infiltrating blood vessels and tumor response to chemoradiation therapy”
This project aims to develop a new MR method to quantitatively measure the changes in pancreatic tumor infiltrating blood vessels in response to chemoradiation therapy and help identify surgery eligible patients.
Role: Co-PI

NIH/NHLBI R01 HL147355 (PI: Fan) 03/15/2019-02/29/2024
“Longitudinal and quantitative MR plaque imaging for prediction of response to medical management in symptomatic intracranial atherosclerosis”
This project aims to develop a complete intracranial vessel wall imaging and analysis package and validate its value in medical management of patients with ischemic stroke caused by intracranial atherosclerosis.
Role: PI

NIH/NHLBI K23 HL125941 (PI: Wei) 09/01/2016-08/31/2021
“Magnetic resonance imaging for global atherosclerosis risk assessment”
This project aims to demonstrate that global measurements of MRI plaque burden and adverse plaque features in three vascular beds will improve discrimination of lower and higher risk subjects.
Role: Collaborator

Completed Research Support

NIH/NHLBI R56 HL131871 (PI: Tamarappoo) 09/15/2016-07/31/2020
“Detection of vulnerable atherosclerotic plaque with a novel 18F-labeled Integrin targeted PET imaging agent”
This project aims to develop qualitative and quantitative evaluation of MR-based vulnerable plaque burden and compositional characteristics.
Role: Co-Investigator

Race to Erase MS Young Investigator Award (PI: Kaisey) 02/01/2019-06/30/2021
“Assessing arterial and venous markers in the brain and retina in multiple sclerosis”
This project aims to assess the value of using individual and combined arterial and venous markers in the brain and retina for diagnosing multiple sclerosis.
Role: Co-Investigator

NIH/NHLBI 2R01HL096119 (PI: Li) 07/01/2015-06/30/2020
“3D MRI characterization of high risk carotid artery plaques without contrast media”
This project aims to develop a non-invasive magnetic resonance imaging method to identify carotid atherosclerotic plaques that have a high probability of causing neurovascular events such as stroke or transient ischemic attack.
Role: Co-Investigator

AHA 15SDG25710441 (PI: Fan) 07/01/2015-06/30/2019
“Carotid atherosclerotic disease: 3D MRI characterization of vulnerable plaque features without contrast media”
This project aims to develop an MRI technique to provide spatially coregistered multicontrast images for carotid plaque characterization with a single fast scan.
Role: PI

NIH/NCI R03 CA173273 (PI: Yang) 02/01/2013-07/31/2015
“Improving pancreas RT Plans using Respiration-driven Anatomic Deformation”
This project aims to develop an MRI-based motion correction technique for pancreatic cancer RT planning.
Role: Co-Investigator