

Breakout Session 3: Track A

Uncertainty Quantification of AI-Based Imaging Algorithms: The Need and Methods

Dr. Abhinav Jha (Moderator)
Assistant Professor, Washington University

Uncertainty Quantification of AI-Based Algorithms for Medical Imaging: The Need and Methods

Supplemental Award title: A framework to quantify and incorporate uncertainty for ethical application of AI-based quantitative imaging in clinical decision making

Abhinav K. Jha, PhD

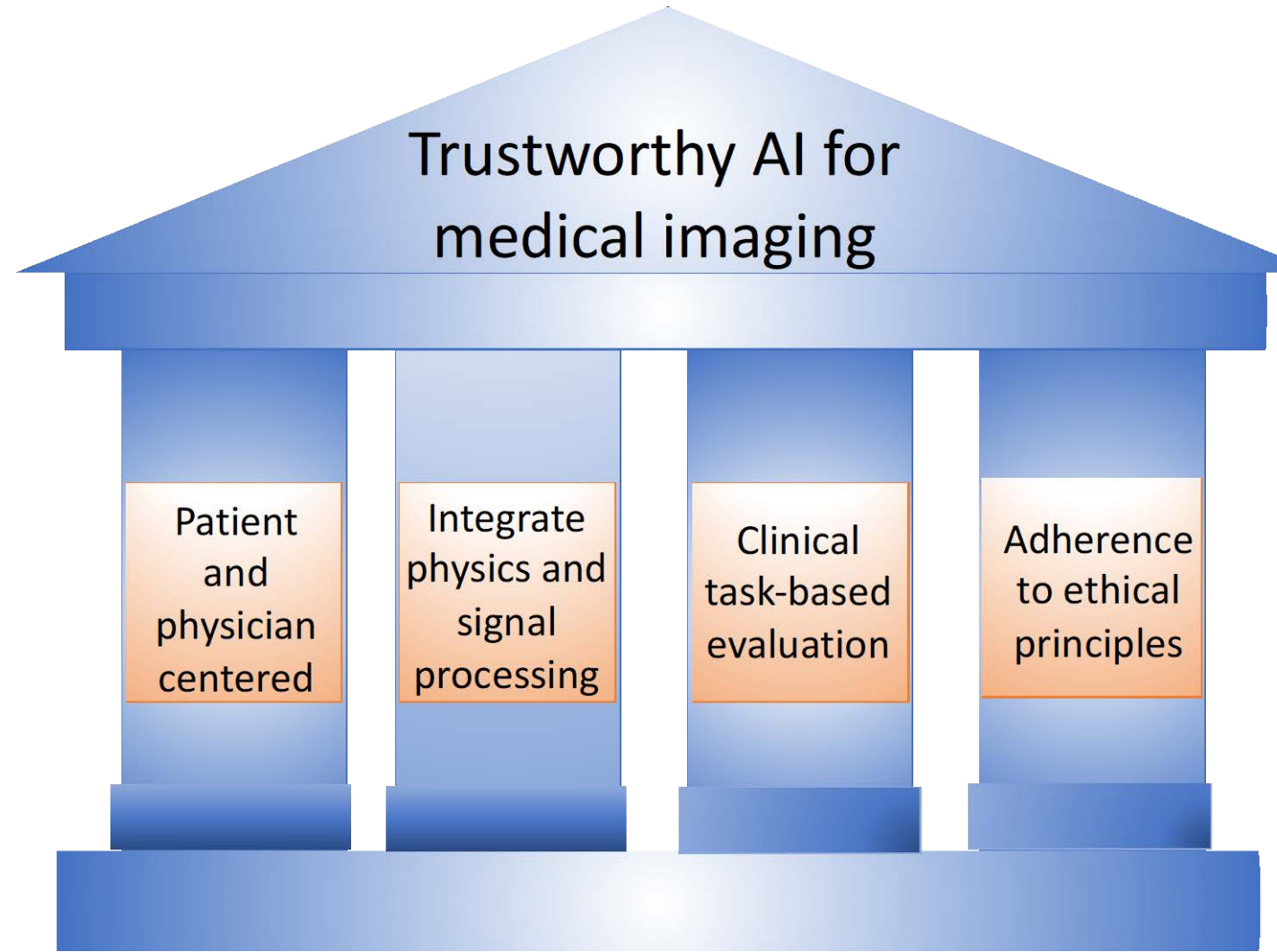
Department of Biomedical Engineering

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SNMMI AI Task Force Member

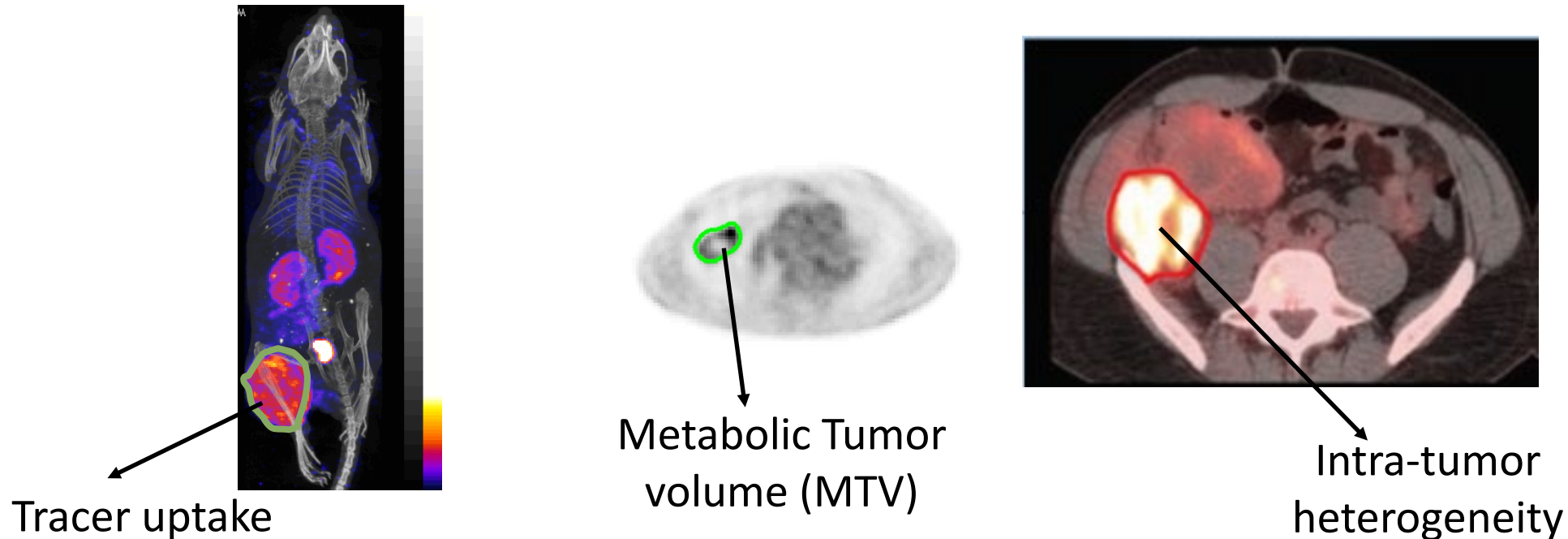
Background

- **Mission of my lab:** Develop computational imaging solutions for improving the diagnosis and treatment of diseases
- **Research expertise:** Image reconstruction, enhancement, quantitative image analysis



Quantitative medical imaging

The extraction of numerical/statistical features from medical images for clinical decision making



Quantitative imaging is emerging as an important tool in the clinic for multiple diagnostic and therapeutic procedures

Challenge: Uncertainty in AI algorithm



Anya Plutynski, PhD
Biomedical Ethicist

- AI is playing a strong role in the development of new quantitative imaging methods. However, these algorithms suffer from uncertainty
- Important that uncertainty be accounted for when making clinical decisions
- A patient-advocate survey we conducted indicated likewise
 - ~90% respondents were uncomfortable/very uncomfortable with the idea that uncertainty of AI algorithm is not conveyed to them
 - > 75% respondents specifically wanted uncertainty to be accounted for when making clinical decisions
- Different patients may have different risk-value profiles related to the use of AI in the clinic

Motivation: Modeling uncertainty in AI when making clinical decisions

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Clinical decisions using AI must consider patient values

[Jonathan Birch](#) , [Kathleen A. Creel](#), [Abhinav K. Jha](#) & [Anya Plutynski](#)

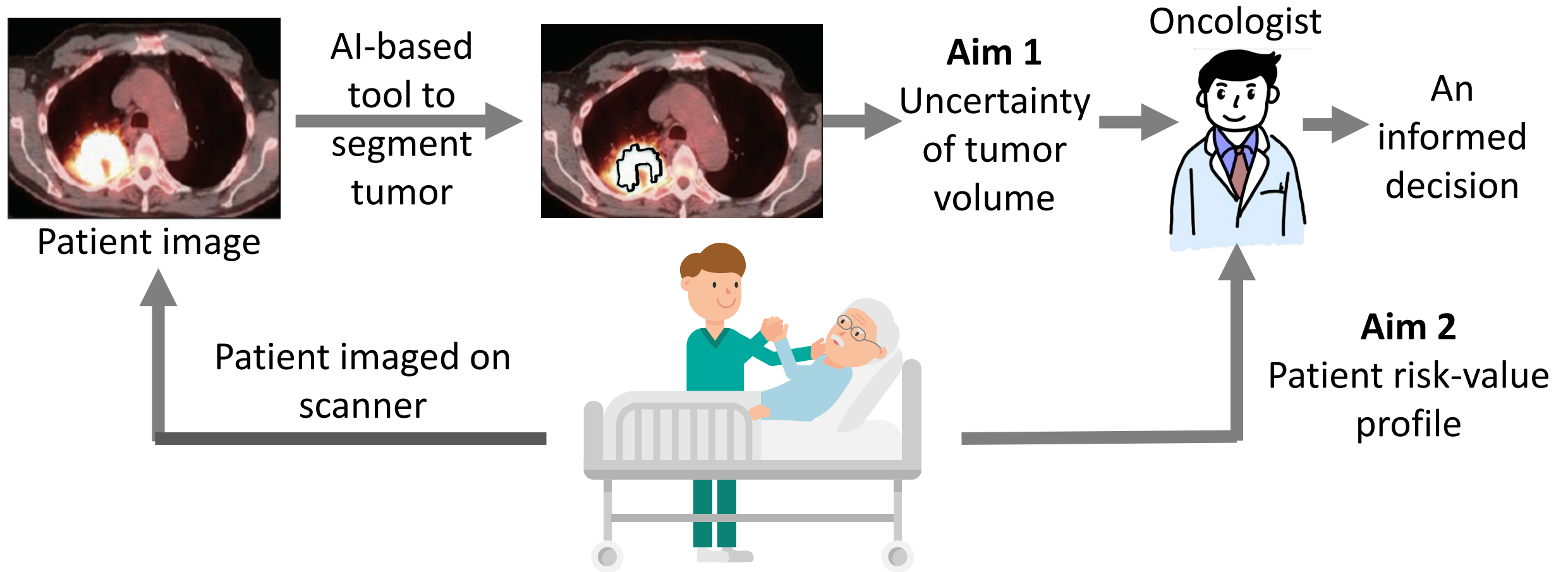
Nature Medicine **28**, 229–232 (2022) | [Cite this article](#)

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Built-in decision thresholds for AI diagnostics are ethically problematic, as patients may differ in their attitudes about the risk of false-positive and false-negative results, which will require that clinicians assess patient values.

An important unmet need for strategies to measure and account for uncertainty when using AI-based quantitative imaging for making clinical decisions

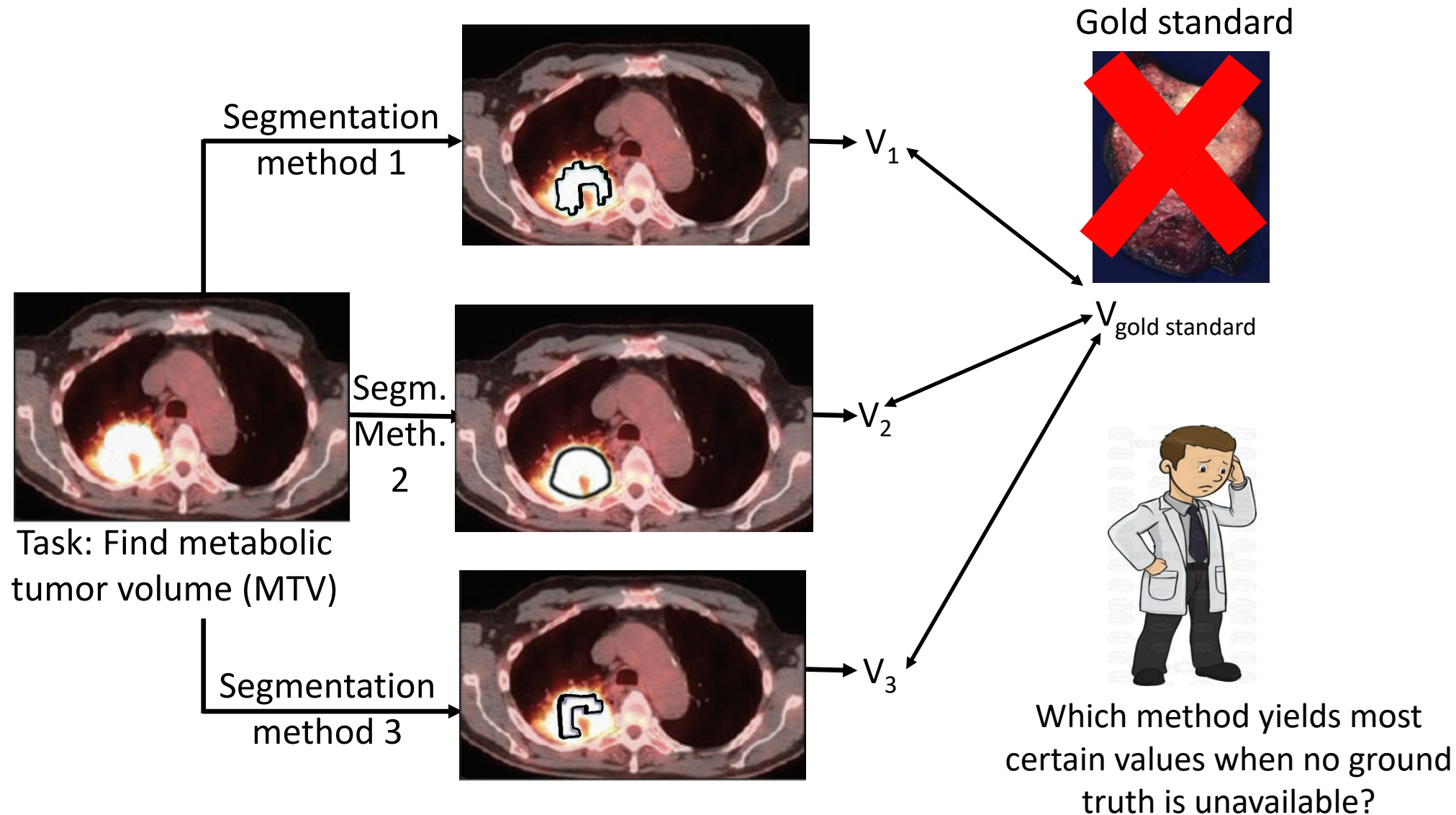
Illustration: Project aims



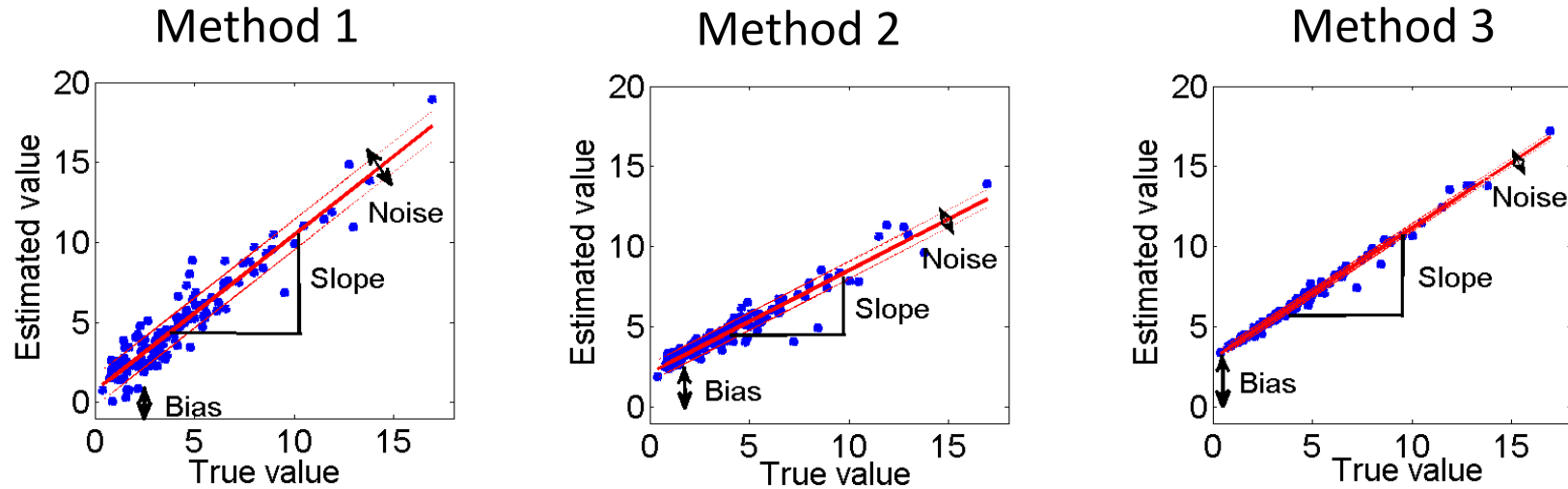
Aim 1: Uncertainty quantification without ground truth

- Existing uncertainty-quantification methods for AI algorithms typically assume the availability of a gold standard.
- Obtaining such a gold standard is time-consuming, expensive, and in many cases, even impossible
- Towards addressing this issue, we have developed an uncertainty quantification technique for evaluating AI-based quantitative imaging methods that does not require ground truth

Uncertainty quantification with clinical data



No-gold-standard evaluation (NGSE): Premise



Assumption 1: True and estimated quantitative values related linearly by a slope, bias and noise standard-deviation term

Assumption 2: True values sampled from a parametric distribution function

No-gold-standard evaluation (NGSE) idea: Estimate the slope, bias, and noise standard-deviation terms without knowledge of the true quantitative values¹⁻⁴

¹Hoppin et al 2001, Trans. Med. Imag., ²Jha et al 2016, Phys. Med. Biol.

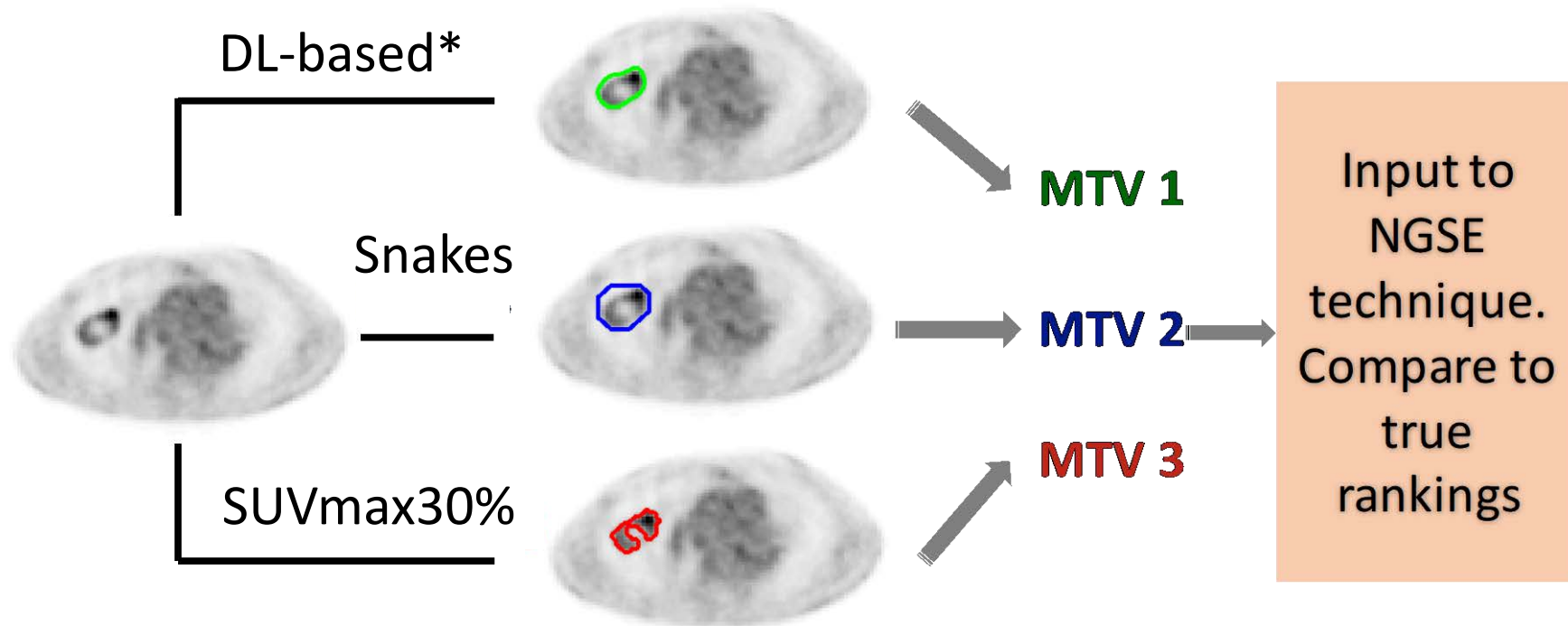
³Jha et al, J. Med. Imag. 2017 ⁴Liu et al, Proc. SPIE Med. Imag. 2022

Example study on validating the no-gold-standard evaluation (NGSE) technique



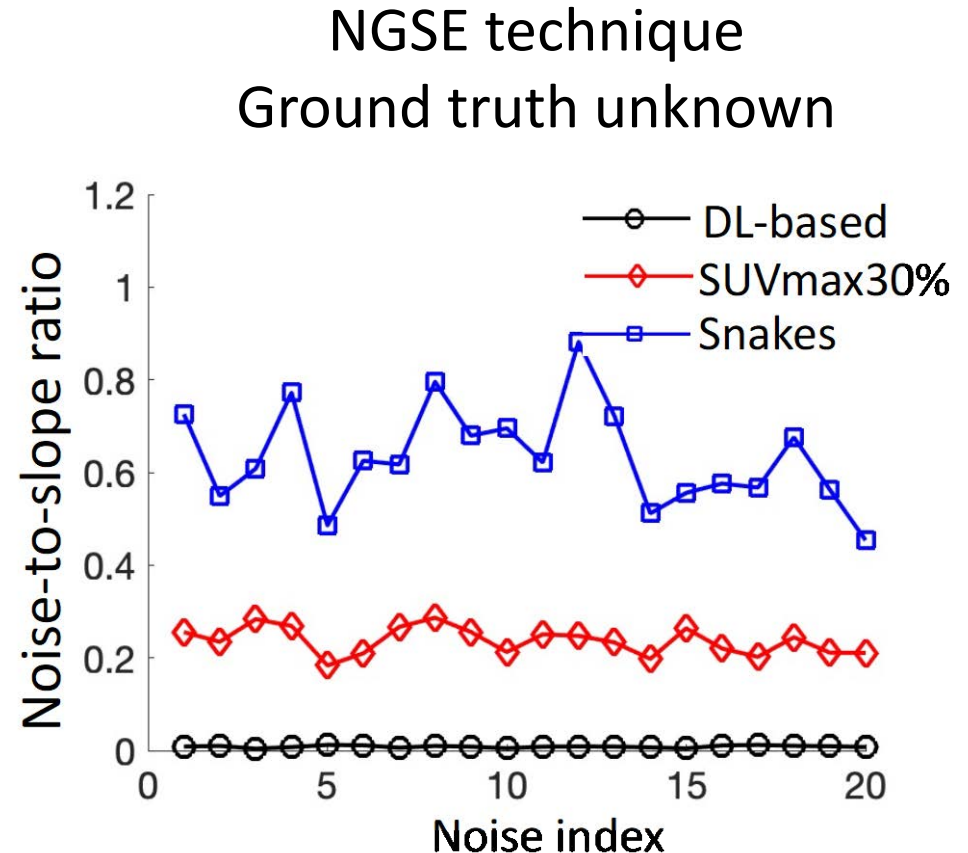
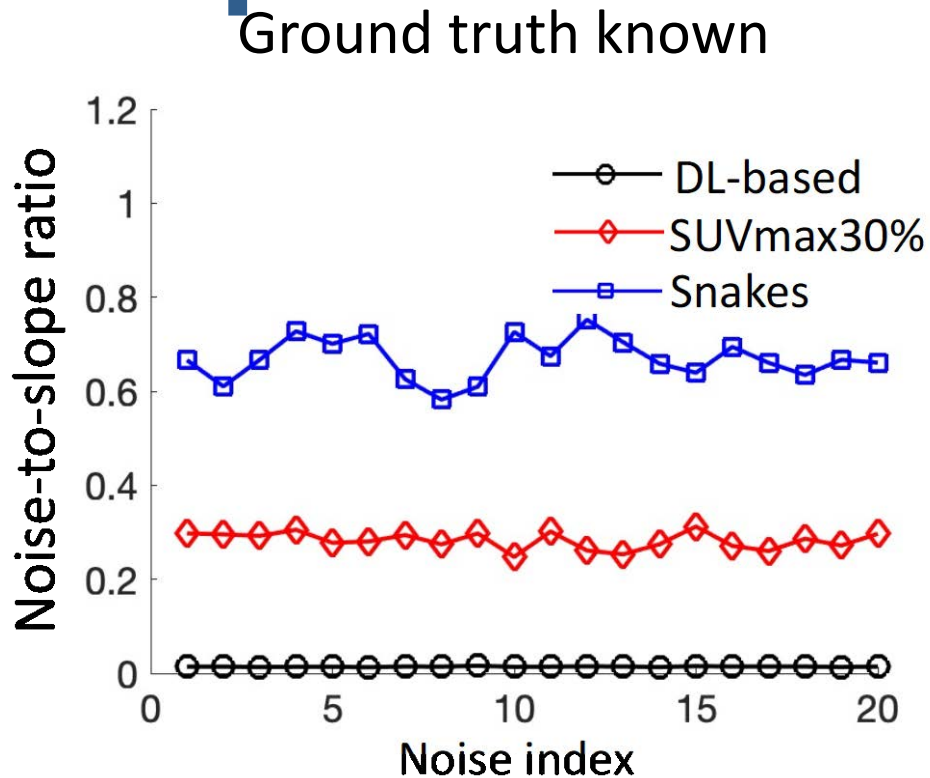
Ziping Liu, PhD

Evaluate PET segmentation methods on the task of measuring metabolic tumor volume (MTV)



*Liu et al, Phys. Med. Biol., 2021

Results: Validation of the NGSE technique



Proposed NGSE technique yielded the same rankings of the segmentation methods as when ground truth was available*

We have demonstrated similar efficacy for multiple other medical imaging modalities and developed methods to guide use of NGSE techniques**

*Liu et al, J. Nuc. Med. (suppl)

**Liu et al, Proc. SPIE Med. Imag. 2024

Aim 2: Designing survey to elicit patient risk-value profiles

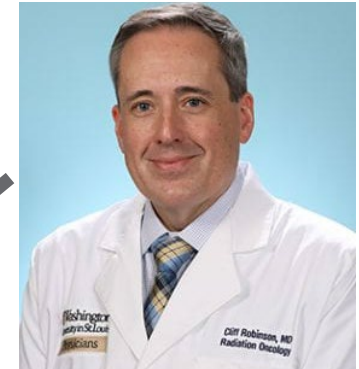


Anya Plutynski, PhD
Biomedical Ethicist

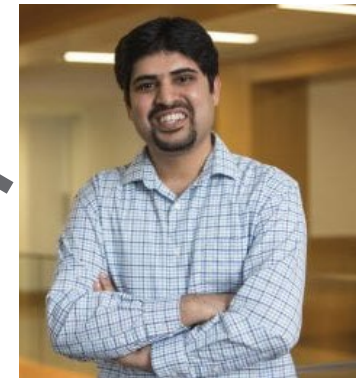


Tyler Fraum, MD
Radiologist

Designing a survey to elicit patient risk-value profiles in using AI for analysis of their scans



Clifford Robinson, MD
Radiation oncologist



Abhinav Jha, PhD
Computational imaging scientist

Survey design

- **Context:** Using AI-based tools for delineation of tumors from positron emission tomography/computed tomography (PET/CT) scans in patients with stage III non-small cell lung cancer
- **Goal:** Assess the patient's risk-value profiles about the use of AI-based tools in analysis of their PET/CT exams, with the objective that this could help physicians in modeling these values
- **Structure:** Educational introduction followed by questions to gauge patient attitudes about AI, risk-value profiles, and uncertainty
- **Next steps:** Finalize survey and circulate amongst patient advocates to obtain feedback and refine survey questions
- **Outcome:** A survey to elicit patient risk-value profiles to incorporate AI uncertainty

Efforts at a community level

As member of the Society of Nuclear Medicine and Molecular Imaging task force, we published papers on ethical considerations for AI in medical imaging

The image shows two screenshots of the JNM website. The top screenshot displays the article title "Ethical Considerations for Artificial Intelligence in Medical Data Collection, Development, and Evaluation" with authors Jonathan Herington, Melissa D. McCradden, Kathleen Creel, Ronald Boellaard, Elizabeth C. Jones, Abhinav K. Jha, Arman Rahmim, Peter J.H. Scott, John J. Sunderland, Richard L. Wahl, Sven Zuehlsdorff and Babak Saboury. The bottom screenshot displays the article title "Ethical Considerations for Artificial Intelligence in Medical Imaging: Deployment and Governance" with the same authors. Both screenshots show the JNM logo, a navigation menu, and a search bar.

Research Article | State of the Art

Ethical Considerations for Artificial Intelligence in Medical Data Collection, Development, and Evaluation

Jonathan Herington, Melissa D. McCradden, Kathleen Creel, Ronald Boellaard, Elizabeth C. Jones, Abhinav K. Jha, Arman Rahmim, Peter J.H. Scott, John J. Sunderland, Richard L. Wahl, Sven Zuehlsdorff and Babak Saboury

Journal of Nuclear Medicine December 2023, 64 (12) 1848-1854; DOI: <https://doi.org/10.2967/jnumed.123.266080>

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Research Article | State of the Art

Ethical Considerations for Artificial Intelligence in Medical Imaging: Deployment and Governance

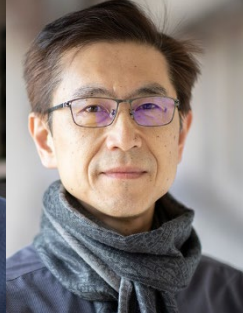
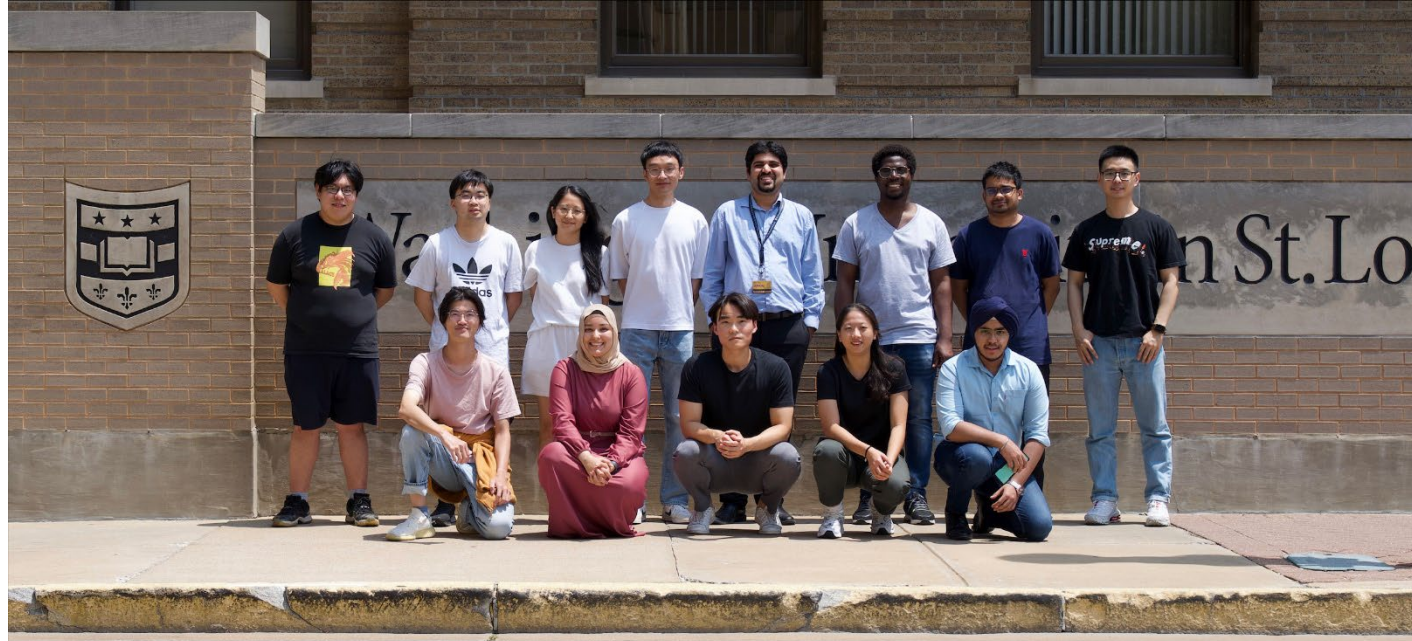
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Journal of Nuclear Medicine October 2023, 64 (10) 1509-1515; DOI: <https://doi.org/10.2967/jnumed.123.266110>

Scholarly work

1. J. Birch, K. A. Creel, **A. K. Jha**, A Plutynski, “Clinical decisions using AI must consider patient values”, Nature Medicine, 28, pp. 229–232, Jan 2022, PMID: 35102337 ([Go to the article](#))
2. Y. Liu and A. K. Jha, “How accurately can quantitative imaging methods be ranked without ground truth: an upper bound on no-gold-standard evaluation”, SPIE Med. Imag. 2024 (Finalist: Robert F. Wagner Best Student Paper award)
3. J. Herington, M. D. McCradden, K. Creel, R. Boellaard, E. C. Jones, P. KC, **A. K Jha**, A. Rahmim, P. J.H. Scott, J. Sunderland, R. L. Wahl, S. Zuehlsdorff, and B. Saboury, “Ethical Considerations for Artificial Intelligence in Medical Imaging: Data Collection, Development, and Evaluation”, J. Nuc. Med., 64(12), 2023, PMID: 37827839 ([Go to the article](#))
4. J. Herington, M. D. McCradden, K. Creel, R. Boellaard, E. C. Jones, P. KC, **A. K Jha**, A. Rahmim, P. J.H. Scott, J. Sunderland, R. L. Wahl, S. Zuehlsdorff, and B. Saboury, “Ethical Considerations for Artificial Intelligence in Medical Imaging: Deployment and Governance”, J. Nuc. Med., 2023, 64 (10) 1509-1515 ([Go to the article](#))
5. Z. Liu, Z. Li, J. C. Mhlanga, B. A. Siegel, **A. K. Jha***, “No-gold-standard evaluation of quantitative imaging methods in the presence of correlated noise”, Proc. SPIE Med. Imag. 2022, PMID: 36465994 ([Go to the article](#)) (Finalist: Robert F. Wagner Best Student Paper award)
6. “Measuring, defining, and reframing uncertainty in AI for clinical medicine”, final stages of preparation

Acknowledgements



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This has been a fantastic research experience!