NMmmWave Collaboration

Catalyst: Dr. William A. Worstell
PicoRad Imaging

Washington University School of Medicine in St. Louis

leidos

PHOTO DIAGNOSTIC SYSTEMS

LEIDOS BIOMEDICAL

Frederick National Laboratory for Cancer Research

Yale University School of Medicine

MGH 1811

Harvard Medical School

Massachusetts General Hospital
Founding Member, Mass General Brigham

Brigham and Women's Hospital
Founding Member, Mass General Brigham

UBC
University of British Columbia

Medical Imaging
UNIVERSITY OF TORONTO

CIMS
Centre d'imagerie moléculaire de Sherbrooke

Revolutionizing Diagnostic Imaging and Radiation Therapy

MIT CSAIL
Computer Science & Artificial Intelligence Laboratory

SNMMI
SOCIETY OF NUCLEAR MEDICINE & MOLECULAR IMAGING

The NMmmWaveCardiac Collaboration brings together a diverse group of leading academic institutions and industry partners, each contributing unique expertise and resources to advance the project's goals. Here is an overview of the key collaborators and their roles:

1. **Washington University Group:**
   - **Role:** Development of CBmmWave camera technology.
   - **Expertise:** Specializes in mmWave imaging technology and prototype development. Their pioneering work in mmWave technology will drive the development and optimization of the imaging systems.

2. **Georges El Fakhri at Yale:**
   - **Role:** Integration of synthetic CT and deep learning-based attenuation correction.
   - **Expertise:** Renowned for advanced medical imaging technologies and clinical trials. His team brings extensive experience in synthetic CT and machine learning applications in imaging.

3. **Hamid Sabet and his team at MGH:**
   - **Role:** Validation of mmWave technology integration with medical imaging.
   - **Expertise:** Offers clinical expertise and access to cutting-edge imaging facilities, essential for validating the new imaging systems in real-world clinical settings.

4. **Leidos:**
   - **Role:** Development of total body surface imaging technology.
   - **Expertise:** Known for their expertise in security imaging and technology integration, Leidos will contribute advanced imaging technologies and support the development of comprehensive body surface imaging systems.

5. **RT Group at Brigham and Women's Hospital:**
   - **Role:** Integration of mmWave technology into radiation therapy systems.
   - **Expertise:** Brings extensive experience in radiation therapy and clinical trials, facilitating the incorporation of mmWave technology into therapeutic applications.

6. **Olof Johnson of PhotoDiagnostic Systems:**
   - **Role:** Technical development and industry expertise.
   - **Expertise:** Provides oversight for technical developments and facilitates industry collaborations. His extensive experience in medical imaging systems will ensure the successful development and deployment of the new technologies.

7. **SNMMI (Joyita Dutta):**
   - **Role:** Advocacy and support for NIH funding and international collaboration.
   - **Expertise:** As the head of the Physics, Instrumentation, and Data Sciences division, she brings leadership in the nuclear medicine community and connections with key stakeholders to support and promote the project.

8. **Arman Rahmin and the PyTomography Team at UBC:**
   - **Role:** Development and validation of advanced tomography algorithms.
   - **Expertise:** Specializes in tomography and image reconstruction, contributing to the development of robust algorithms and the execution of multicenter clinical trials.

9. **Steve Adler and the Frederick National Laboratory for Cancer Research:**
   - **Role:** Advanced PET and SPECT imaging research.
   - **Expertise:** Provides infrastructure and technical support for PET and SPECT imaging research, leveraging their extensive experience in imaging technologies.

10. **Quanzheng Li and his team at MGH:**
    - **Role:** Advanced image reconstruction and kinetic modeling.
    - **Expertise:** Renowned for research in PET, SPECT, multimodal MRI, quantitative PET-MR imaging, and machine learning for anatomical imaging. His team will drive the development of advanced image reconstruction techniques.

11. **Washington University PET Instrumentation Group (Radiology/Nuclear Medicine Research):**
    - **Role:** Development and innovation in PET instrumentation.
    - **Expertise:** Led by Yuan-Chuan Tai, this group specializes in enhancing PET technology and integrating it with mmWave imaging for superior diagnostic performance. Their AWSM-PET technology enhances resolution and sensitivity, significantly improving diagnostic accuracy.

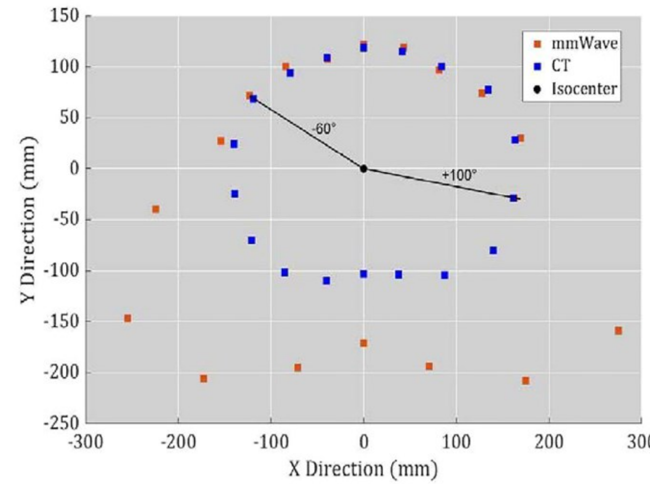
12. **Canadian PET Imaging Research Teams:**
    - **Role:** Parallel efforts in Canada to complement the NMmmWaveCardiac Collaboration.
    - **Expertise:** Includes leading research teams from Toronto, Sherbrooke (led by Roger Lecomte), Montreal, and UBC, known for their innovative work in PET imaging. These teams bring expertise in high-resolution PET imaging, advanced radiochemistry, and multimodal imaging technologies.

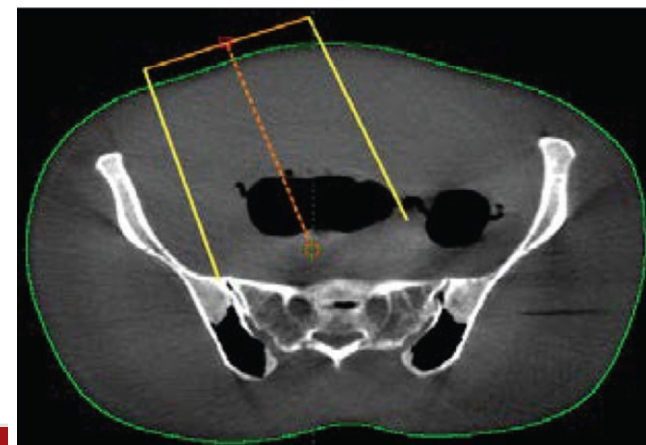
13. **MIT CSAIL (Polina Golland's Medical Vision Group):**
    - **Role:** Development of advanced deformable registration techniques.
    - **Expertise:** Specializes in the development of diffDRR and diffPose algorithms. Their expertise will be critical in integrating these advanced techniques into the mmWave-augmented SPECT and PET imaging systems.

These collaborators bring a wealth of knowledge and expertise to the NMmmWaveCardiac Collaboration, ensuring a comprehensive and multidisciplinary approach to developing and validating mmWave-augmented SPECT and PET imaging systems.

Bressler, M., Zhu, J., Olick-Gibson, J., Haefner, J., Zhou, S., Chen, Q., Mazur, T., Hao, Y., Carter, P. and Zhang, T., 2024. Millimeter wave-based patient setup verification and motion tracking during radiotherapy. *Medical physics*, *51*(4), pp.2967-2974.

This group built a co-registered mmWave imaging system for Radiation Therapy integrated with kilovolt X-ray imaging





Washington University School of Medicine in St. Louis

The mmWave device developed by the team can monitor breathing and cardiac motion simultaneously, and can decompose a chest displacement profile into breathing and cardiac waveforms

Shi, L., Onofrey, J.A., Liu, H., Liu, Y.H. and Liu, C., 2020. [Deep learning-based attenuation map generation for myocardial perfusion SPECT.](#) *European Journal of Nuclear Medicine and Molecular Imaging*, *47*, pp.2383-2395.

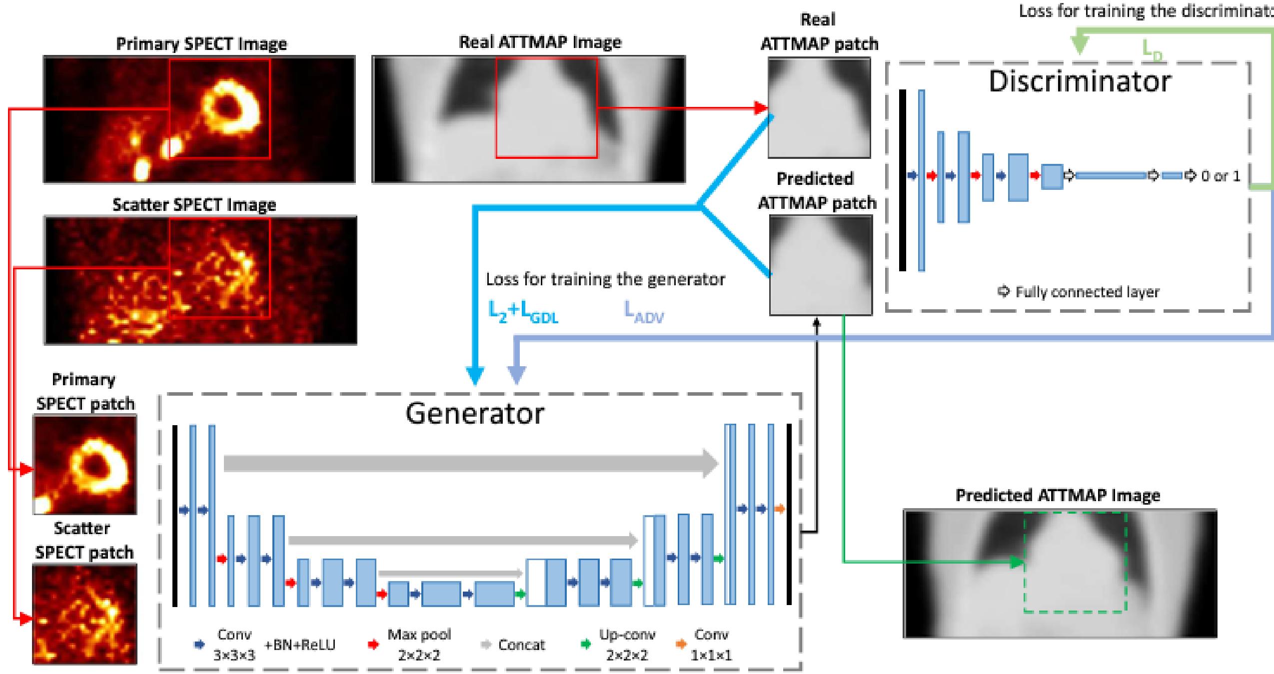
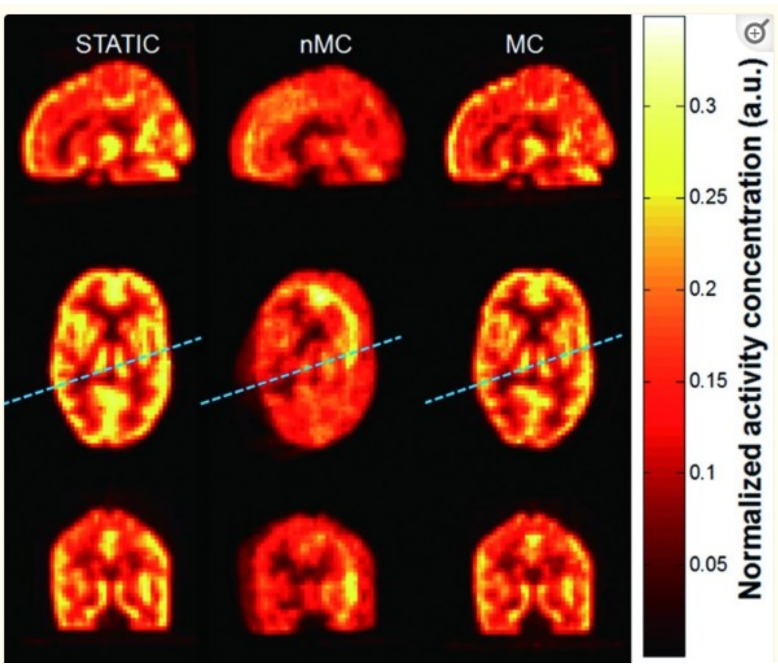


Fig. 1 Overall semantic illustration of the proposed method

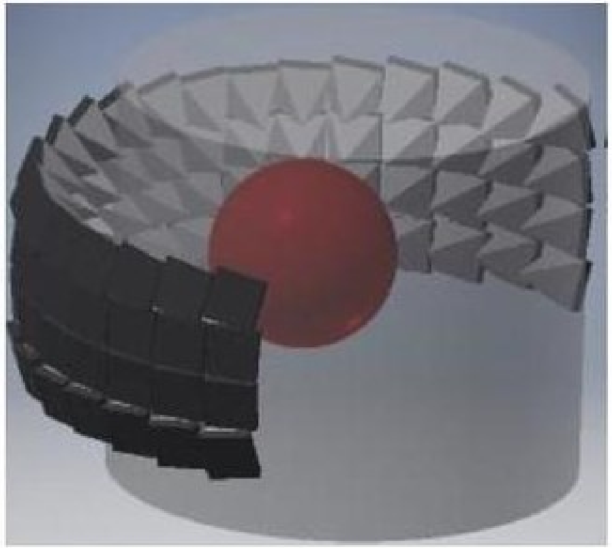


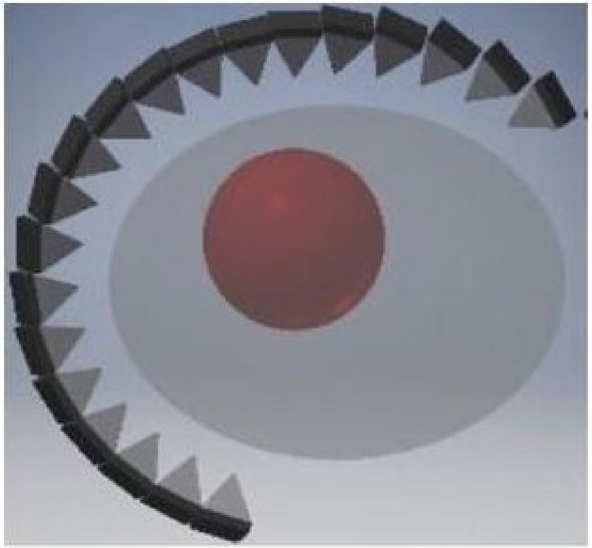
Huang, C., Ackerman, J.L., Petibon, Y., Brady, T.J., El Fakhri, G. and Ouyang, J., 2014. [MR-based motion correction for PET imaging using wired active MR microcoils in simultaneous PET-MR: Phantom study](#). *Medical physics*, *41*(4), p.041910.

Yale University School of Medicine

Massachusetts General Hospital
Founding Member, Mass General Brigham

Radiation Physics and Instrumentation Laboratory



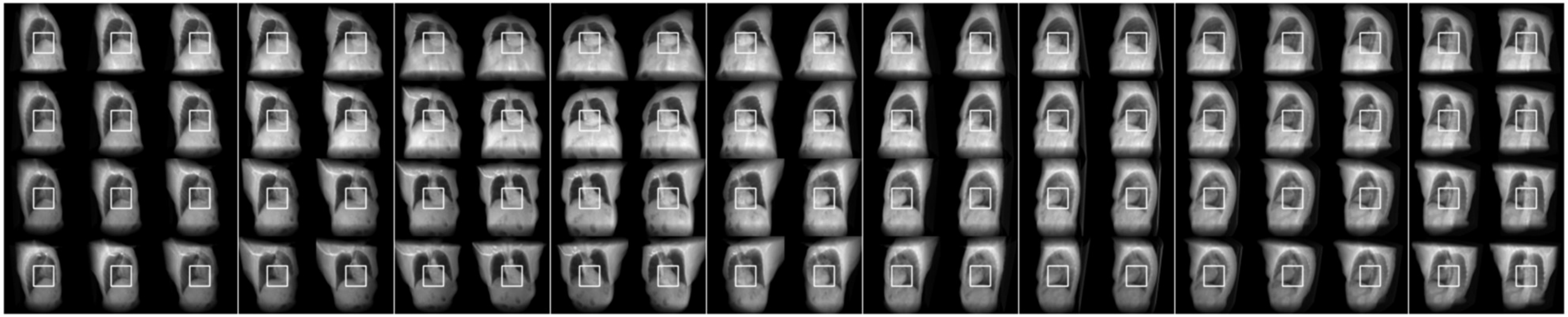


DC-SPECT Dynamic Cardiac SPECT A stationary SPECT system for dynamic cardiac imaging application

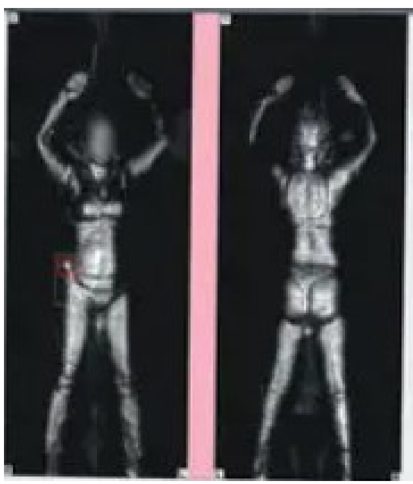
Bläckberg, L., Sajedi, S., Anderson, O.A., Feng, Y., El Fakhri, G., Furenlid, L. and Sabet, H., 2020, October. Dynamic Cardiac SPECT for diagnostic and theranostics applications: latest results. In *2020 IEEE nuclear science symposium and medical imaging conference (NSS/MIC)* (pp. 1-3). IEEE.

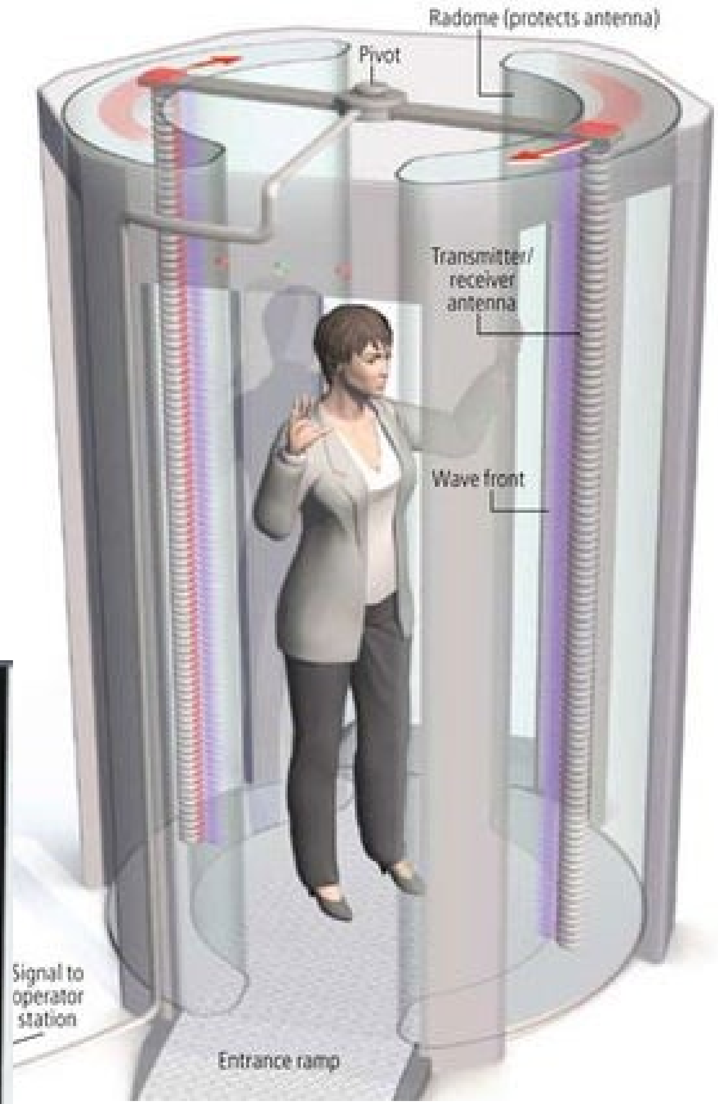
Atenuation correction for DC-SPECT

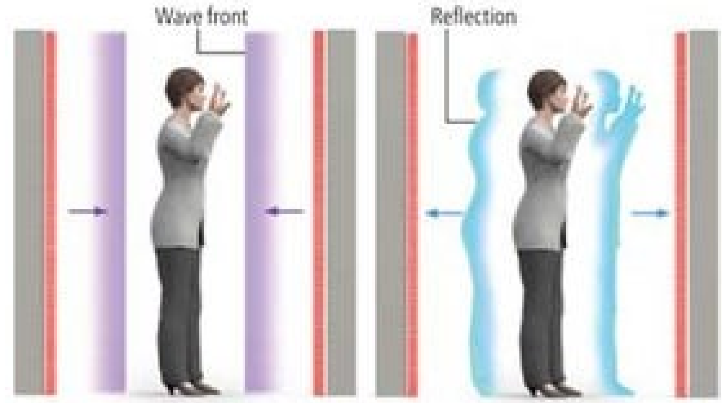
ExtraWideFOV



Nowacki, G. and Paszukow, B., 2019. [New Technologies in the Field of Ensuring Security for Restricted and Public Areas at Airports](). *Autobusy–Technika, Eksploatacja, Systemy Transportowe*, *23 2*(7-8), pp.57-61.







MILLIMETER-WAVE IMAGING

A passenger steps inside. Two vertical banks of transmitter/receivers pivot in tandem, each emitting a wave front that penetrates clothing and reflects off the person's body and any concealed objects. For privacy, the security operator viewing the resulting image sits at a remote location.

Scan time = 10 seconds
Beam frequency = 24–30 GHz
Beam power density = 6×10^{-6} mW/cm^2

[The Ferenc Jolesz National Center for Advanced Technologies for Image Guided Therapy (AT-NCIGT)]()

Brigham and Women's Hospital
Founding Member, Mass General Brigham

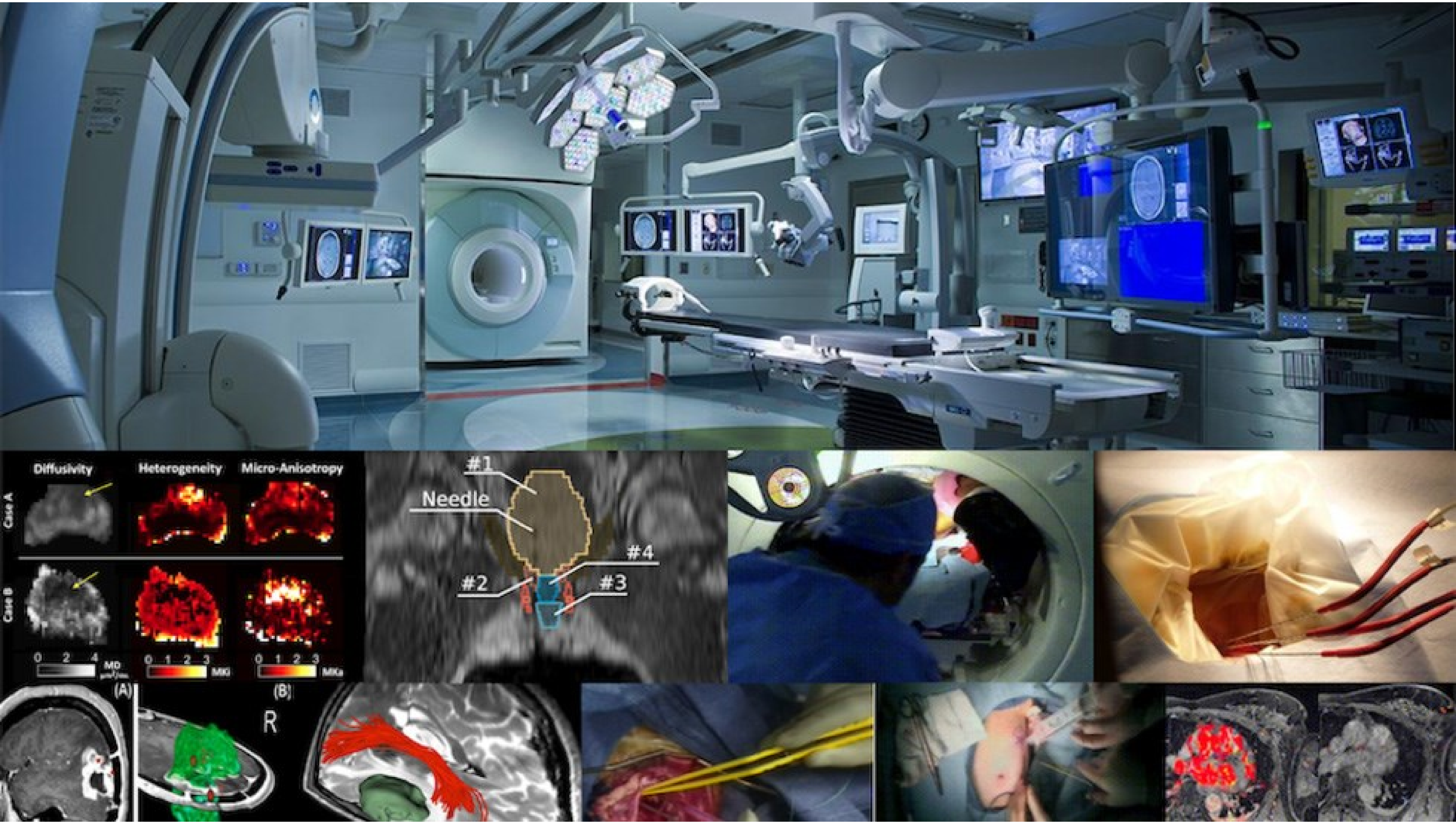
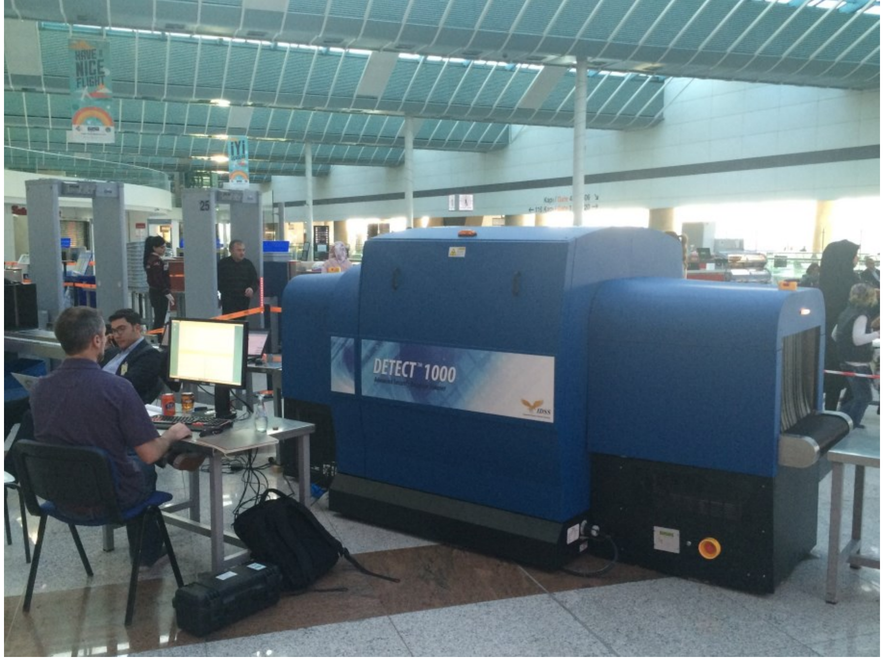


PHOTO DIAGNOSTIC SYSTEMS

Koning Breast CT



DETECT1000 Airport Security Scanner

Grogg, K.S., Toole, T., Ouyang, J., Zhu, X., Normandin, M.D., Li, Q., Johnson, K., Alpert, N.M. and El Fakhri, G., 2016. National Electrical Manufacturers Association and clinical evaluation of a novel brain PET/CT scanner. *Journal of Nuclear Medicine*, *57*(4), pp.646-652.

Zhu, X. and El Fakhri, G., 2013. Proton therapy verification with PET imaging. *Theranostics*, *3*(10), p.731.

SOCIETY OF NUCLEAR MEDICINE & MOLECULAR IMAGING

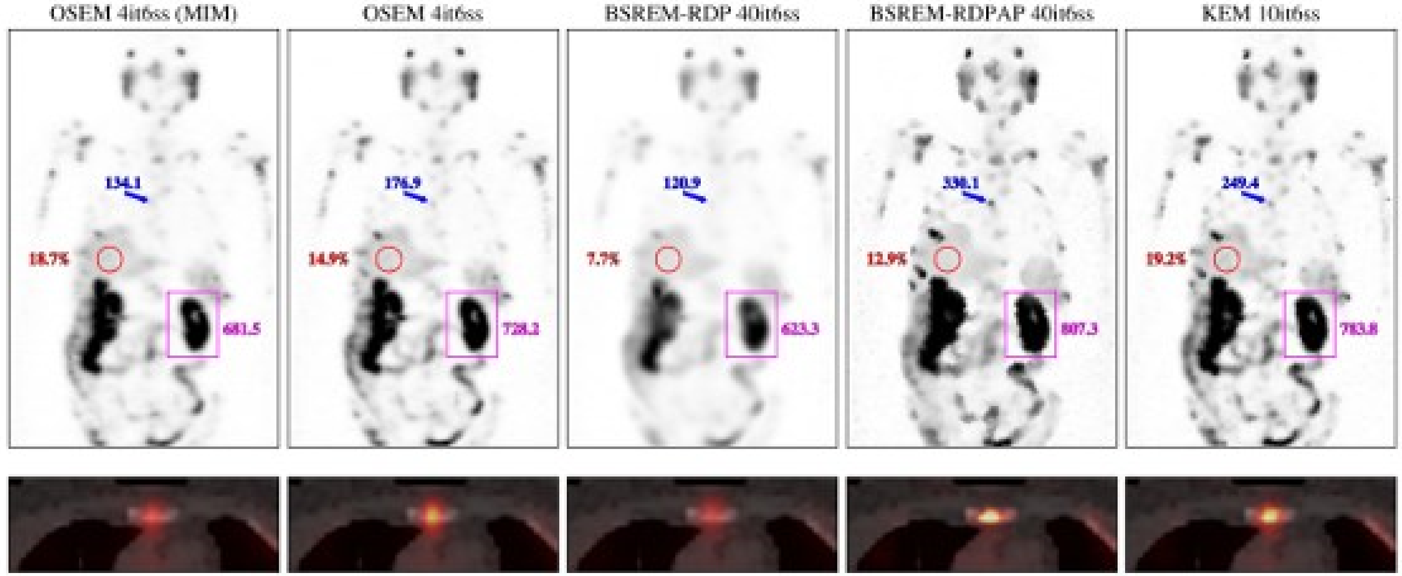
The Physics, Instrumentation and Data Sciences Council (PIDSC) is composed of Society members who have an interest in medical physics, nuclear instrumentation, and data analysis and their applications in therapeutic, diagnostic or investigational nuclear medicine.

•Joyita Dutta, PhD (Council President)

Al-Mallah, M.H., Bateman, T.M., Branch, K.R., Crean, A., Gingold, E.L., Thompson, R.C., McKenney, S.E., Miller, E.J., Murthy, V.L., Nieman, K. and Villines, T.C., 2022. 2022 ASNC/AAPM/SCCT/SNMMI guideline for the use of CT in hybrid nuclear/CT cardiac imaging. *Journal of Nuclear Cardiology*, *29*(6), pp.3491-3535.

PIDSC's mission is to promote the dissemination of knowledge and the advancement of medical physics, nuclear instrumentation, and data analysis and their applications for diagnosis and treatment in nuclear medicine to its members and to the Society of Nuclear Medicine and Molecular Imaging as a whole. The objectives of the Council to carry out the mission are:

1. To promote effective use of medical physics, nuclear instrumentation, and data analysis in the diagnostic, therapeutic, and investigational applications of nuclear medicine, including molecular imaging initiatives;
2. To provide a forum for the members of the Society of Nuclear Medicine who have an interest in medical physics, nuclear instrumentation, and data analysis;
3. To provide members of the Society of Nuclear Medicine with a source of information on medical physics, nuclear instrumentation, and data analysis.



Polson, L., Fedrigo, R., Li, C., Sabouri, M., Dzikunu, O., Ahamed, S., Rahmim, A. and Uribe, C., 2023. [PyTomography: A Python Library for Quantitative Medical Image Reconstruction](). *arXiv preprint arXiv:2309.01977*.

Polson, L., Karakatsanis, N., Rahmim, A. and Uribe, C., 2024. [PyTomography: Advancements in AI-Based Image Reconstructions.]()

PyTomography

PyTomography is an open-source, GPU-accelerated python library which provides both extensive system modeling for SPECT/PET systems as well as associated reconstruction algorithms for quantitative imaging.

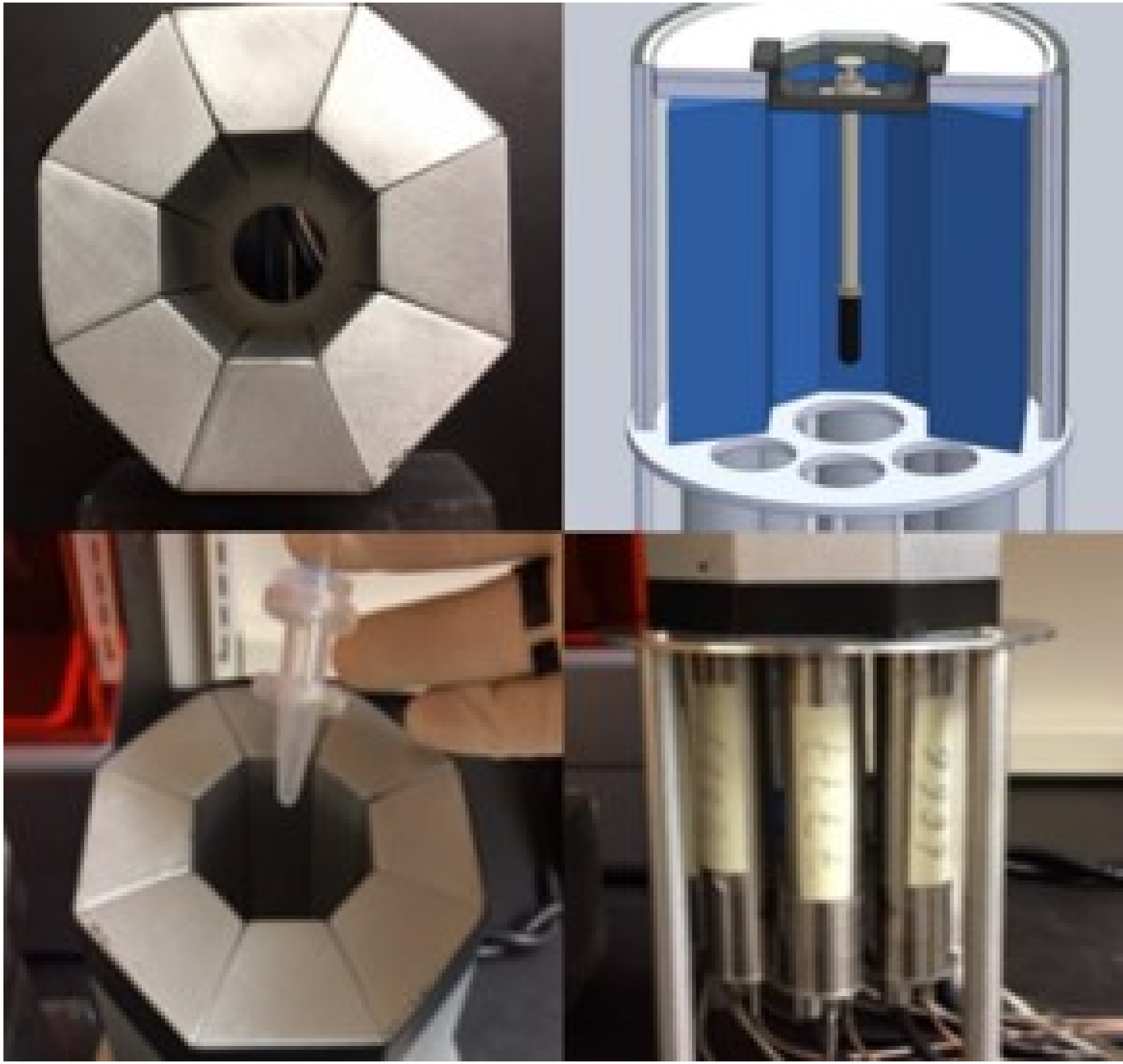
Frederick National Laboratory for Cancer Research

Center for Innovation and Strategic Partnership

Adler, S. and Choyke, P., 2018. Development and performance measurements of a micro-dose calibrator.

Jagoda, E.M., Basuli, F., Olkowski, C., Weiss, I., Phelps, T.E., Wong, K., Ton, A.T., Lane, K.C., Adler, S., Butcher, D. and Edmondson, E.F., 2023. Immuno-PET imaging of Siglec-15 using the Zirconium-89-Labeled therapeutic antibody, NC318. *Molecular Imaging*, *2023*, p.3499655.

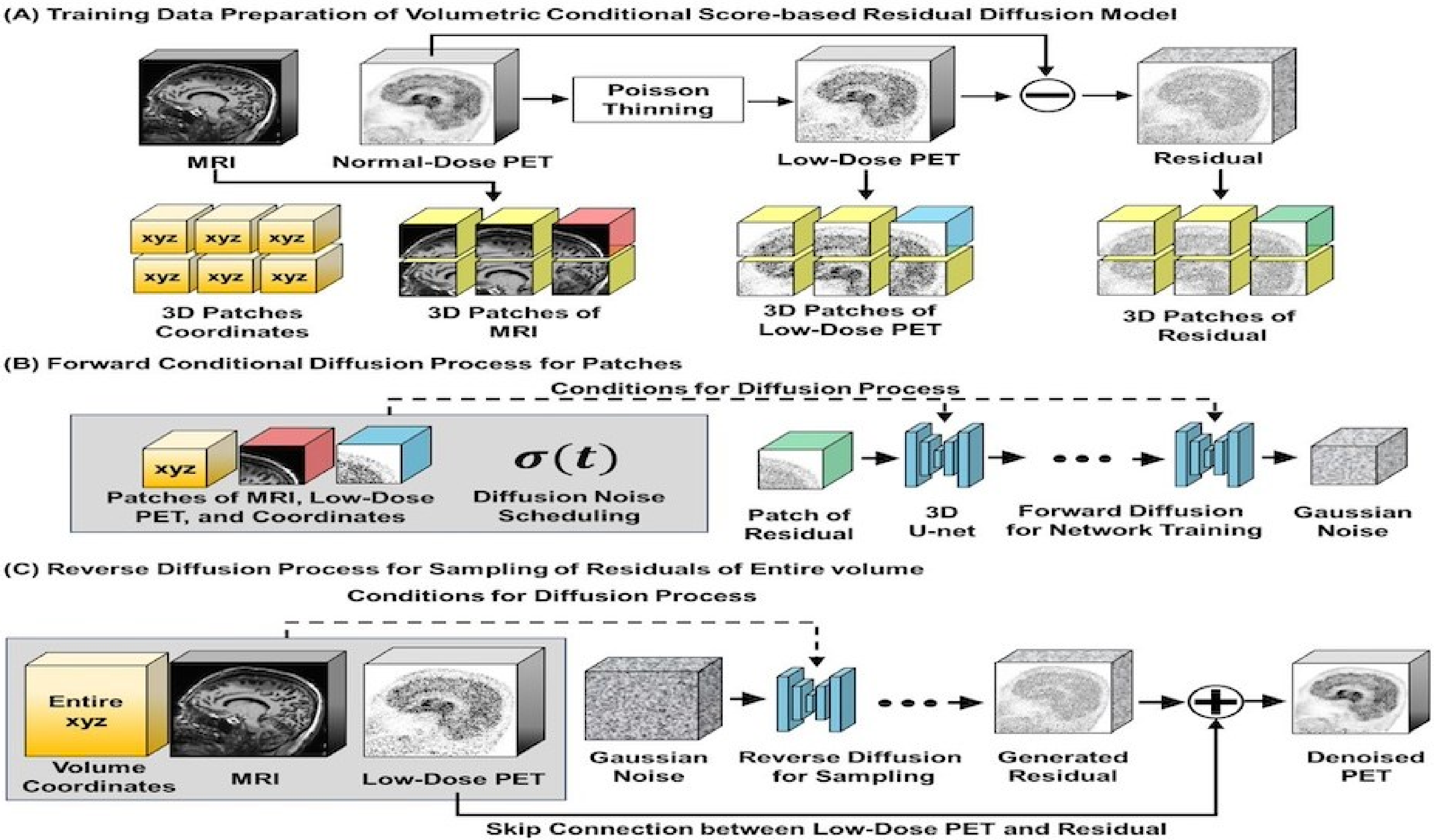
NIH NATIONAL CANCER INSTITUTE



CAMCA

Center for Advanced Medical Computing and Analysis

Tivnan, M., Yoon, S., Chen, Z., Li, X., Wu, D. and Li, Q., 2024. [Hallucination Index: An Image Quality Metric for Generative Reconstruction Models.](#) *arXiv preprint arXiv:2407.12780*.



Washington University School of Medicine in St. Louis

MIR Mallinckrodt Institute of Radiology

Chen, Y., Hambdi, M., Komarov, S., Mintzer, R.A., Cho, S., Pocci, D., Thomas, A., Corbeil, J., Breuer, J., Judenhofer, M. and Wu, N., 2023, November. Initial Results of a Prototype AWSM-PET Device for Augmented Whole-body PET Imaging. In *2023 IEEE Nuclear Science Symposium, Medical Imaging Conference and International Symposium on Room-Temperature Semiconductor Detectors (NSS MIC RTSD)* (pp. 1-2). IEEE.

Jiang, J., Samanta, S., Li, K., Siegel, S.B., Mintzer, R.A., Cho, S., Conti, M., Schmand, M., O'Sullivan, J. and Tai, Y.C., 2019. Augmented whole-body scanning via magnifying PET. *IEEE transactions on medical imaging*, *39*(11), pp.3268-3277.

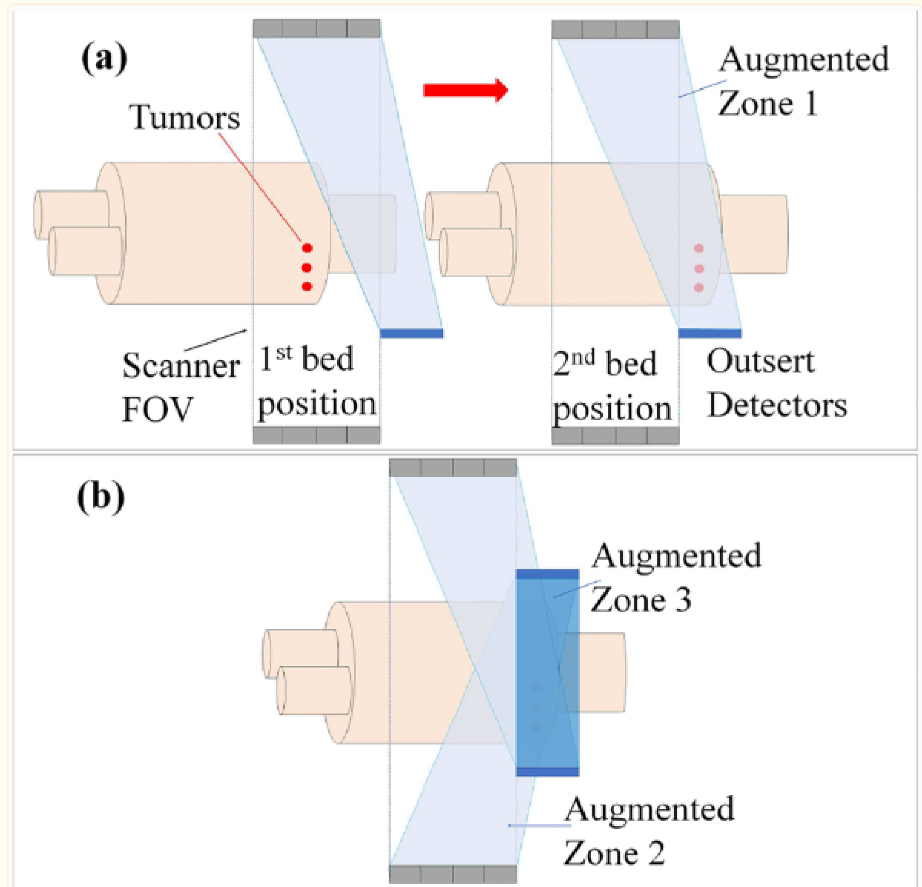
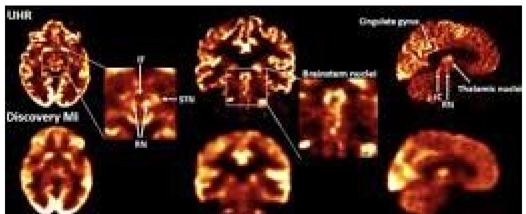


Fig. 1.

(a) A basic AWSM-PET system consists of high-resolution detectors (an Outsert) placed outside the scanner's axial FOV to survey the body in conjunction with scanner detectors. At the first bed position, the three tumors (represented by red circles) are in the native scanner's imaging FOV. When the patient is moved to the second bed position, these tumors are outside the scanner's FOV but inside the augmented zone 1. These additional coincidence events detected by an Outsert are information-rich. Joint image reconstruction using SS events from the bed position 1 and OS events from bed position 2 can enhance both the image resolution and system sensitivity. (b). An AWSM-PET system with dual-panel Outserts creates additional augmented zones 2 and 3 to further

Centre d'imagerie moléculaire de Sherbrooke

Lecomte, R., Auger, É., Loignon-Houle, F., Toussaint, M., Doyon, V., Thibaudeau, C., Beaudoin, J.F., Leroux, J.D., Gaudreault, M., Samson, A. and Arpin, L., 2023. NEMA Performance Characteristics of the UHR Brain PET Scanner.



Brain region	UHR Relative SUV	Discovery MI Relative SUV
Subthalamic nuclei (STN)	1.21	0.98
Red nuclei (RN)	1.27	1.06
Interpeduncular fossa (IF)	0.69	0.87
Inferior colliculus (IC)	1.79	0.94
Hippocampus	0.73	0.72
Amygdala	0.72	0.72
Putamen	1.28	1.19

*Image quality obtained with the Discovery MI is suboptimal due to whole-body acquisition protocol.

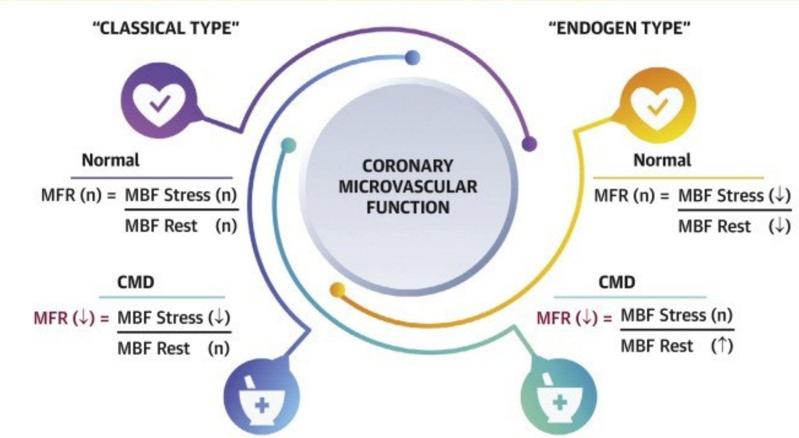
Doyon, V., Sarrhini, O., Loignon-Houle, F., Toussaint, M., Auger, E., Thibaudeau, C., Croteau, E., Lavallée, E., Dumulon-Perreault, V., Beaudoin, J.F. and Leroux, J.D., 2023, November. Microliter in vivo Brain PET Imaging with the Ultra-High Resolution (UHR) Scanner. In *2023 IEEE Nuclear Science Symposium, Medical Imaging Conference and International Symposium on Room-Temperature Semiconductor Detectors (NSS MIC RTSD)* (pp. 1-1). IEEE.

UNIVERSITÉ DE SHERBROOKE

Medical Imaging UNIVERSITY OF TORONTO

Schindler, T.H., Fearon, W.F., Pelletier-Galarneau, M., Ambrosio, G., Sechtem, U., Ruddy, T.D., Patel, K.K., Bhatt, D.L., Bateman, T.M., Gewirtz, H. and Shirani, J., 2023. Myocardial perfusion PET for the detection and reporting of coronary microvascular dysfunction: a JACC: cardiovascular imaging expert panel statement. *Cardiovascular Imaging*, *16*(4), pp.536-548.

CENTRAL ILLUSTRATION: Classical and Endogen Types of Normal and Abnormal Coronary Microvascular Function are Displayed

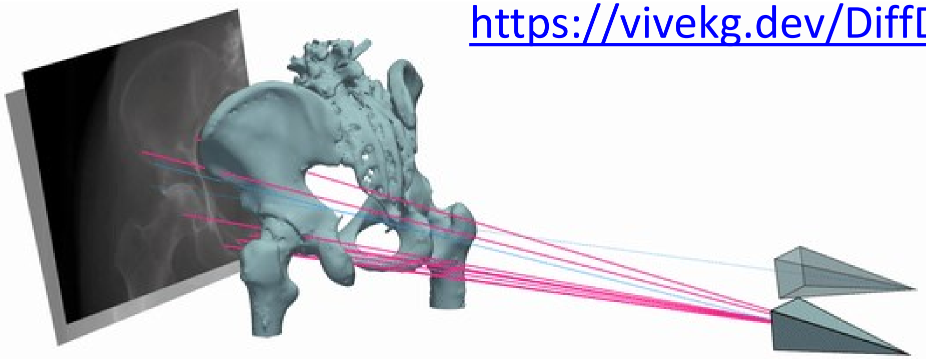


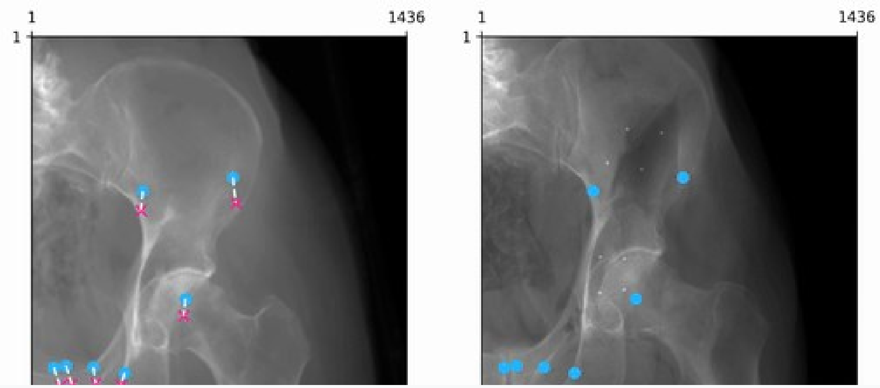
Schindler TH, et al. J Am Coll Cardiol Img. 2023;16(4):536-548.

MIT CSAIL Computer Science & Artificial Intelligence Laboratory

Gopalakrishnan, V. and Golland, P., 2022, September. [Fast auto-differentiable digitally reconstructed radiographs for solving inverse problems in intraoperative imaging]. In *Workshop on Clinical Image-Based Procedures* (pp. 1-11). Cham: Springer Nature Switzerland.

https://vivekg.dev/DiffDRR/





Gopalakrishnan, V., Dey, N. and Golland, P., 2024. [Intraoperative 2d/3d image registration via differentiable x-ray rendering]. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 11662-11672).

DiffDRR is a PyTorch-based digitally reconstructed radiograph (DRR) generator that provides

1. Differentiable X-ray rendering
2. GPU-accelerated synthesis and optimization
3. A pure Python implementation

Most importantly, DiffDRR implements DRR rendering as a PyTorch module, making it interoperable in deep learning pipelines.