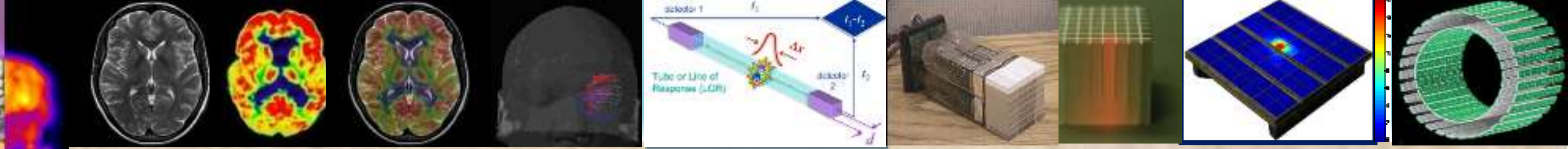

# Artificial intelligence-powered multimodality medical imaging: Challenges and opportunities

Habib Zaidi[1,2,3,4]

*Óbuda University, Budapest, 12 Sepember 2023*

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Email: habib.zaidi@hcuge.ch
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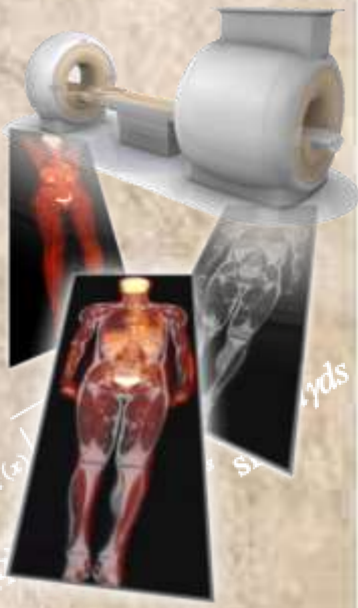

PINLab PET Instrumentation & Neuroimaging Lab

HUG Hôpitaux Universitaires Genève | FACULTÉ DE MÉDECINE

UNIVERSITÉ DE GENÈVE

# *Outline*

- Advances in multimodality medical imaging
- Why artificial intelligence in multimodality imaging?
- Promise of AI in multimodality medical imaging
  - PET instrumentation (event positioning & TOF)
  - Low-dose CT/PET/SPECT imaging (chest/brain/WB/cardiac)
  - Medical image segmentation (CT and PET)
  - Cross-modality image conversion (MRI→CT)
  - Quantification (attenuation & scatter correction in PET)
  - Computational modeling and radiation dosimetry
  - Prognostic modeling and outcome prediction
- Summary and future perspectives

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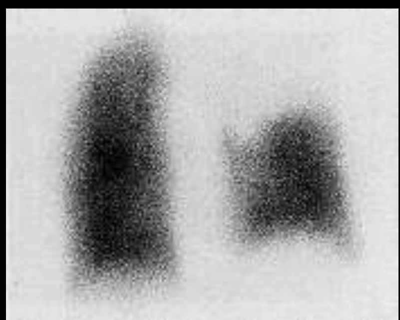
# From 2-D to 5-D multimodality imaging

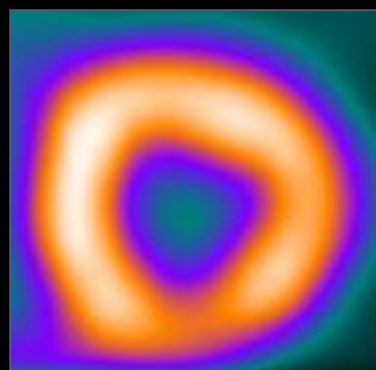
## *Navigating beyond the 5th dimension …*

## *Beyond pretty images …*

2-D projections

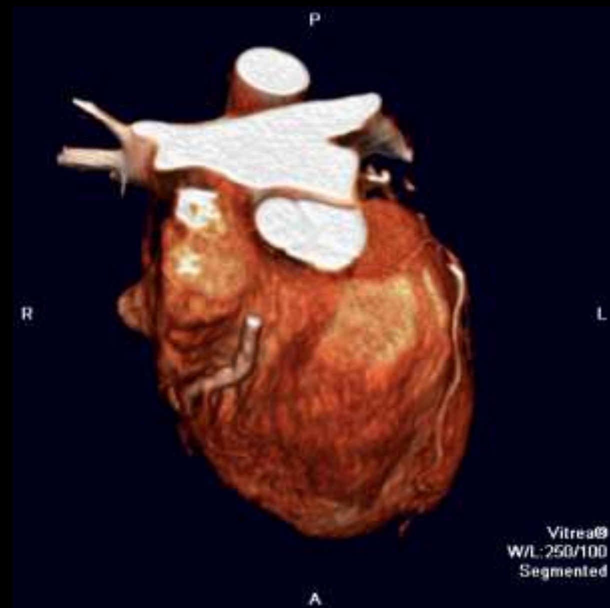


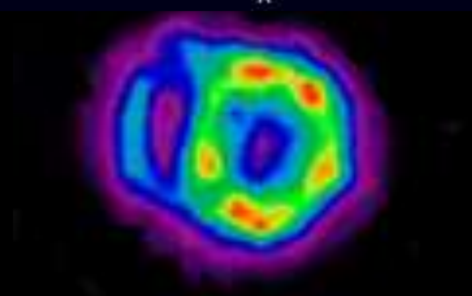
3-D CT



3-D PET

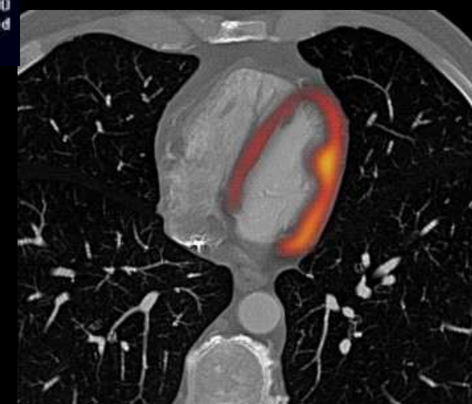
4-D CT



4-D PET

5-D PET/CT



Zaidi H. Navigating beyond the 6th dimension: A challenge in the era of multi-parametric molecular imaging (2009) EJNMMI **36:** 1025-28

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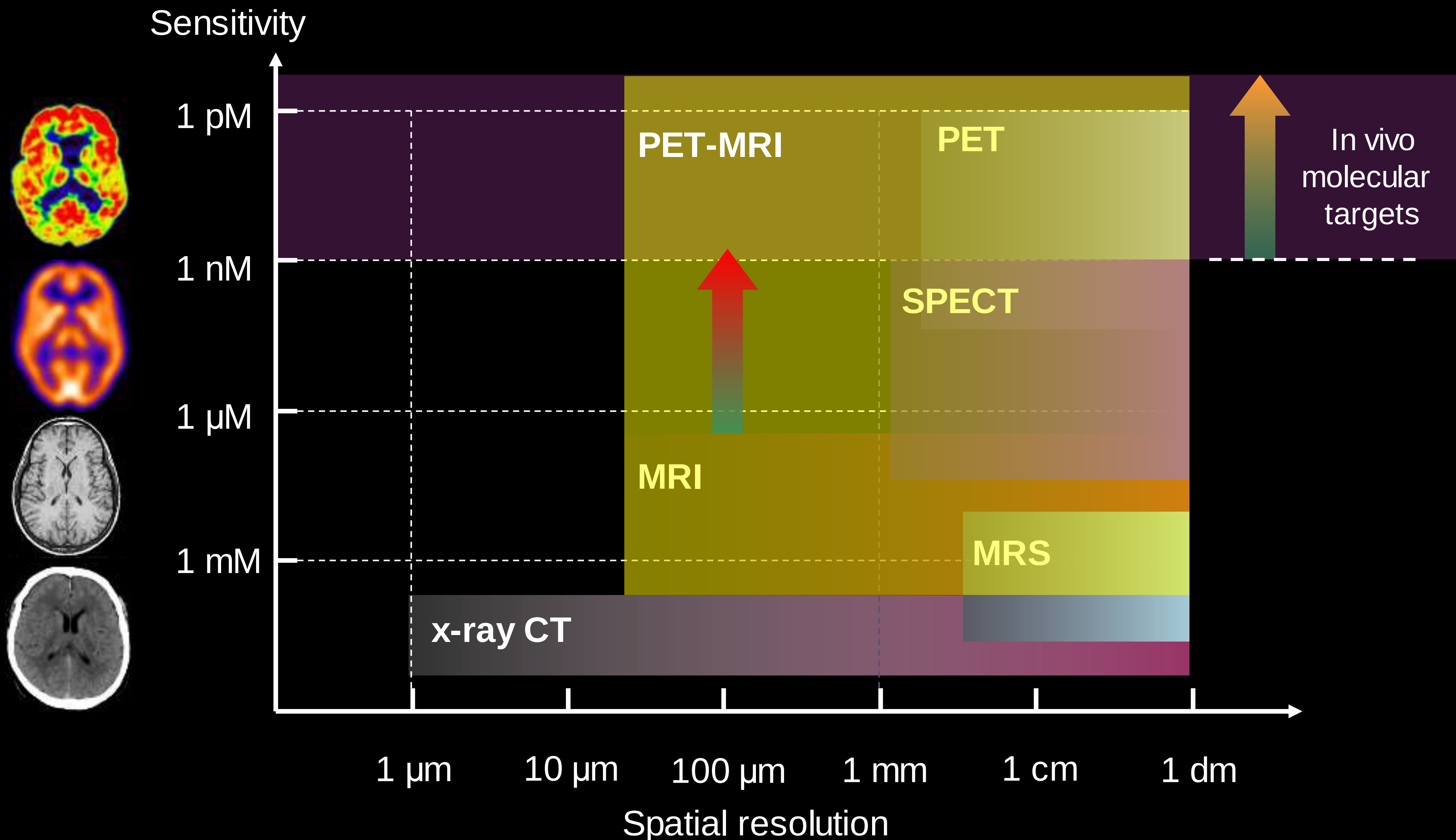
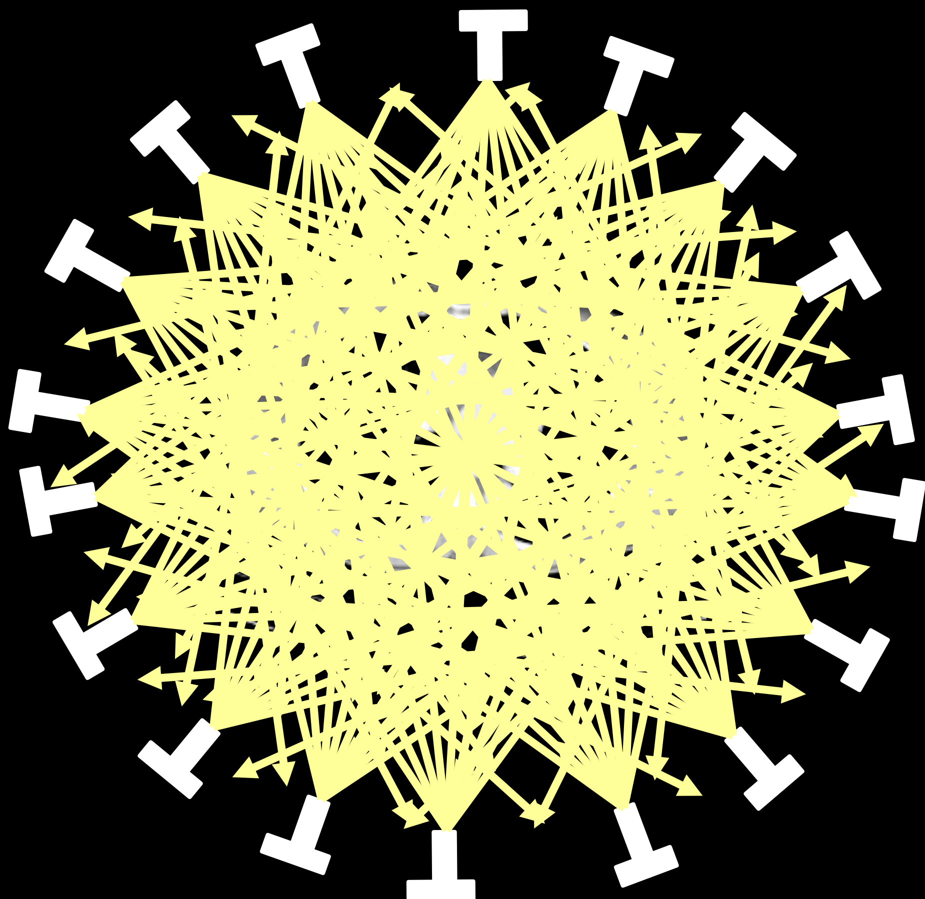
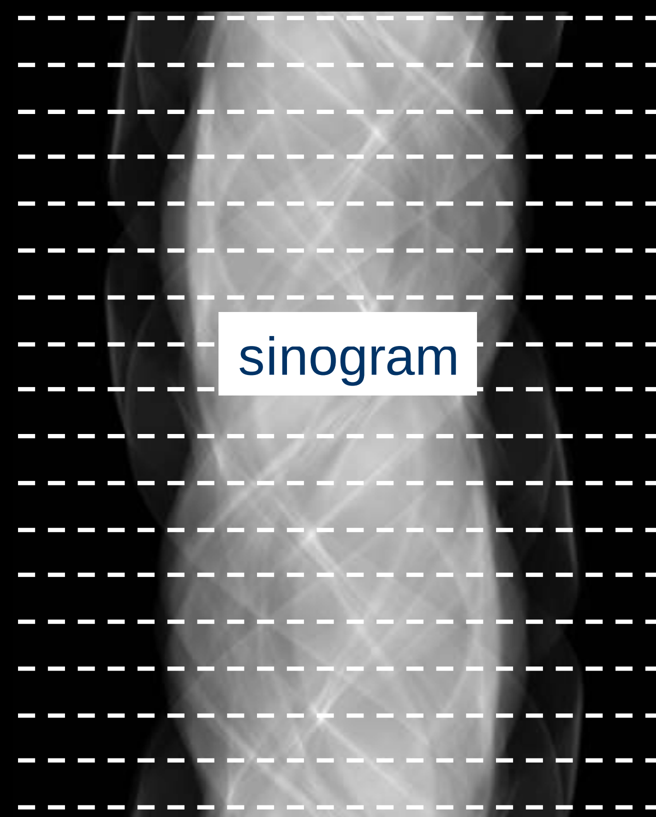
# *Molecular Imaging: sensitivity vs resolution*



# Principles of x-ray CT scanning





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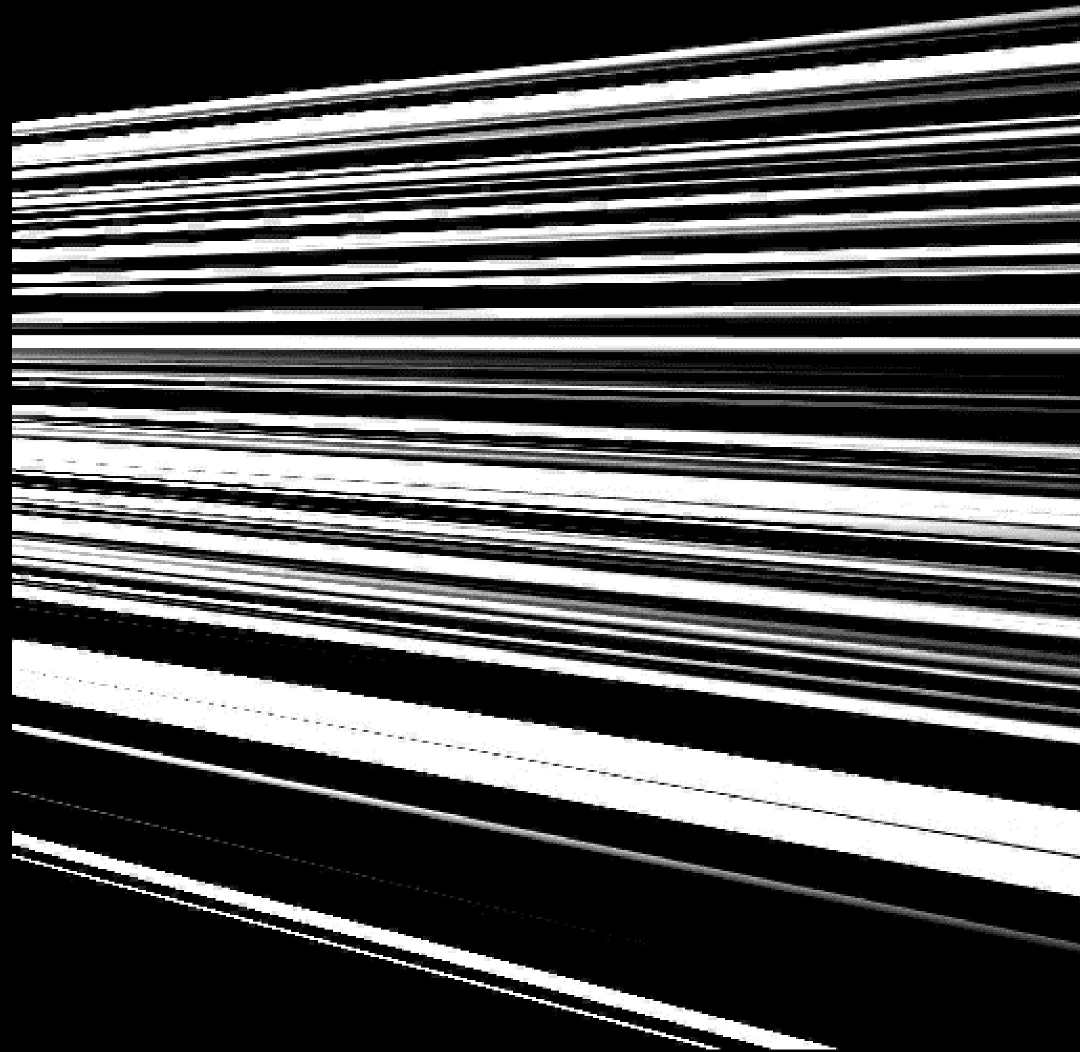
# *Image reconstruction from projections*

**Analytic**

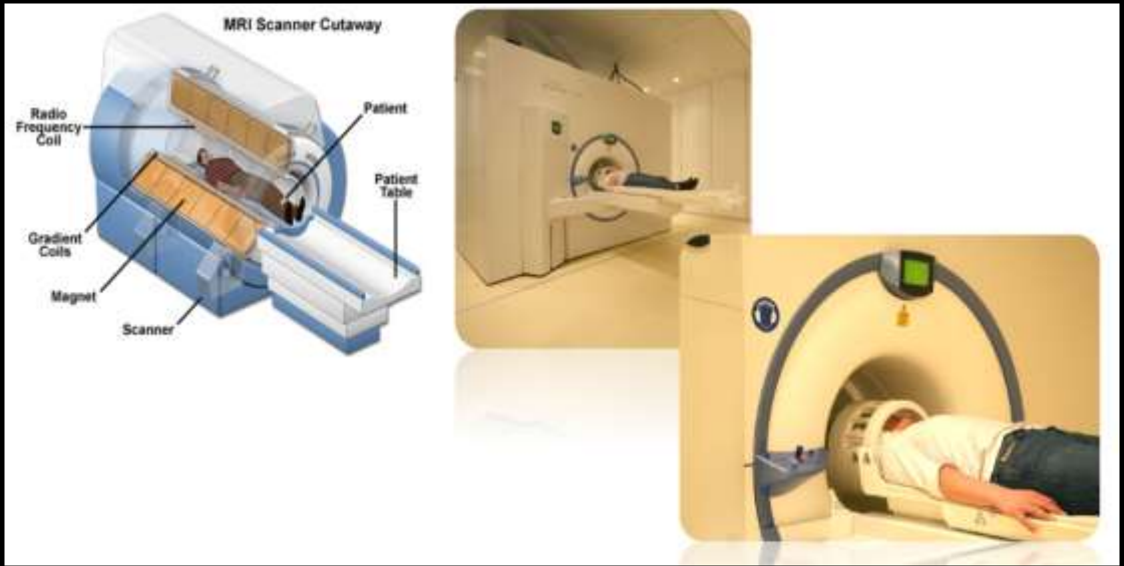
$$f(x,y)=\int_0^{\pi}\mathrm{d}\phi\left[\int_{-\infty}^{+\infty}\mathrm{d}\nu_s\,|\,\nu_s|\,\mathrm{e}^{2\pi\mathrm{i}\nu_s s}\,P_{\phi}(\nu_s)\right]$$

# *Multiparametric brain imaging using MRI*

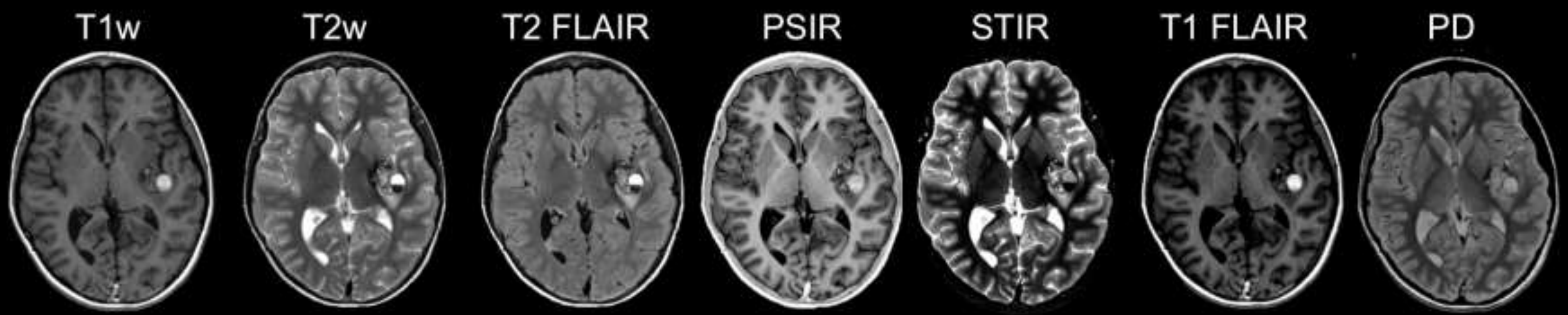
## Magnetic Resonance Imaging

Major ingredients:

- ✓ Nuclear spin
- ✓ Strong external magnetic field
- ✓ Resonance (typically radio-frequency range)
- ✓ Switchable field gradients to encode position

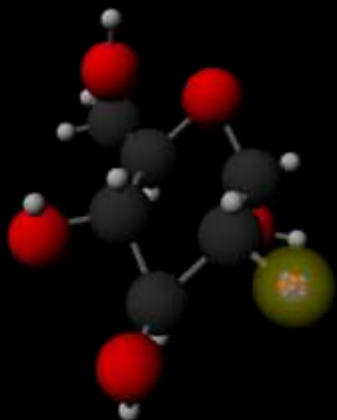



MRI is muliparametric by nature – many different contrasts (sequences) possible

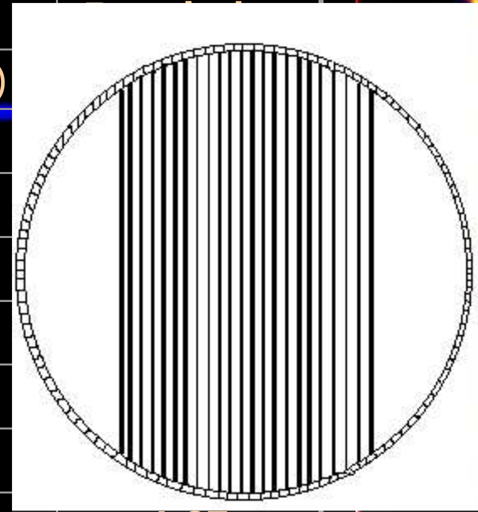


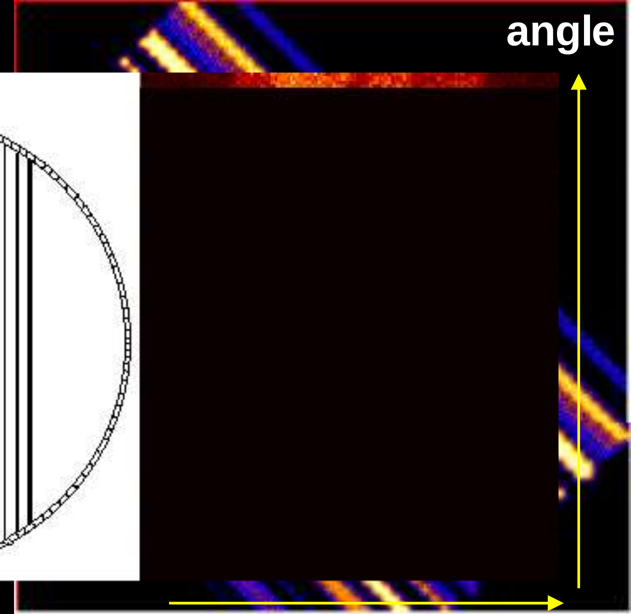
# PET principles

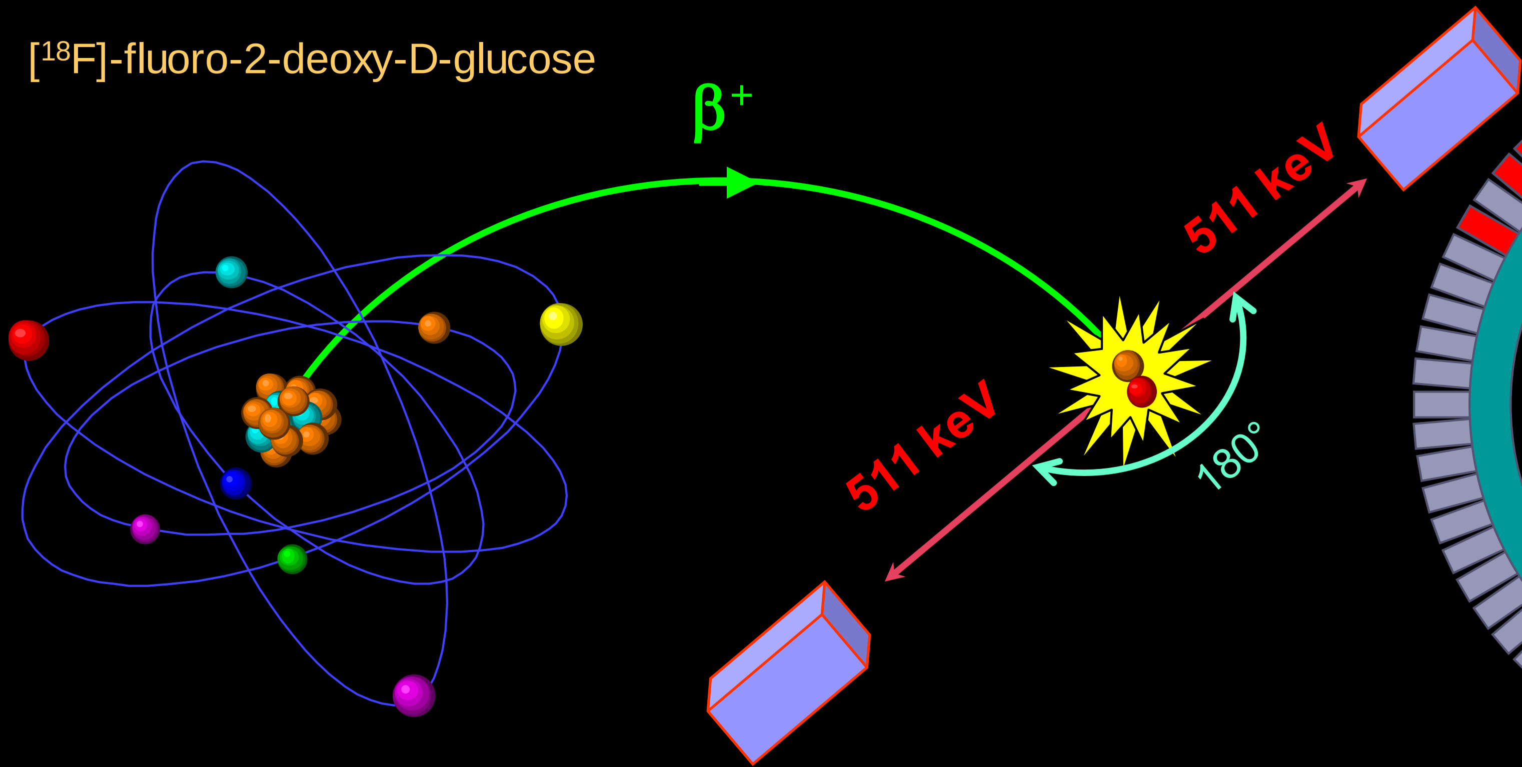
| Isotope | $T_{1/2}$ | $E_{\beta^+}$ (MeV) | |
|---|---|---|---|
| $^{11}C$ | 20 min | 0.96 | |
| $^{13}N$ | 10 min | 1.2 | |
| $^{15}O$ | 122 sec | 1.7 | |
| $^{18}F$ | 110 min | 0.64 | |
| $^{64}Cu$ | 12.8 h | 0.65 | |
| $^{68}Ga$ | 68 min | 1.9 | |
| $^{82}Rb$ | 76 sec | 3.4 | 1.27 |

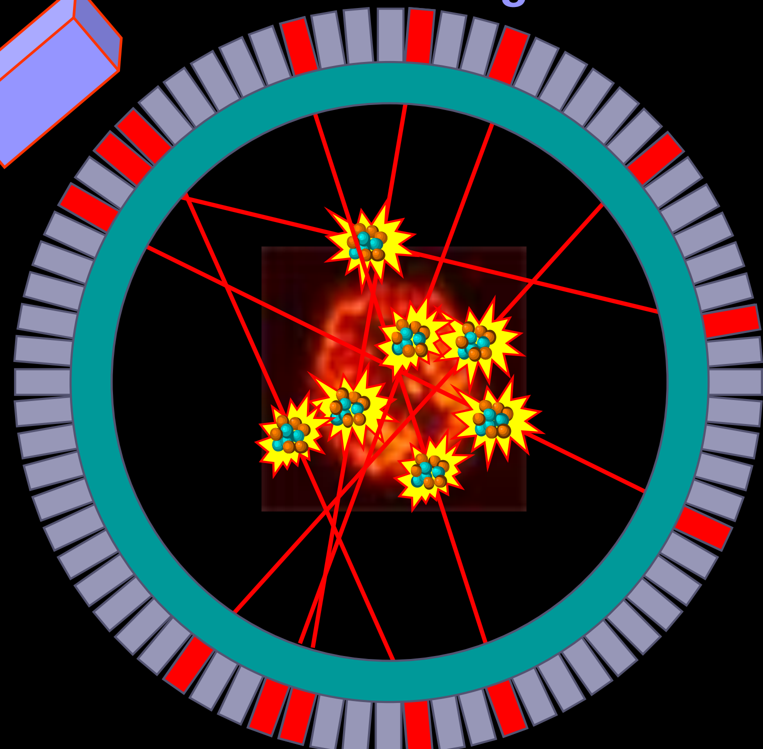


[$^{18}$F]-fluoro-2-deoxy-D-glucose





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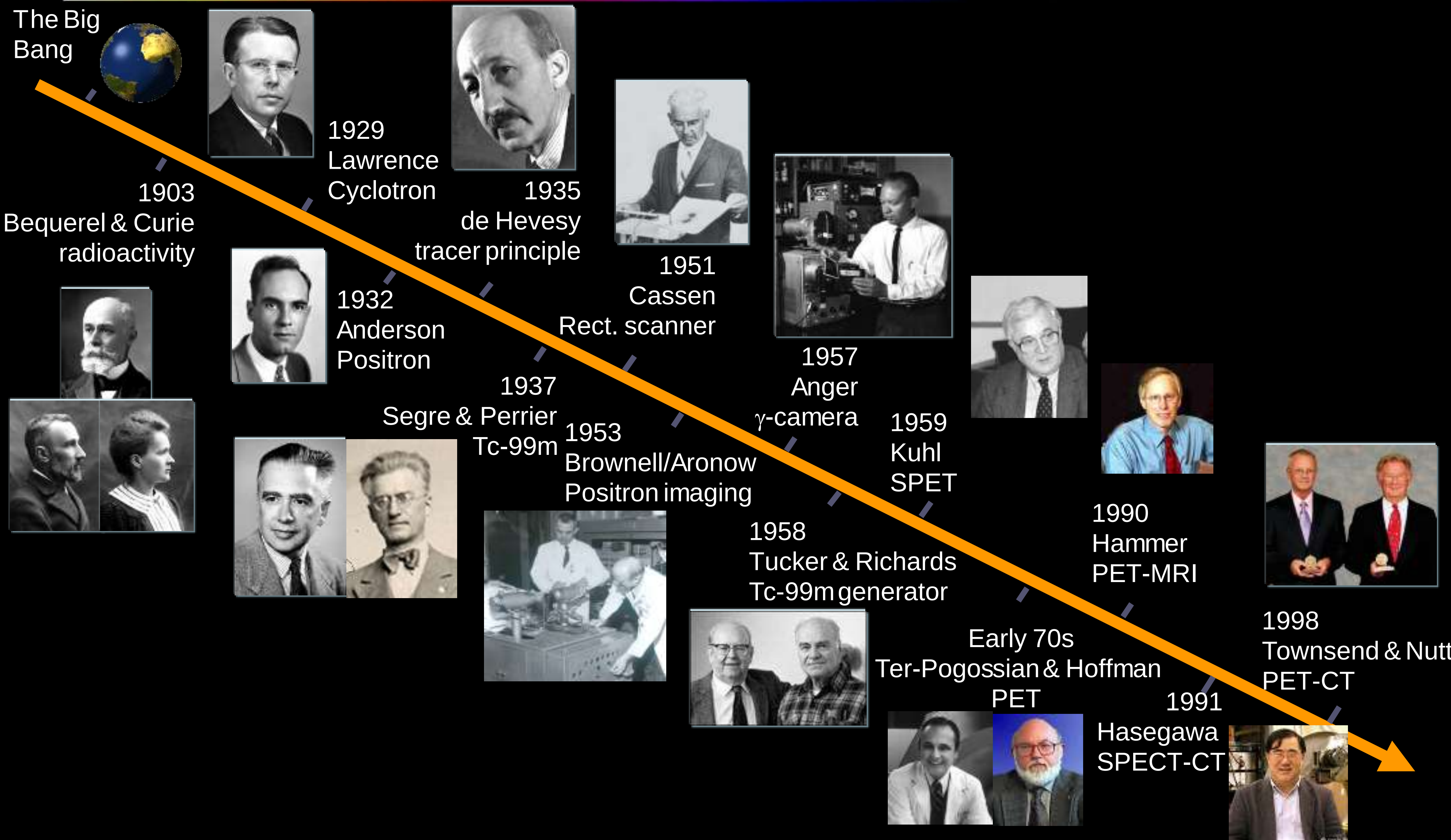
# *Molecular imaging timeline*



# Principles of PET/CT

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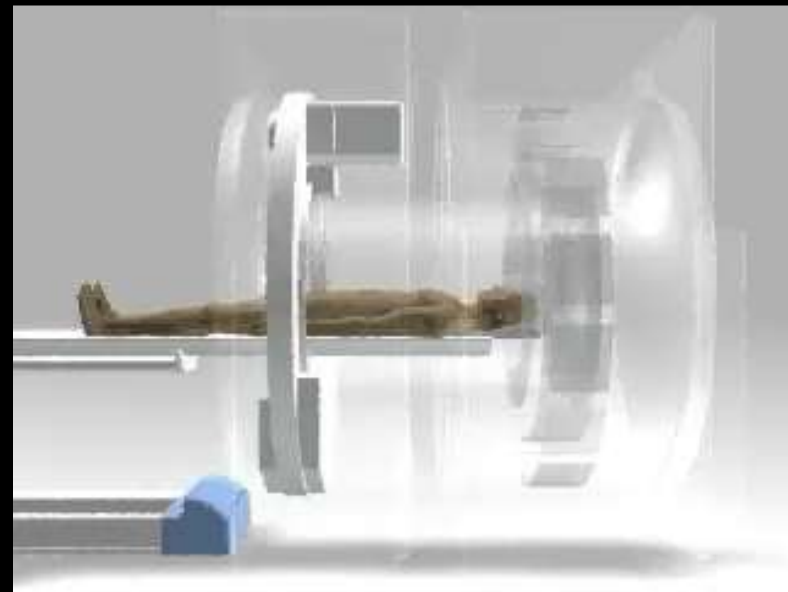
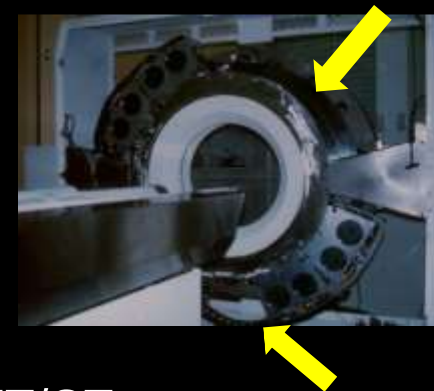
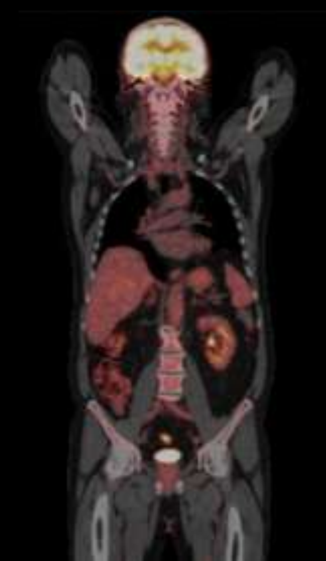




Scout

Spiral CT

PET

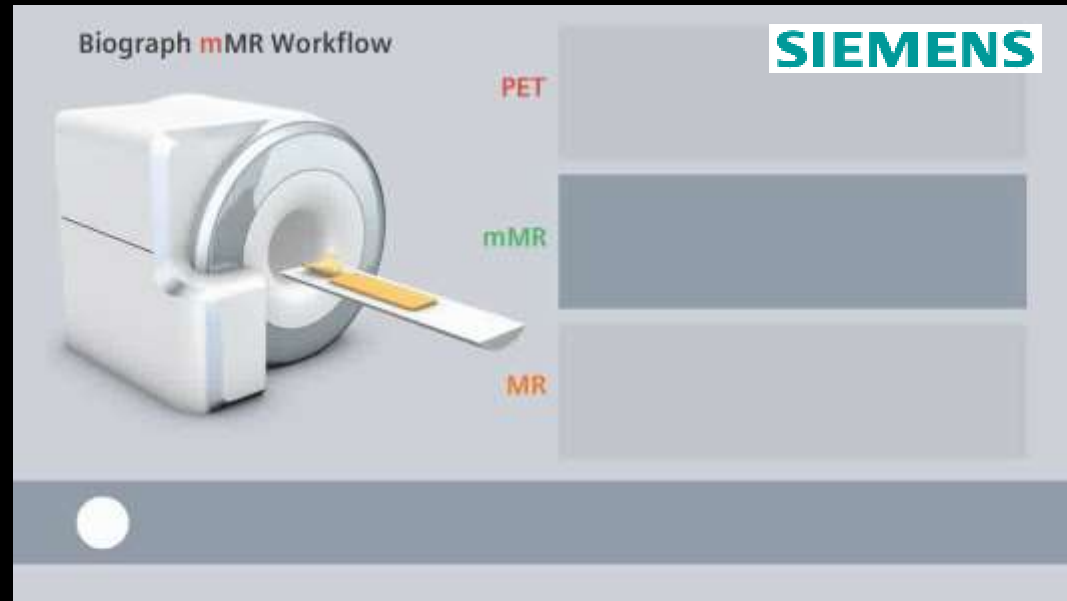


PET/CT

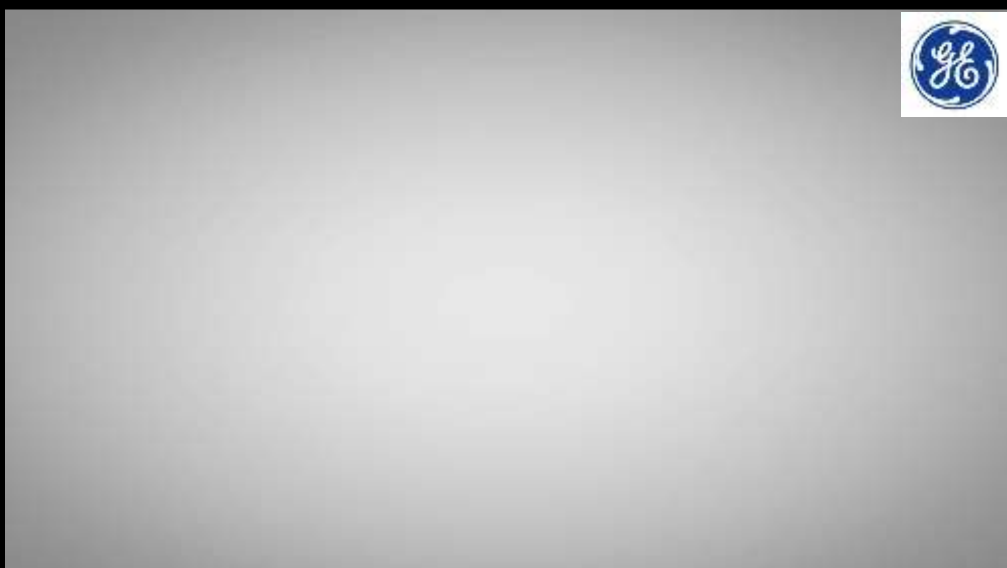
# Commercial whole-body PET/MRI systems

GEMINI TF PET/MR


Biograph mMR




SIGNA PET/MR



uPMR 790 HD TOF PET/MR

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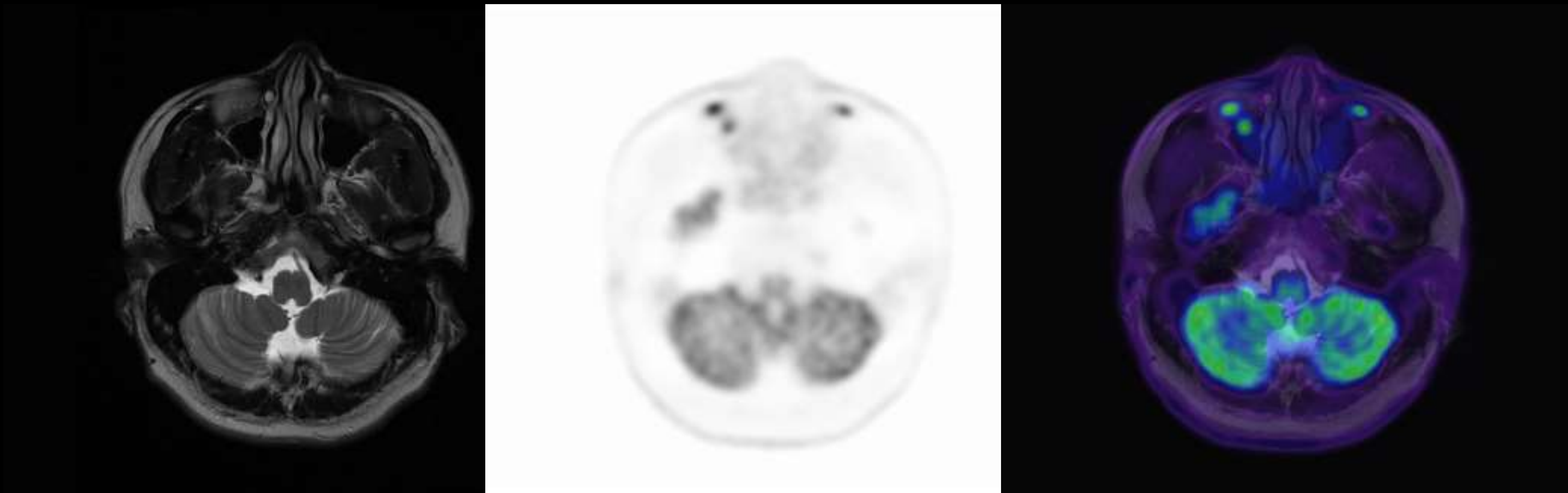
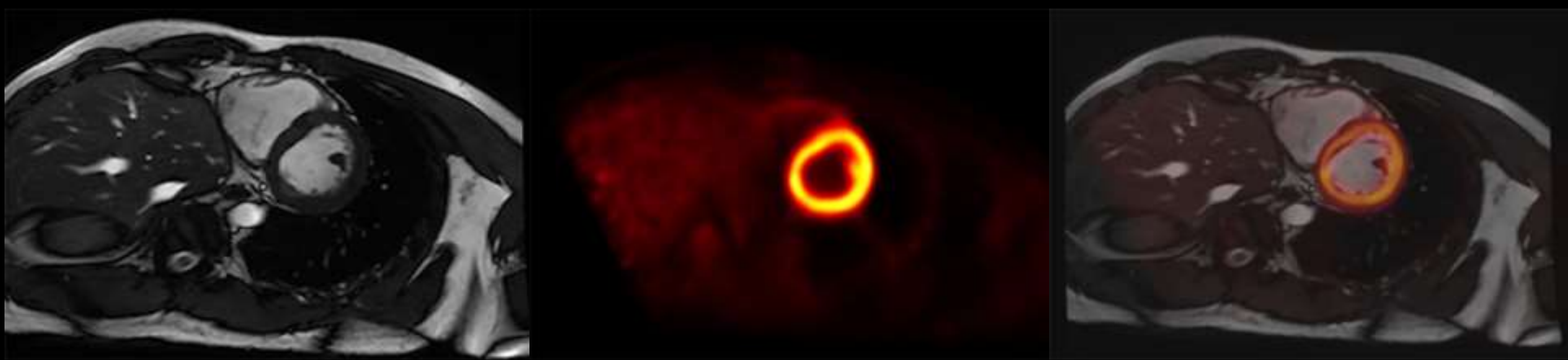
# *Clinical applications of PET/MRI*

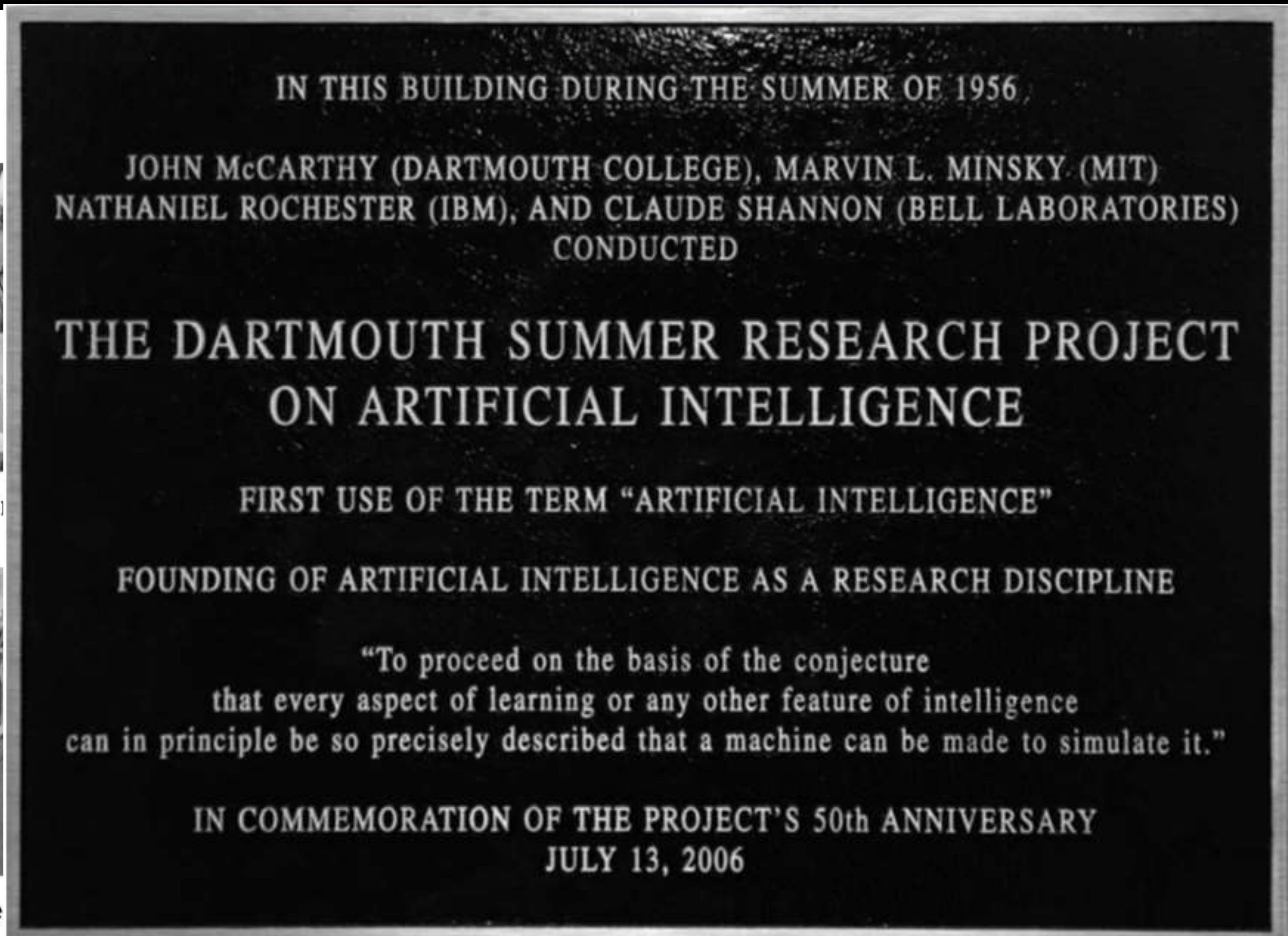


**MRI** **PET** **PET-MRI**



# *Artificial intelligence in medical physics*





# Why do we need AI in medical imaging?

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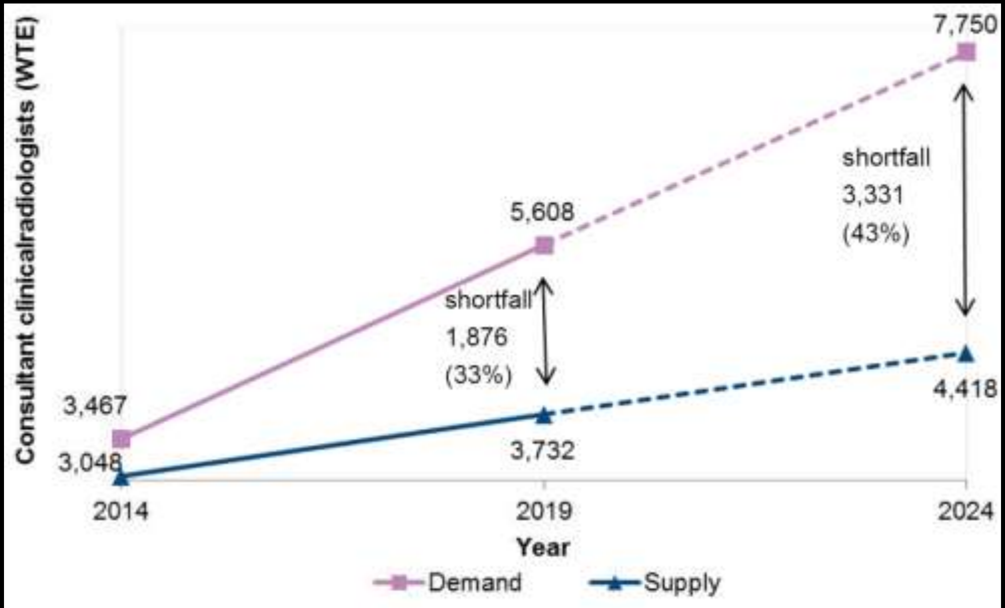
- We are likely to see that many operator-dependent tasks will become increasingly automated to address staff shortages and the increasing demand for medical imaging examinations in an ageing population.

UK consultant radiologist supply and demand



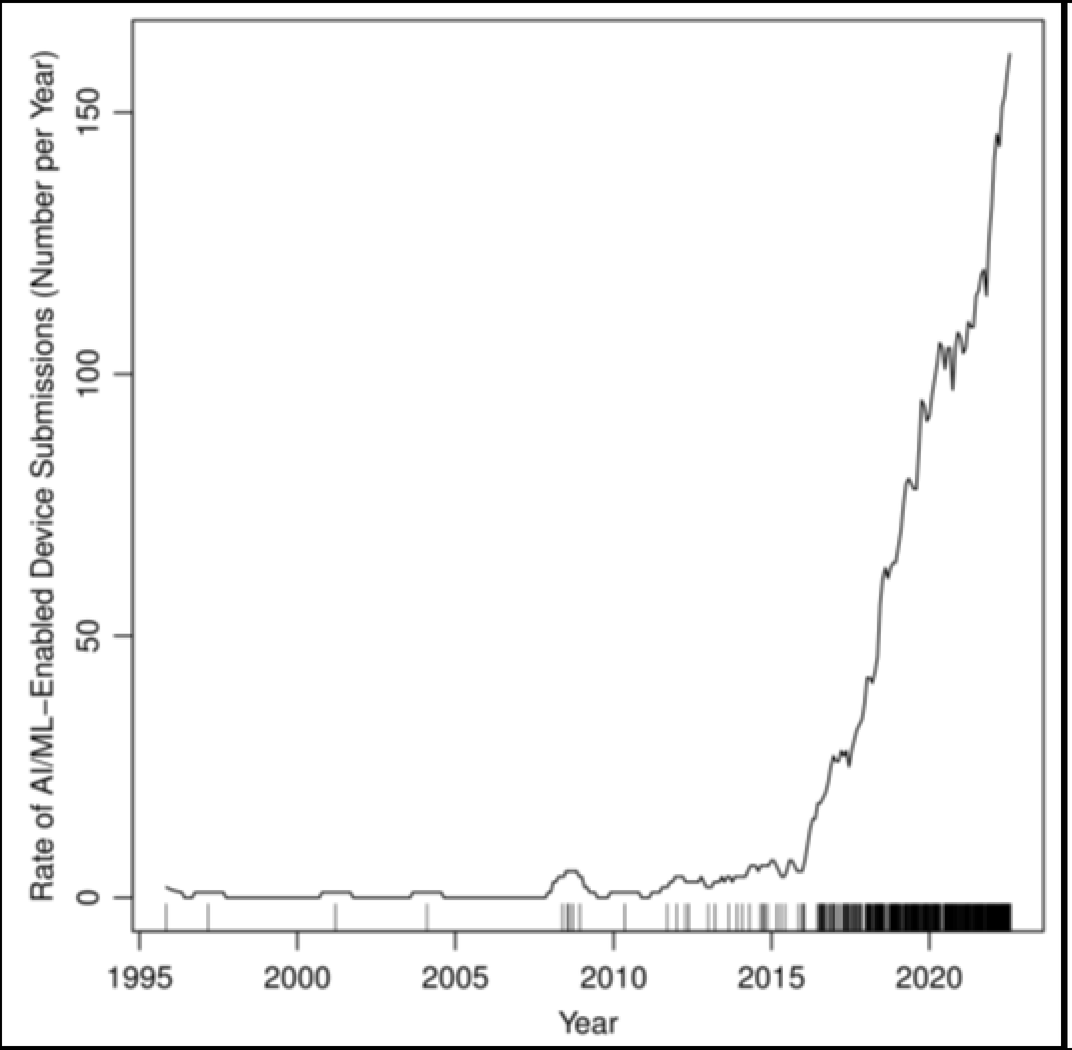

Clinical Radioiogy, UK workforce census 2019 report

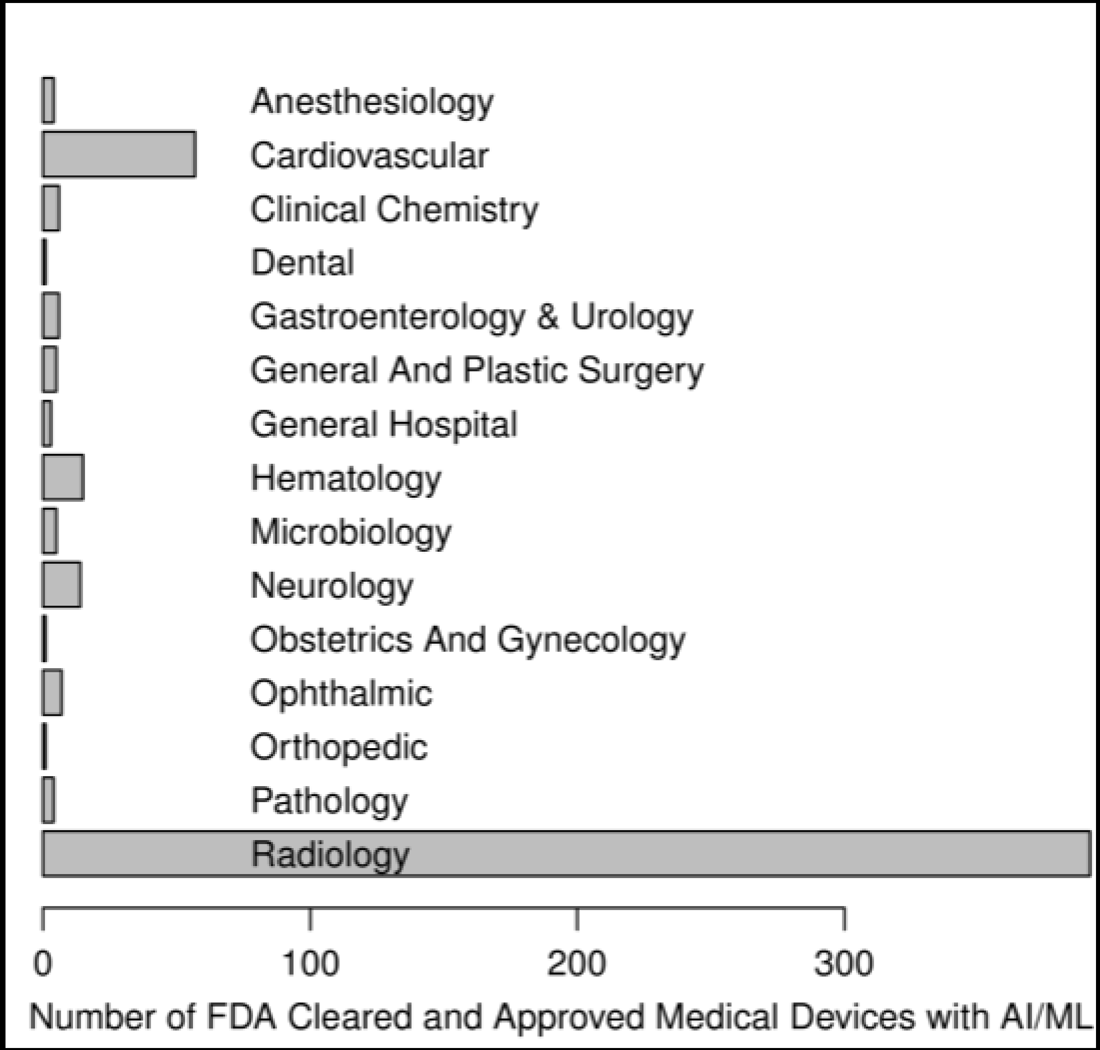
*Closing the gap*

- Increasingly automated diagnosis of routine cases supported by clinical support systems
- Radiologists focus on difficult cases
- Radiologists not only provide reports but are involved in clinical decision-making or provide clinical decisions

# AI/ML/CAD devices by FDA's product areas

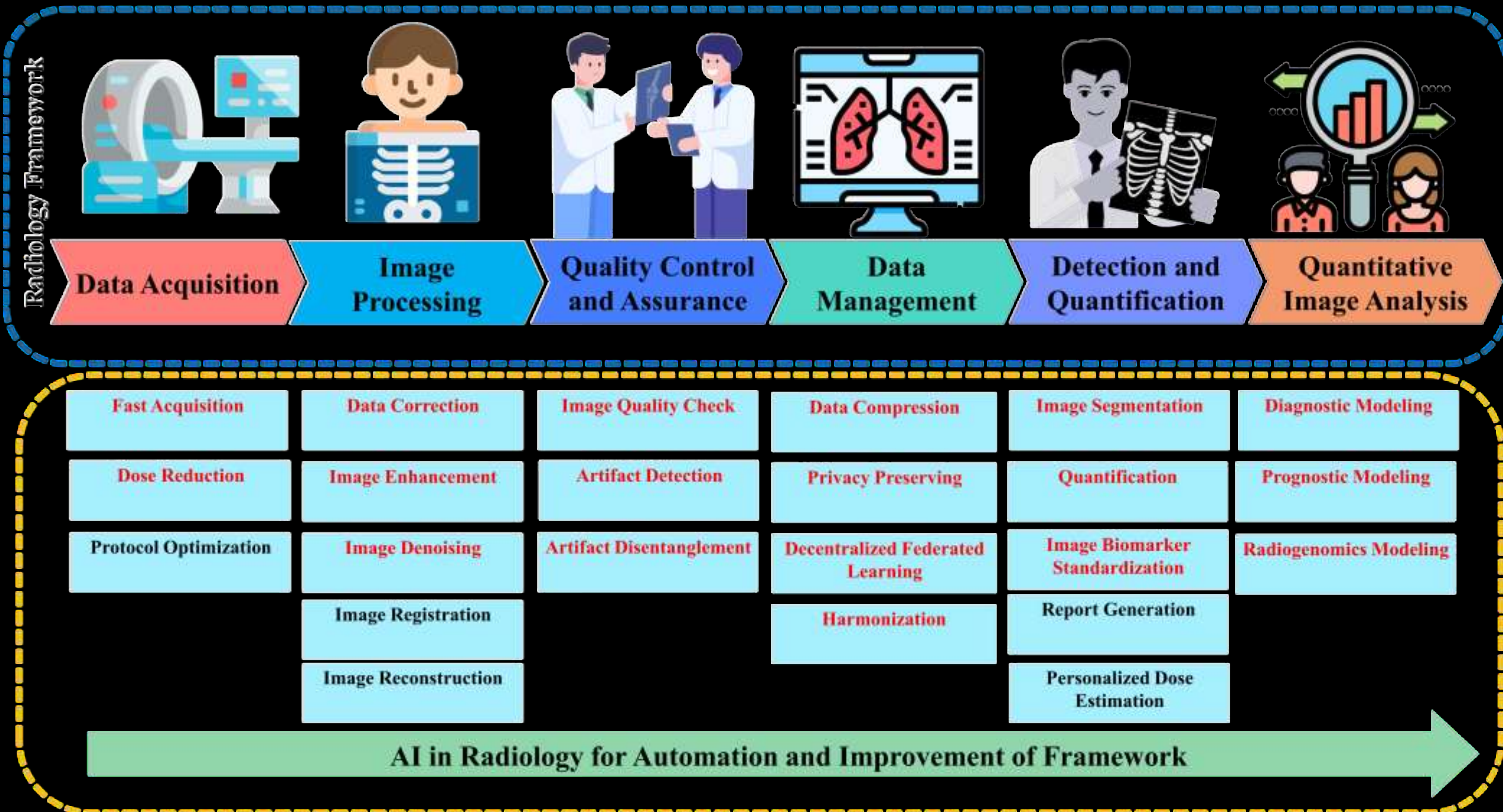
Hôpitaux Universitaires Genève




https://www.fda.gov/medical-devices/software-medical-device-samd/artificial-intelligence-and-machine-learning-aiml-enabled-medical-devices

# *Artificial intelligence impacting radiology*



# Comparative study of algorithms for synthetic CT generation from MRI: Consequences for MRI-guided radiation planning in the pelvic region

Hôpitaux Universitaires Genève

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*Geneva University Neurocenter University of Geneva, Geneva 1205, Switzerland*
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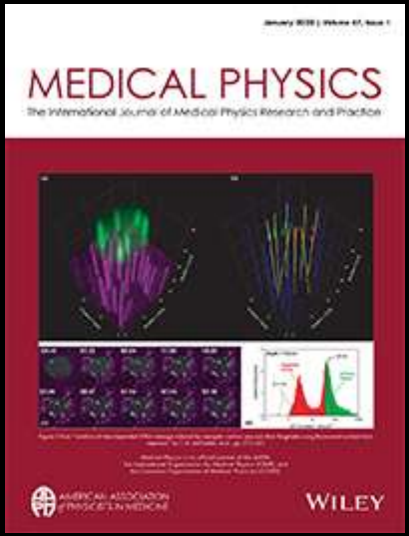
(Received 7 June 2018; revised 29 July 2018; accepted for publication 6 September 2018; published xx xxxx xxxx)

**Purpose:** Magnetic resonance imaging (MRI)-guided radiation therapy (RT) treatment planning is limited by the fact that the electron density distribution required for dose calculation is not readily provided by MR imaging. We compare a selection of novel synthetic CT generation algorithms recently reported in the literature, including segmentation-based, atlas-based and machine learning techniques, using the same cohort of patients and quantitative evaluation metrics.
**Methods:** Six MRI-guided synthetic CT generation algorithms were evaluated: one segmentation technique into a single tissue class (water-only), four atlas-based techniques, namely, median value of atlas images (ALMedian)[1], atlas-based local weighted voting (ALWV)[2], bone enhanced atlas-based local weighted voting (ALWV-Bone)[3], iterative atlas-based local weighted voting (ALWV-Iter)[4], and a machine learning technique using deep convolution neural network (DCNN)[5].
**Results:** Organ auto-contouring from MR images was evaluated for bladder, rectum, bones, and body boundary. Overall, DCNN exhibited higher segmentation accuracy resulting in Dice indices (DSC) of 0.93 ± 0.17, 0.90 ± 0.04, and 0.93 ± 0.02 for bladder, rectum, and bones, respectively. On the other hand, ALMedian showed the lowest accuracy with DSC of 0.82 ± 0.20, 0.81 ± 0.08, and 0.88 ± 0.04, respectively. DCNN reached the best performance in terms of accurate derivation




Arabi et al. *Med Phys* (2018)

# Deep learning-guided estimation of DOI

Hôpitaux Universitaires Genève

applied sciences

MDPI

*Article*

## Depth of Interaction Estimation in a Preclinical PET Scanner Equipped with Monolithic Crystals Coupled to SiPMs Using a Deep Neural Network

**Amirhossein Sanaat [1] and Habib Zaidi [1,2,3,4,*]**

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[2] Geneva University Neurocenter, Geneva University, 1205 Geneva, Switzerland

[3] Department of Nuclear Medicine and Molecular Imaging, University of Groningen, University Medical Center Groningen, 9700 RB Groningen, The Netherlands

[4] Department of Nuclear Medicine, University of Southern Denmark, DK-500 Odense, Denmark

* Correspondence: habib.zaidi@hcuge.ch; Tel.: +41-22-372-7258; Fax: +41-22-372-7169

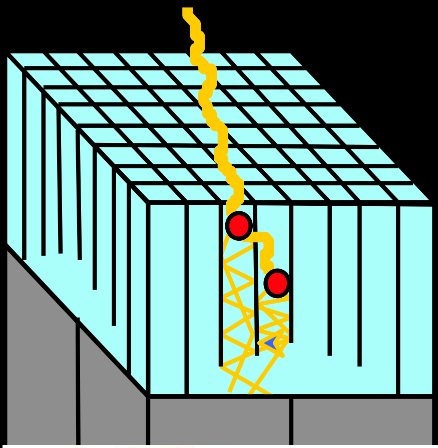
Received: 6 June 2020; Accepted: 8 July 2020; Published: 10 July 2020

Sanaat and Zaidi (2020) *Appl Sci*

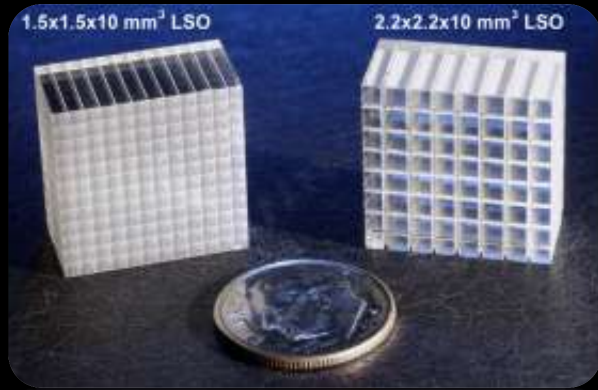
# Deep learning-guided estimation of DOI

Hôpitaux Universitaires Genève

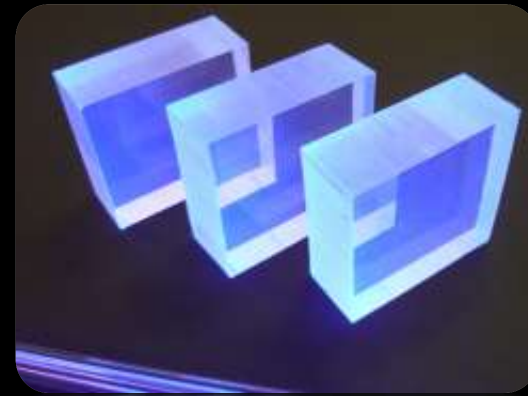
511 keV

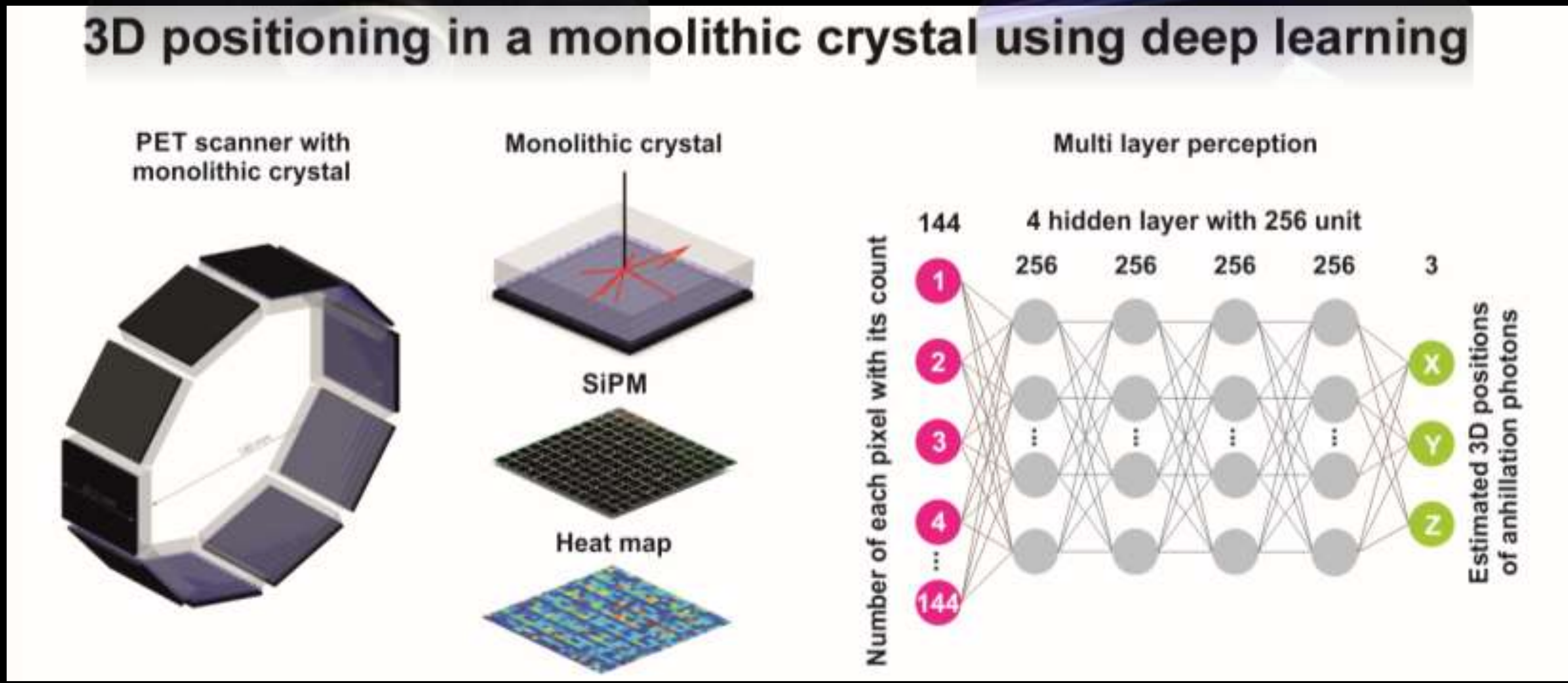


## Pixelated crystals



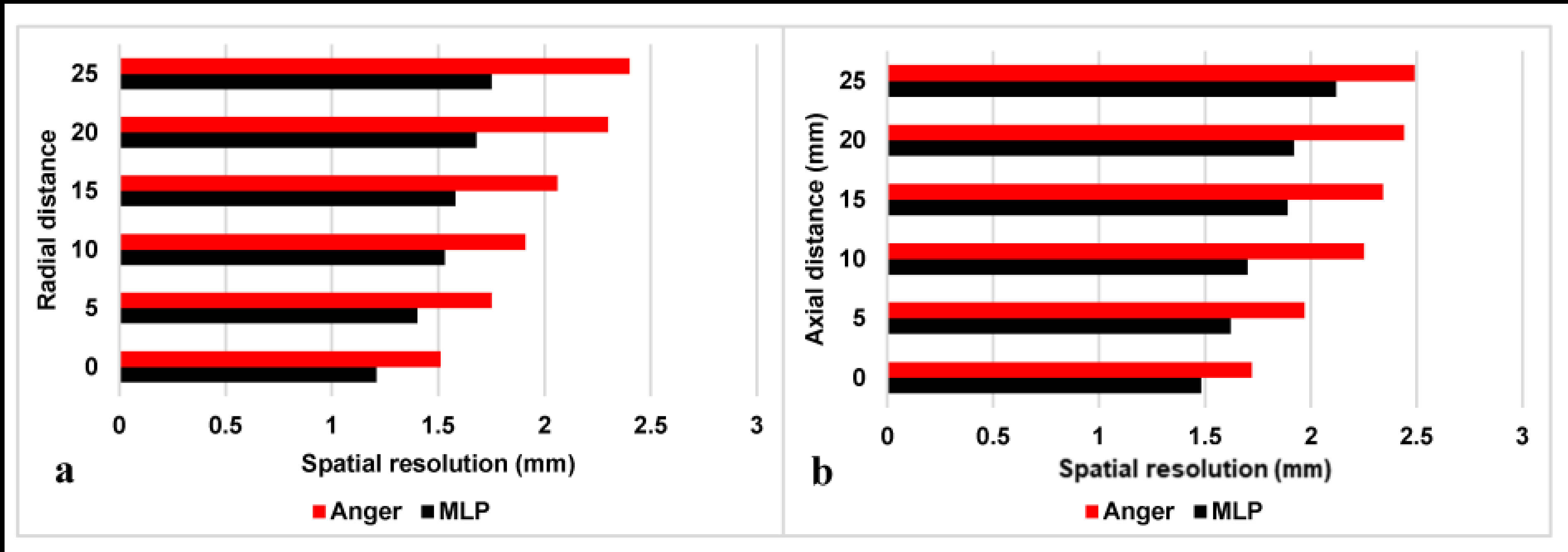

## Monolithic crystal



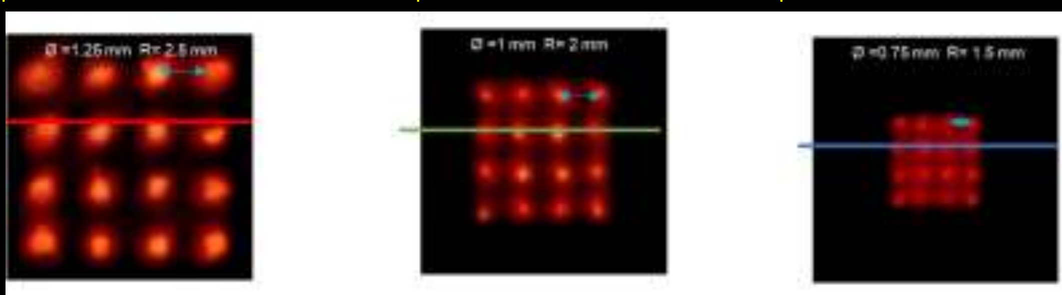

Sanaat and Zaidi (2020) *Appl Sci*

# Deep learning-guided estimation of DOI



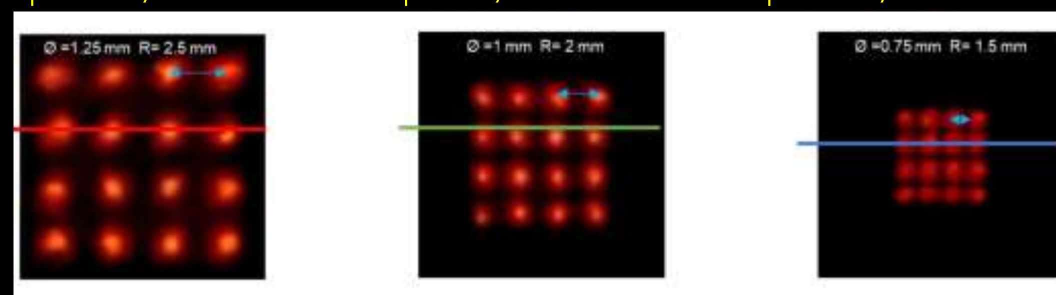

## Anger

ϕ=1.25, d=2.5 mm ϕ=1.0, d=2.0 mm ϕ=0.75, d=1.5 mm




## MLP

ϕ=1.25, d=2.5 mm ϕ=1.0, d=2.0 mm ϕ=0.75, d=1.5 mm




Sanaat and Zaidi (2020) *Appl Sci*

# Generation of TOF-PET from non TOF-PET

Hôpitaux Universitaires Genève

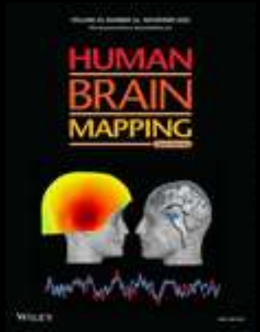
Received: 11 August 2022 | Accepted: 18 August 2022
DOI: 10.1002/hbm.26068

RESEARCH ARTICLE

WILEY

## Deep-TOF-PET: Deep learning-guided generation of time-of-flight from non-TOF brain PET images in the image and projection domains

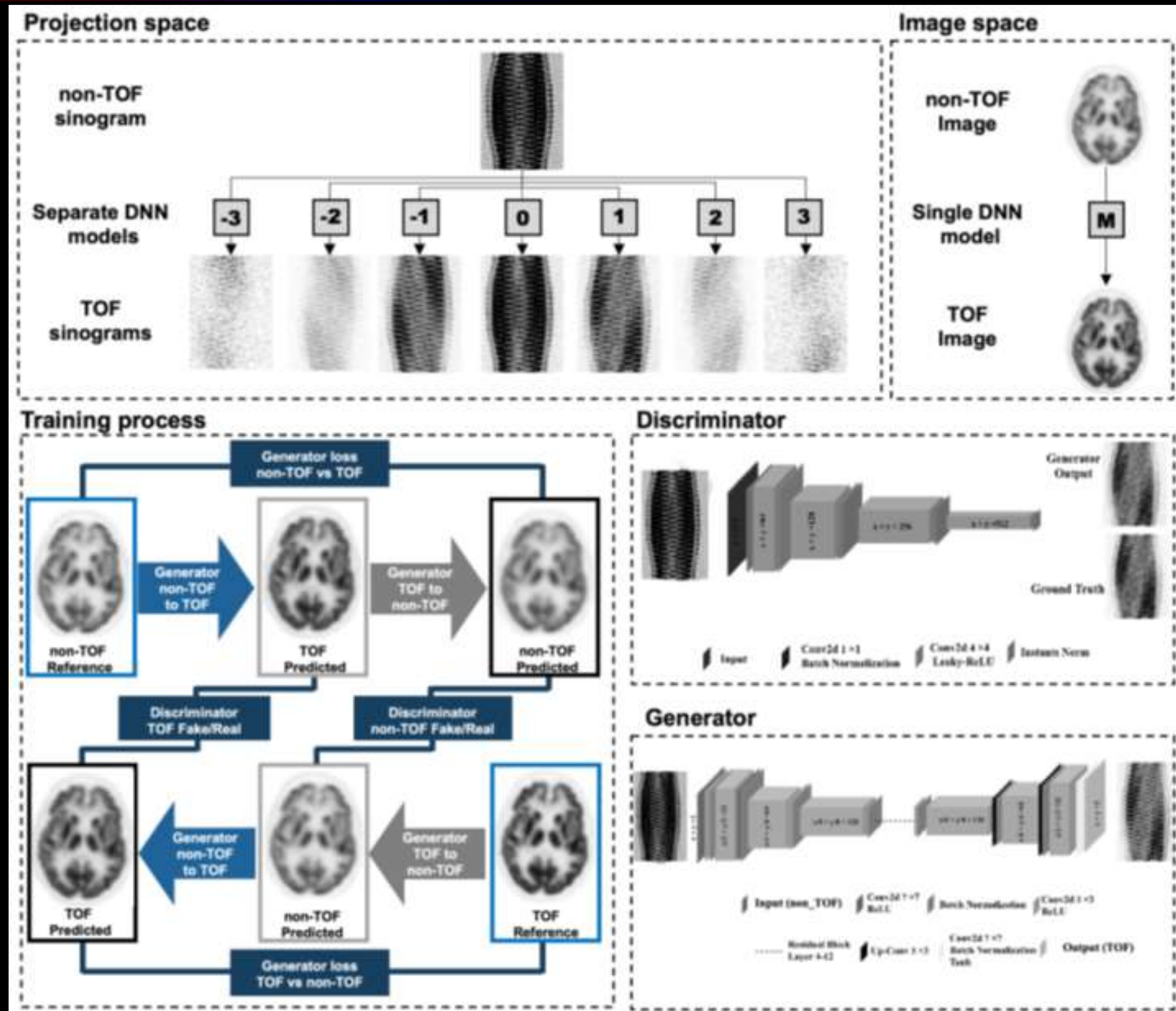
Amirhossein Sanaat[1] | Azadeh Akhavanalaf[1] | Isaac Shiri[1] | Yazdan Salimi[1] | Hossein Arabi[1] | Habib Zaidi[1,2,3,4]




Sanaat et al. (2022) *Hum Brain Mapping*

# Generation of TOF-PET from non-TOF-PET

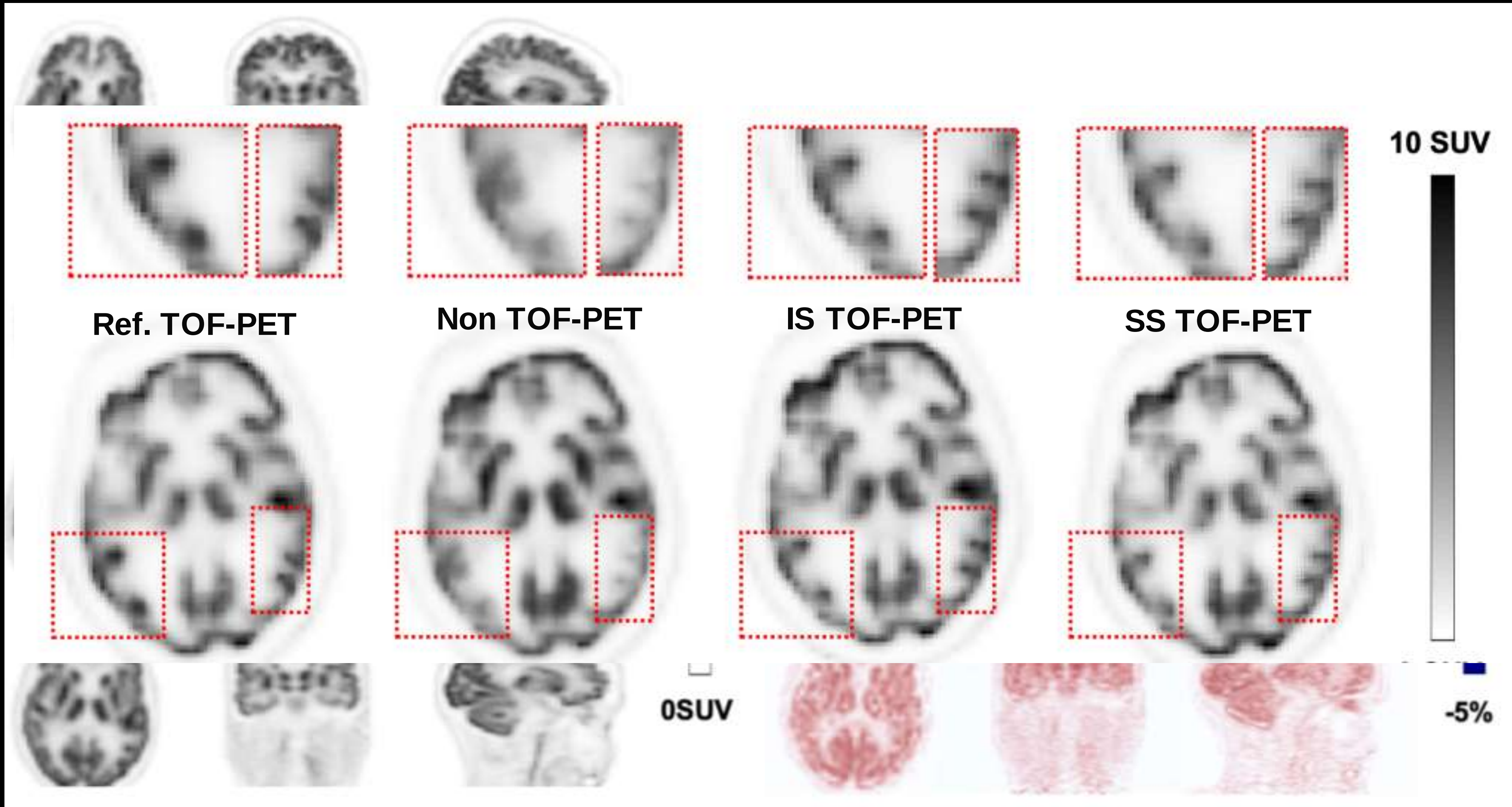
Hôpitaux Universitaires Genève




Sanaat et al. (2022) *Hum Brain Mapping*

Hôpitaux Universitaires Genève

# Generation of TOF-PET from non TOF-PET




Ref. TOF-PET
Non TOF-PET
IS TOF-PET
SS TOF-PET

Sanaat et al. (2022) *Hum Brain Mapping*

# Deep learning-guided low-dose CT imaging

Hôpitaux Universitaires Genève

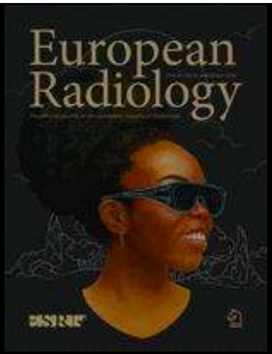
European Radiology (2021) 31:1420–1431
https://doi.org/10.1007/s00330-020-07225-6

COMPUTED TOMOGRAPHY

## Ultra-low-dose chest CT imaging of COVID-19 patients using a deep residual neural network

Isaac Shiri[1] • Azadeh Akhavanallaf[1] • Amirhossein Sanaat[1] • Yazdan Salimi[1] • Dariush Askari[2] • Zahra Mansouri[3] • Sajad P. Shayesteh[4] • Mohammad Hasanian[5] • Kiara Rezaei-Kalantari[6] • Ali Salahshour[7] • Saleh Sandoughdaran[8] • Hamid Abdollahi[9] • Hossein Arabi[1] • Habib Zaidi[1,10,11,12]

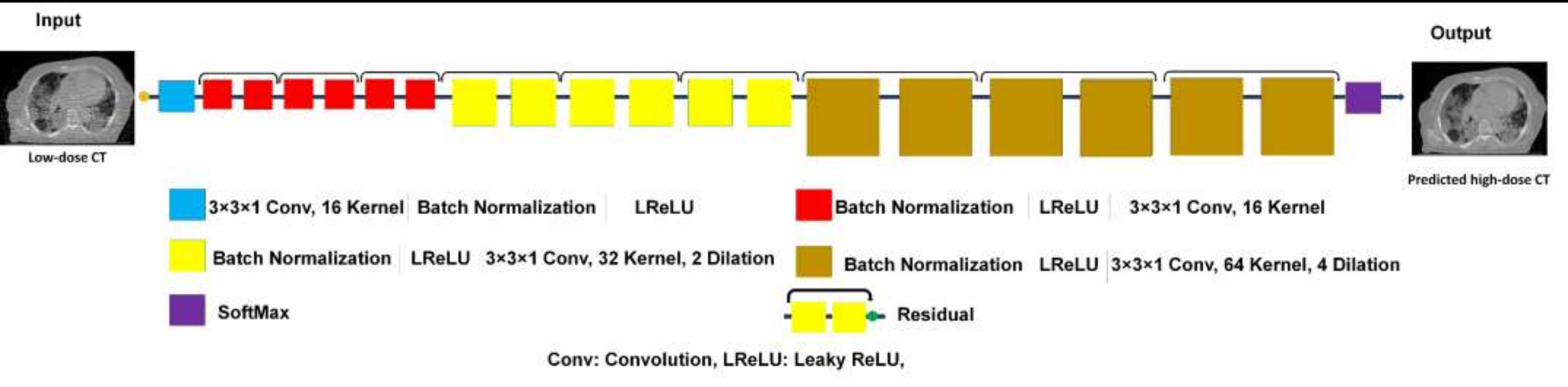
Received: 9 June 2020 / Revised: 13 August 2020 / Accepted: 21 August 2020 / Published online: 3 September 2020


Shiri et al. (2021) *Eur Radiol*

# Deep learning-guided low-dose CT imaging

Hôpitaux Universitaires Genève



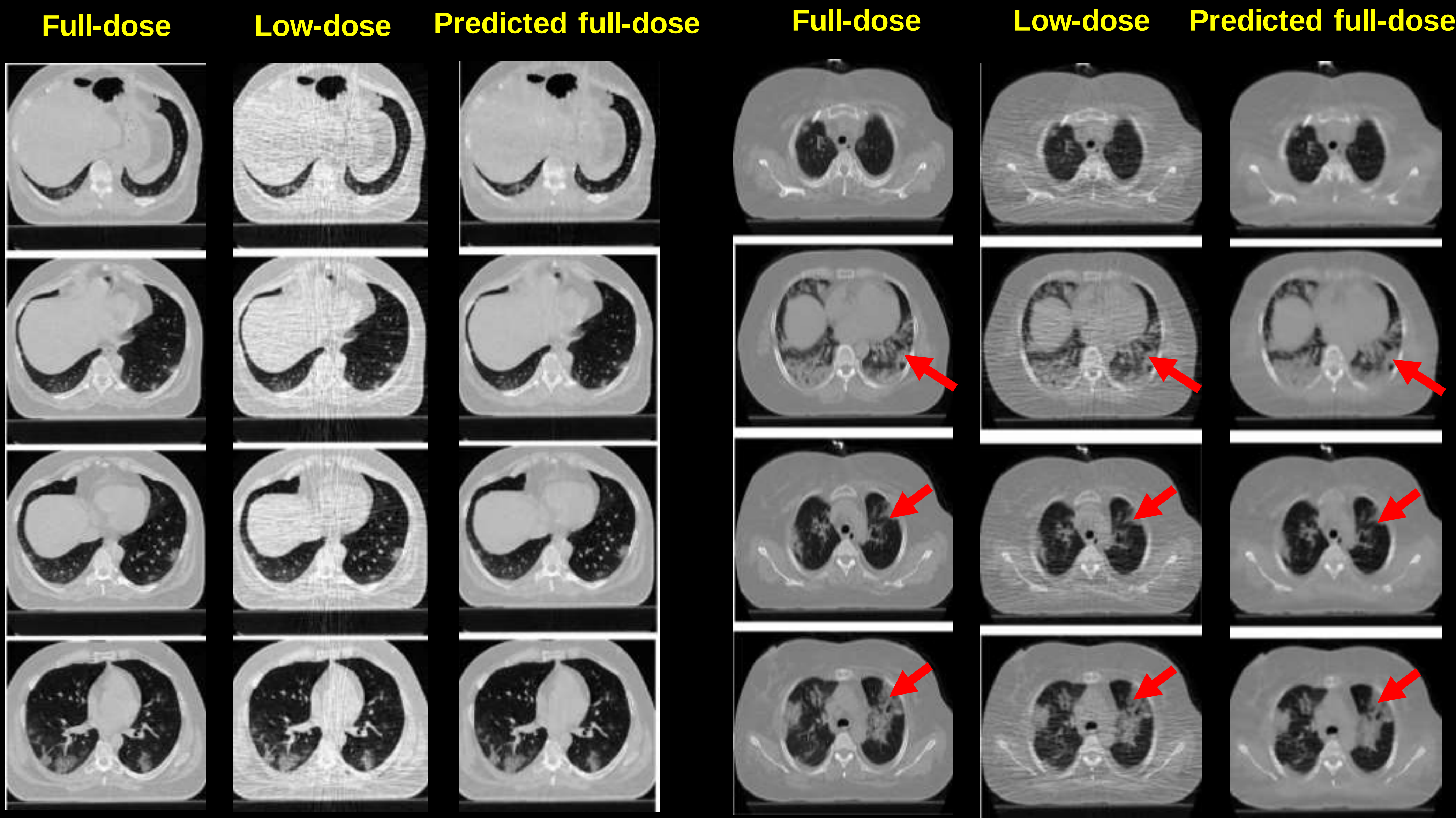

Acquisition parameters of full-dose and low-dose chest CT protocols of COVID-19 patients.

| Parameters | Full-dose CT | Low-dose CT |
|---|---|---|
| $CTDI_{vol}$ (mGy) | 6.5 (4.16-10.5) | 0.72 (0.66-1.03) |
| Voltage (kVp) | 100-120 | 90 |
| Tube current (mA) | 100-150 | 20-45 |
| Pitch factor | 1.3-1.8 | 0.75 |

Shiri et al. (2021) *Eur Radiol*

# Deep learning-guided low-dose CT imaging

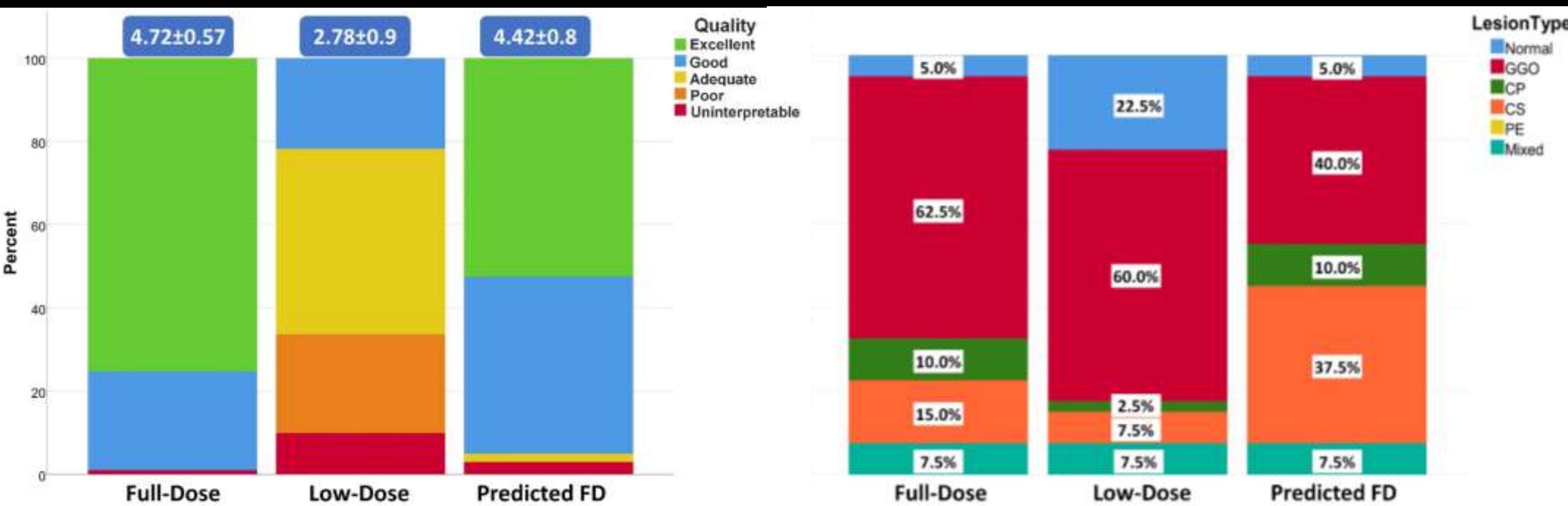
Hôpitaux Universitaires Genève




Shiri et al. (2021) *Eur Radiol*

# *Deep learning-guided low-dose CT imaging*

Hôpitaux Universitaires Genève




1 → unintepretable 2 → poor 3 → adequate 4 → good 5 → excellent

Shiri et al. (2021) *Eur Radiol*

# DL-based segmentation of COVID-19 lesions

Hôpitaux Universitaires Genève

Received: 10 June 2021 | Revised: 18 September 2021 | Accepted: 17 October 2021

DOI: 10.1002/ima.22672

RESEARCH ARTICLE

WILEY

## COLI-Net: Deep learning-assisted fully automated COVID-19 lung and infection pneumonia lesion detection and segmentation from chest computed tomography images

Isaac Shiri[1] | Hossein Arabi[1] | Yazdan Salimi[1] | Amirhossein Sanaat[1] | Azadeh Akhavanallaf[1] | Ghasem Hajianfar[2] | Dariush Askari[3] | Shakiba Moradi[4] | Zahra Mansouri[1] | Masoumeh Pakbin[5] | Saleh Sandoughdaran[6] | Hamid Abdollahi[7] | Amir Reza Radmard[8] | Kiara Rezaei-Kalantari[2] | Mostafa Ghelich Oghli[4,9] | Habib Zaidi[1,10,11,12]

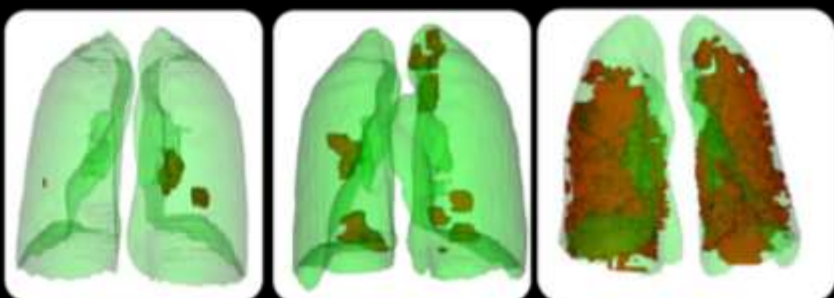


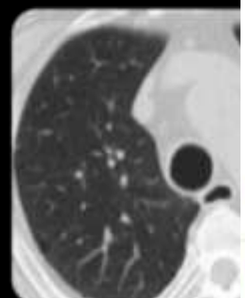
Shiri *et al.* (2022) *Int J Imaging Syst Technol*

# DL-based segmentation of CO

## Clinical routine

Labor intensi
Time-consum





High variability and compl

Shiri *et al*. (2021) *ECR'2021*
Shiri *et al*. (2022) *Int J Imaging Syst Technol*

ECR 2021
MARCH 3–7 VIENNA

POP–UP WORLD TOUR
ONLINE | ON DEMAND

**Isaac Shiri**
(Geneva/CH)

is hereby awarded:

**ECR 2021 – Best Research Presentation Abstract**
within the topic Imaging Informatics & Artificial Intelligence
with the presentation:

Fully automatic COVID-19 lung and pneumonia lesion segmentation from CT images (15797)

I. Shiri1, H. Arabi1, Y. Salimi1, A. Sanaat1, A. Akhavanalaf1, G. Hajianfar2, D. Askari2, K. R. Kalantari2, H. Zaidi1; 1Geneva/CH, 2Tehran/IR

at

**ECR 2021**
**March 3 - 7, 2021**
**Online**

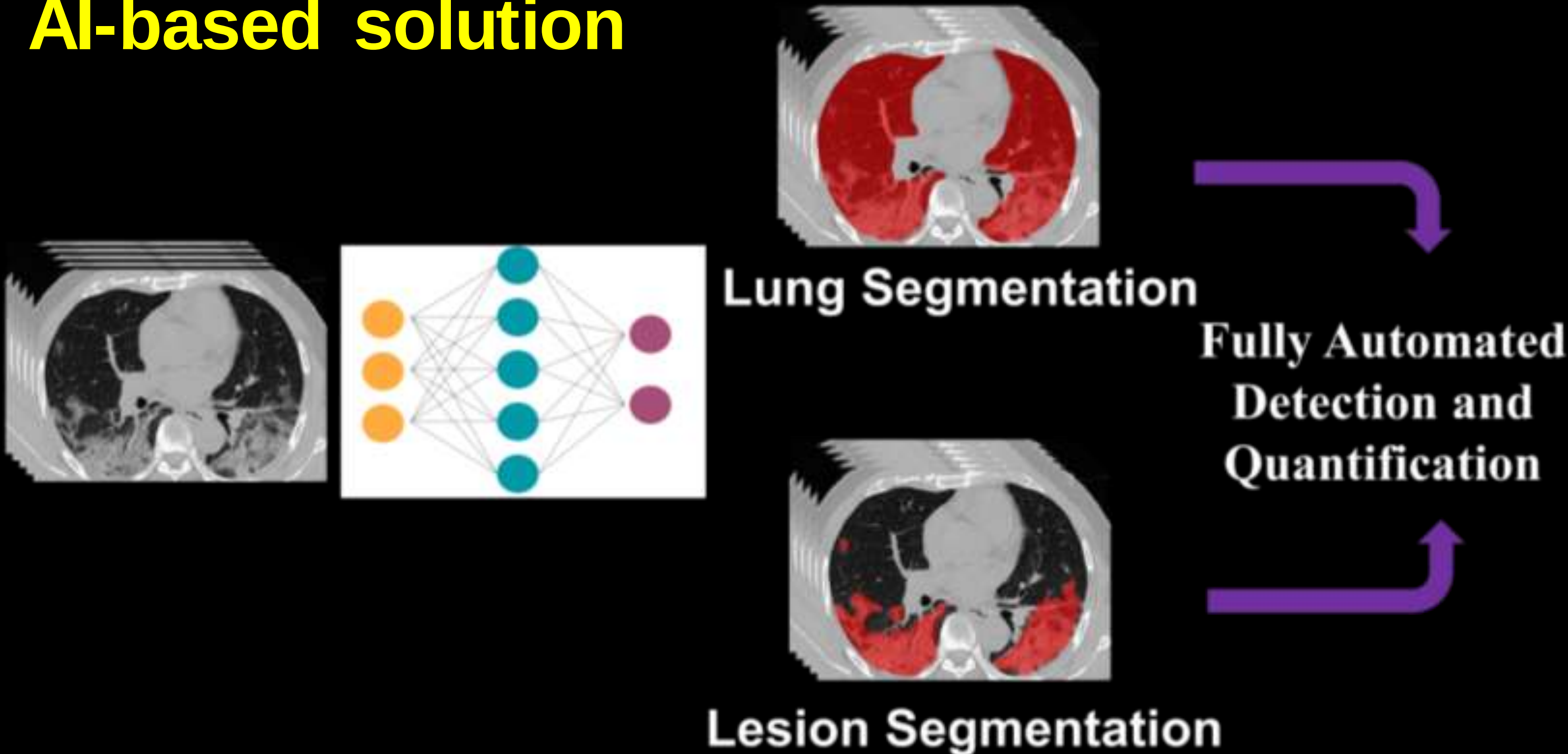
Prof.Dr. Michael H. Fuchsjäger
ESR President

EUROPEAN SOCIETY OF RADIOLOGY

Hôpitaux Universitaires Genève

# *DL-based segmentation of COVID-19 lesions*

## AI-based solution

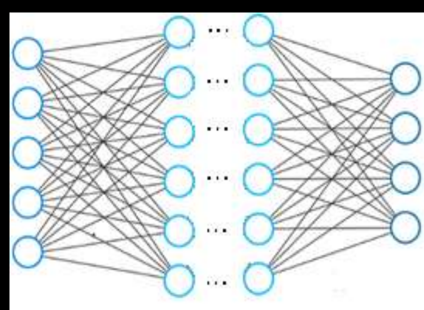



**Pathogens**
- ✓ Mild
- ✓ Moderate
- ✓ Severe

**Centers**
- ✓ USA
- ✓ China
- ✓ Russia
- ✓ Italy
- ✓ Iran

**CT image**

**CNN**

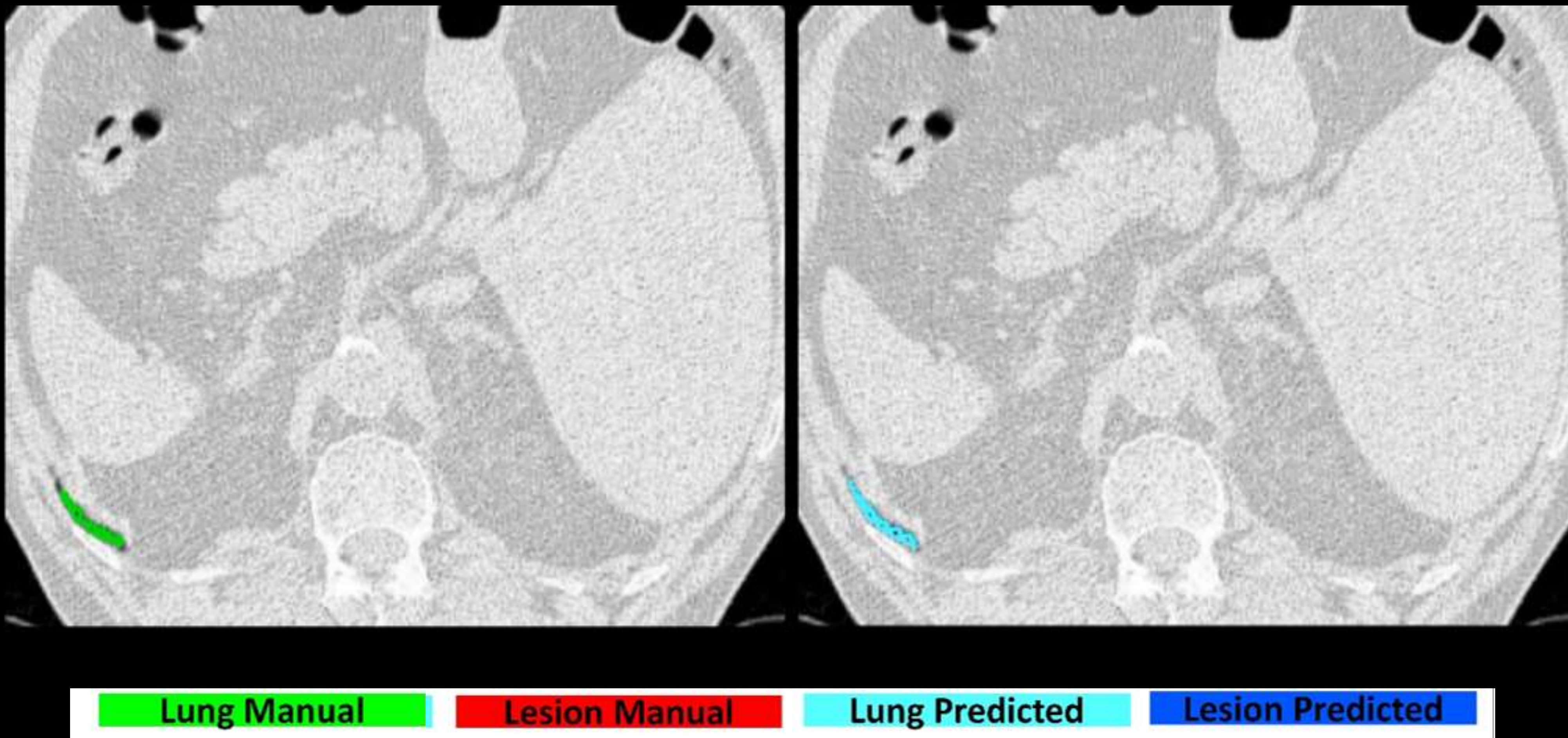


**Segmented lungs/COVID lesions**

Hôpitaux Universitaires Genève

# *DL-based segmentation of COVID-19 lesions*

**Radiologist Segmentation** | **AI Segmentation**

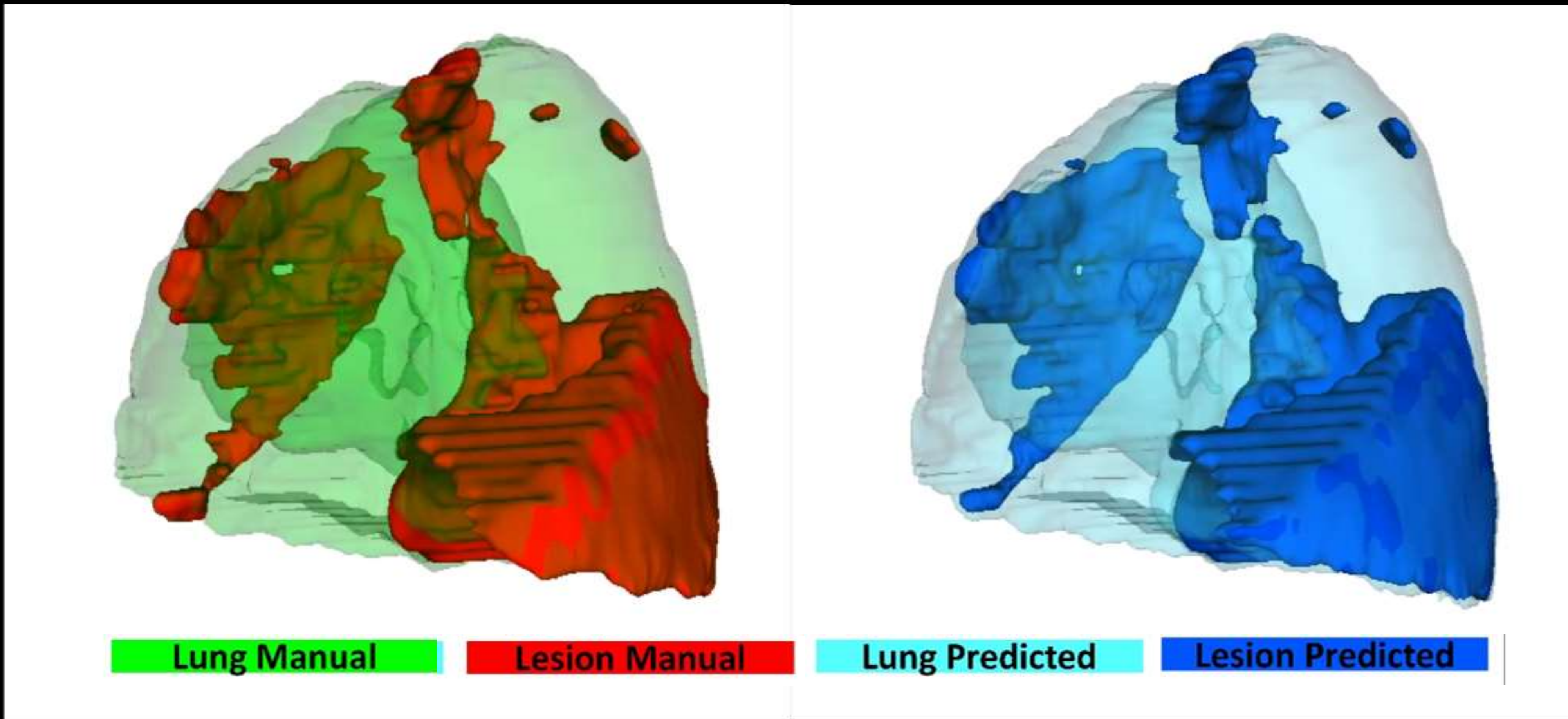



Shiri *et al.* (2022) *Int J Imaging Syst Technol*

# DL-based segmentation of COVID-19 lesions



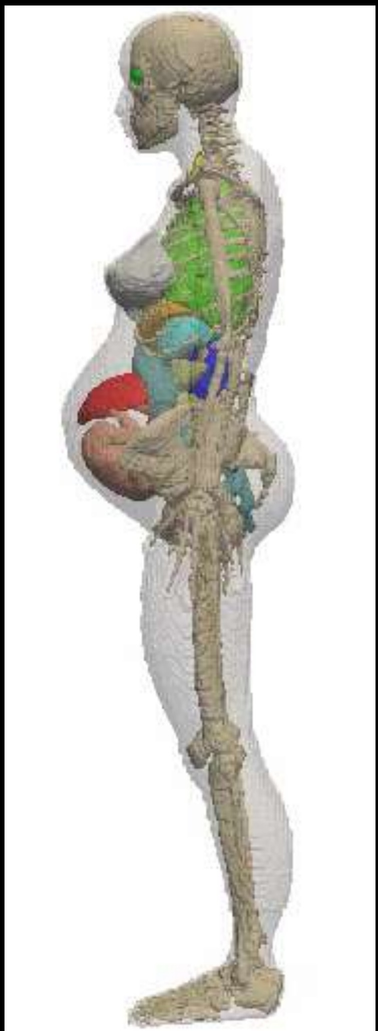
**Radiologist Segmentation** **AI Segmentation**




Shiri *et al.* (2022) *Int J Imaging Syst Technol*

# *Computational pregnant female phantoms*

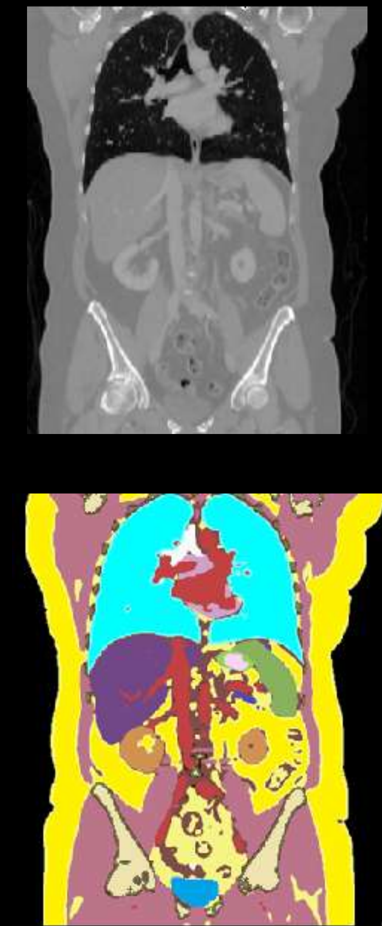
25w-gestation



30w-gestation

Xie and Zaidi *Eur J Nucl Med Mol Imaging* (2016)

Thorax-abdo



Xie et al. (2019) *Med* Phys

Non-human primate

Xie et al. (2020) *Med Phys*

# Automated generation of anatomical models

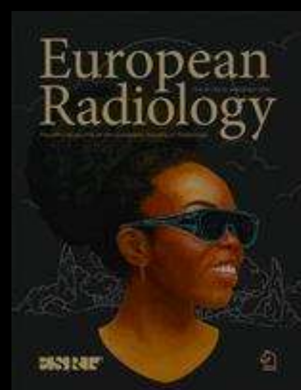
European Radiology (2019) 29:6805–6815
https://doi.org/10.1007/s00330-019-06296-4

PHYSICS

## Estimation of the radiation dose in pregnancy: an automated patient-specific model using convolutional neural networks

Tianwu Xie[1] · Habib Zaidi[1,2,3,4]

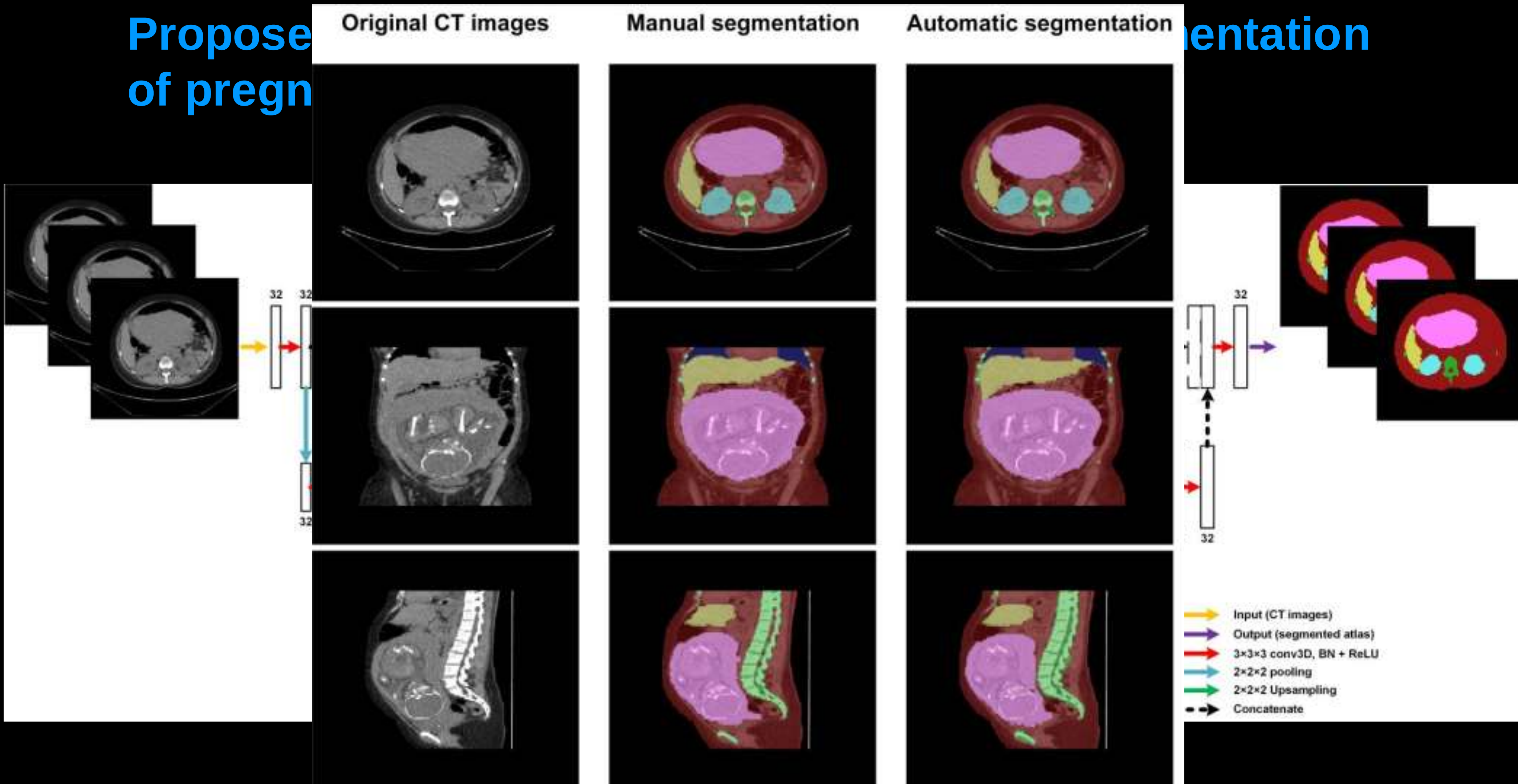
Received: 23 April 2019 / Revised: 16 May 2019 / Accepted: 29 May 2019 / Published online: 21 June 2019


Xie H and Zaidi (2019) *Eur Radiol*

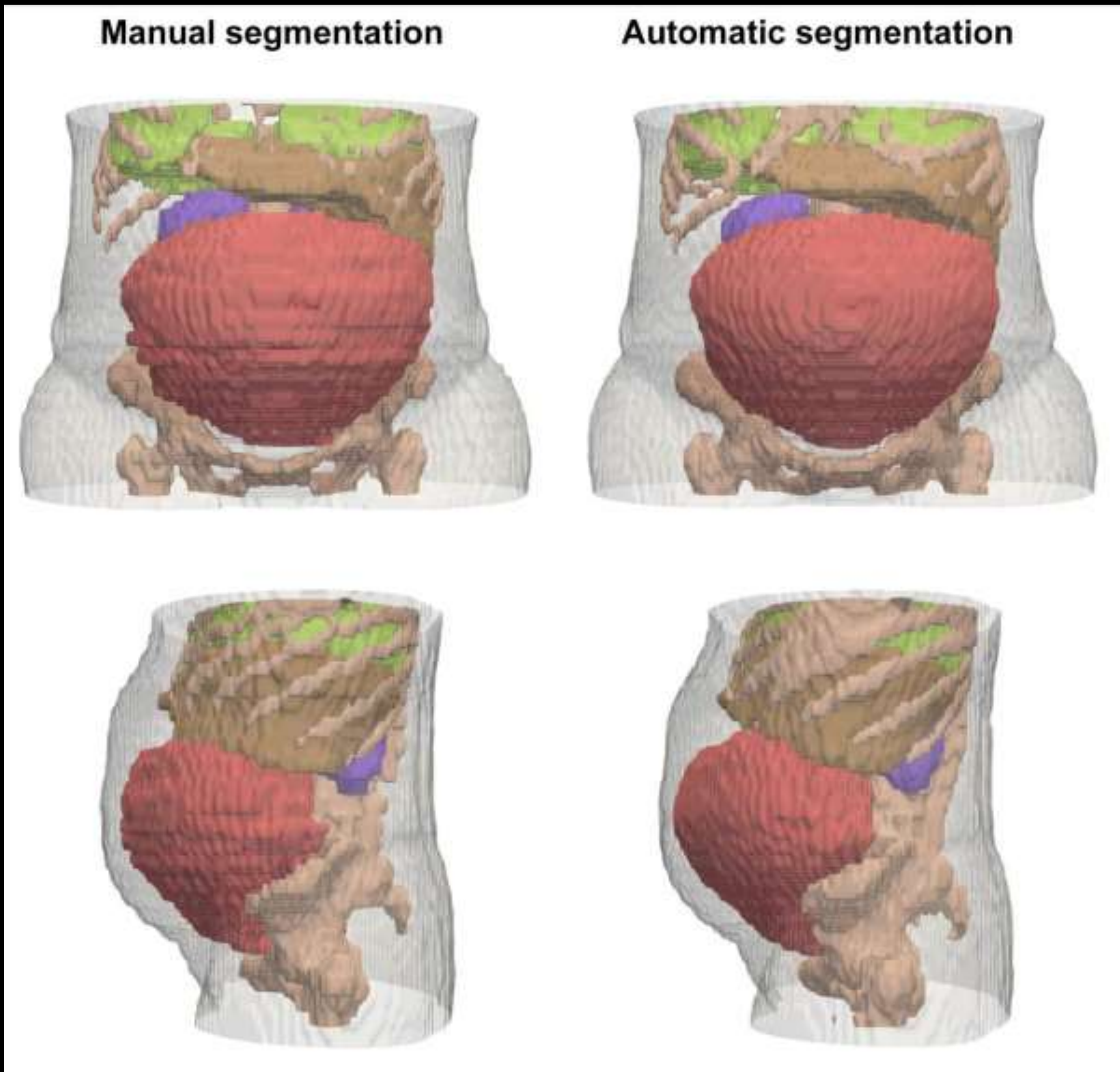
# *Automated generation of anatomical models*

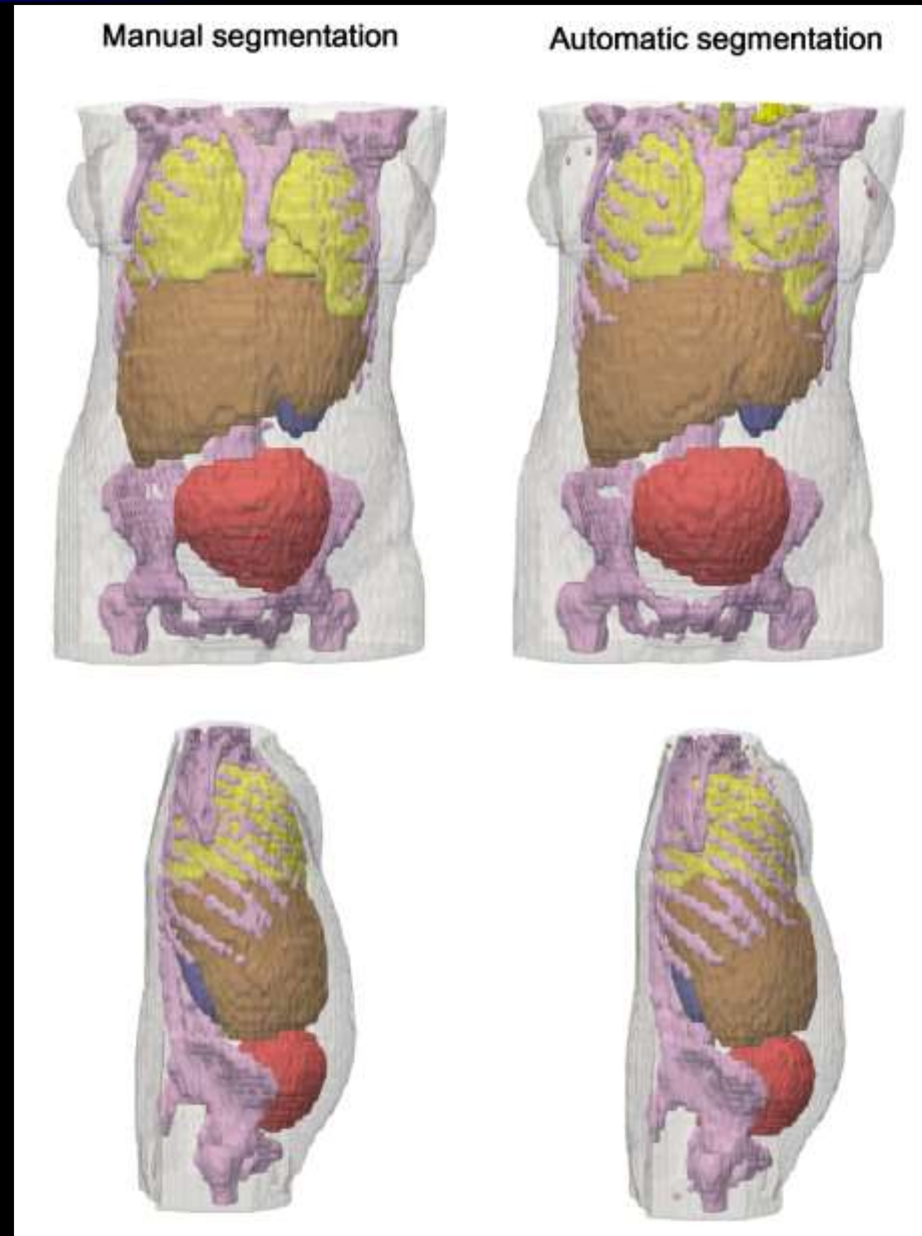
## Propose … entation of pregn…




Xie and Zaidi (2019) *Eur Radiol*

# *Automated generation of anatomical models*




Xie and Zaidi (2019) *Eur Radiol*

# Deep learning-guided low-dose PET imaging

Hôpitaux Universitaires Genève

European Journal of Nuclear Medicine and Molecular Imaging
https://doi.org/10.1007/s00259-020-05167-1

ORIGINAL ARTICLE

Check for updates

## Deep learning-assisted ultra-fast/low-dose whole-body PET/CT imaging

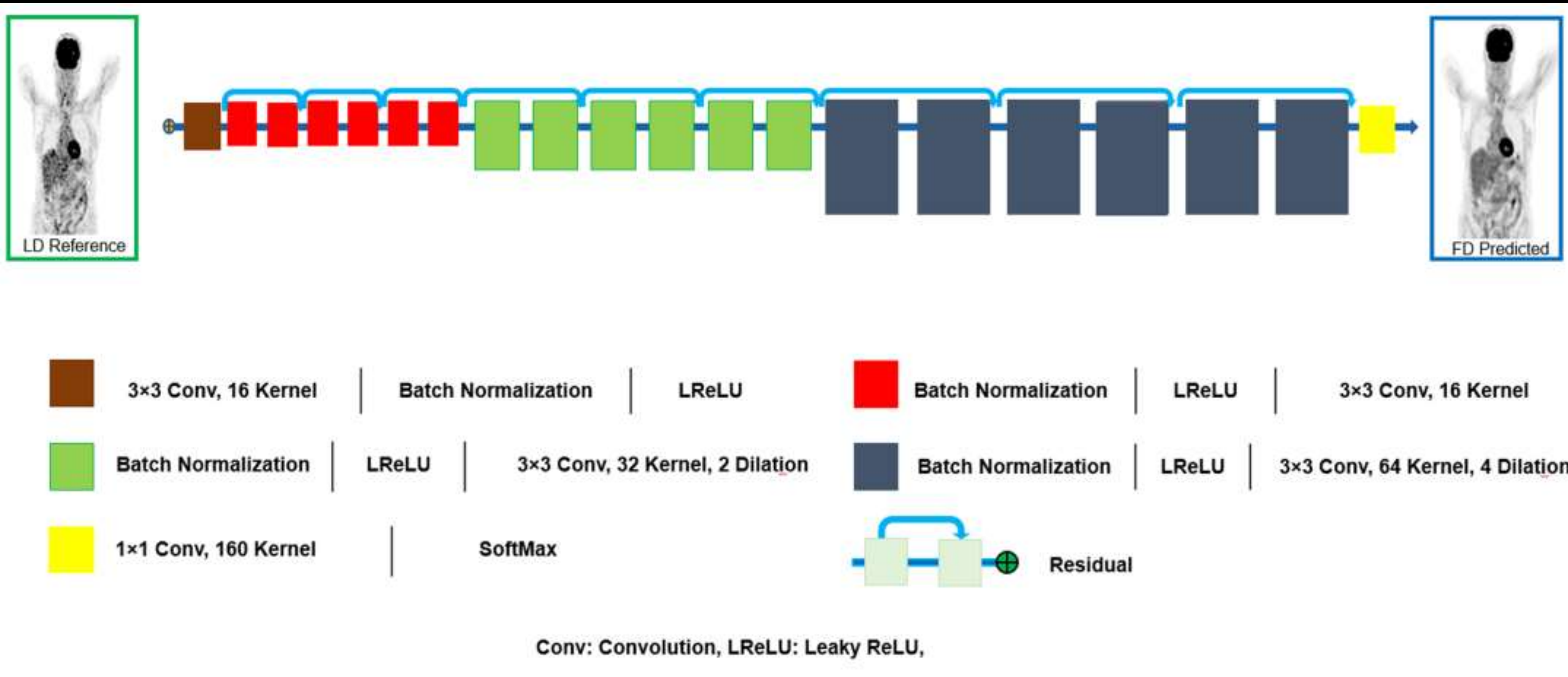
Amirhossein Sanaat[1] · Isaac Shiri[1] · Hossein Arabi[1] · Ismini Mainta[1] · René Nkoulou[1] · Habib Zaidi[1,2,3,4]

Received: 5 October 2020 / Accepted: 15 December 2020



Sanaat et al. (2021) *Eur J Nucl Med Mol Imaging*

# Deep learning-guided low-dose PET imaging

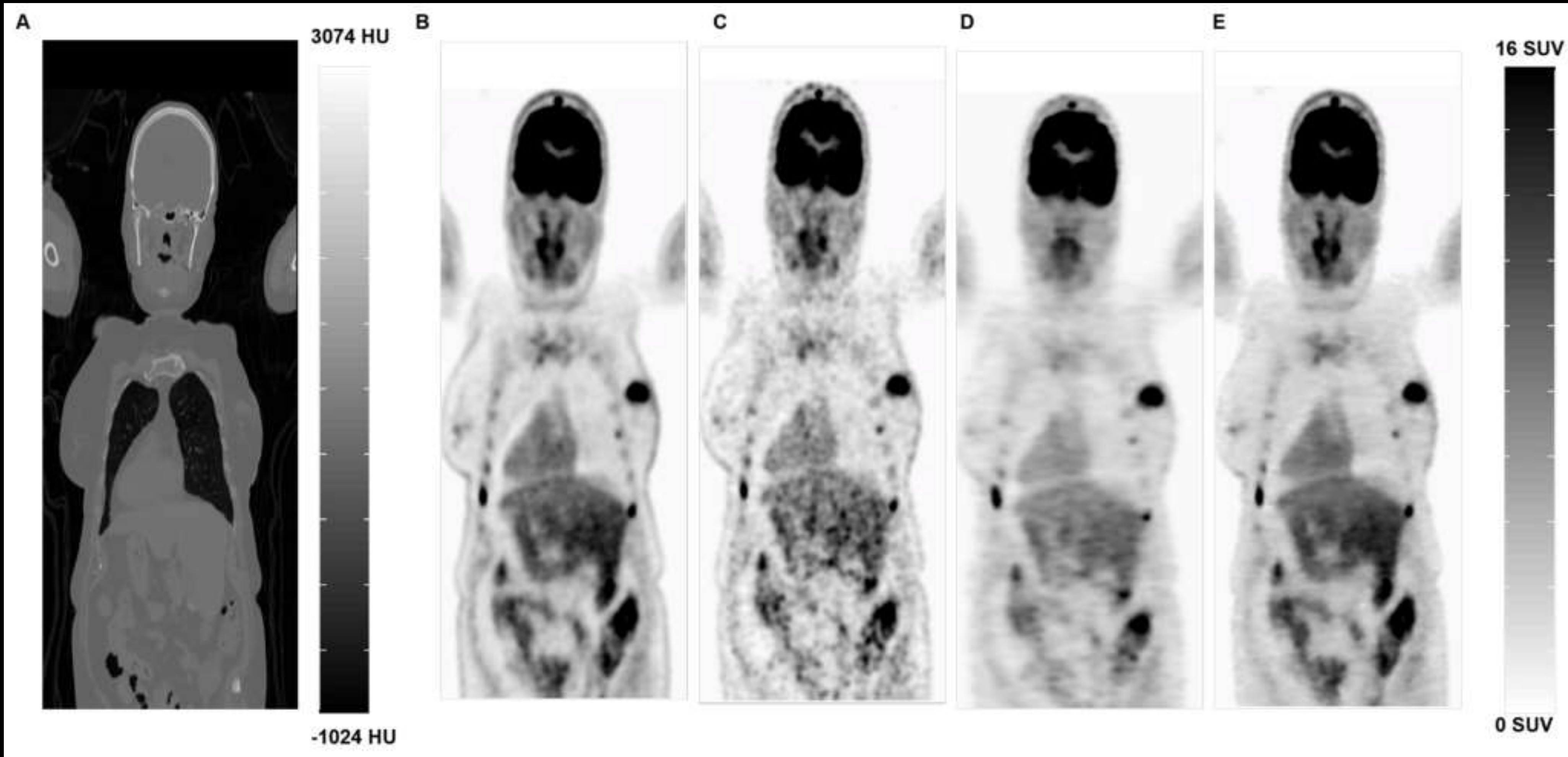



Sanaat et al. (2021) *Eur J Nucl Med Mol Imaging*

Hôpitaux Universitaires Genève

# *Deep learning-guided low-dose PET imaging*

**Low-dose CT** | **Full dose PET** | **Low dose PET** | **Pred. PET (RNET)** | **Pred. PET (CGAN)**

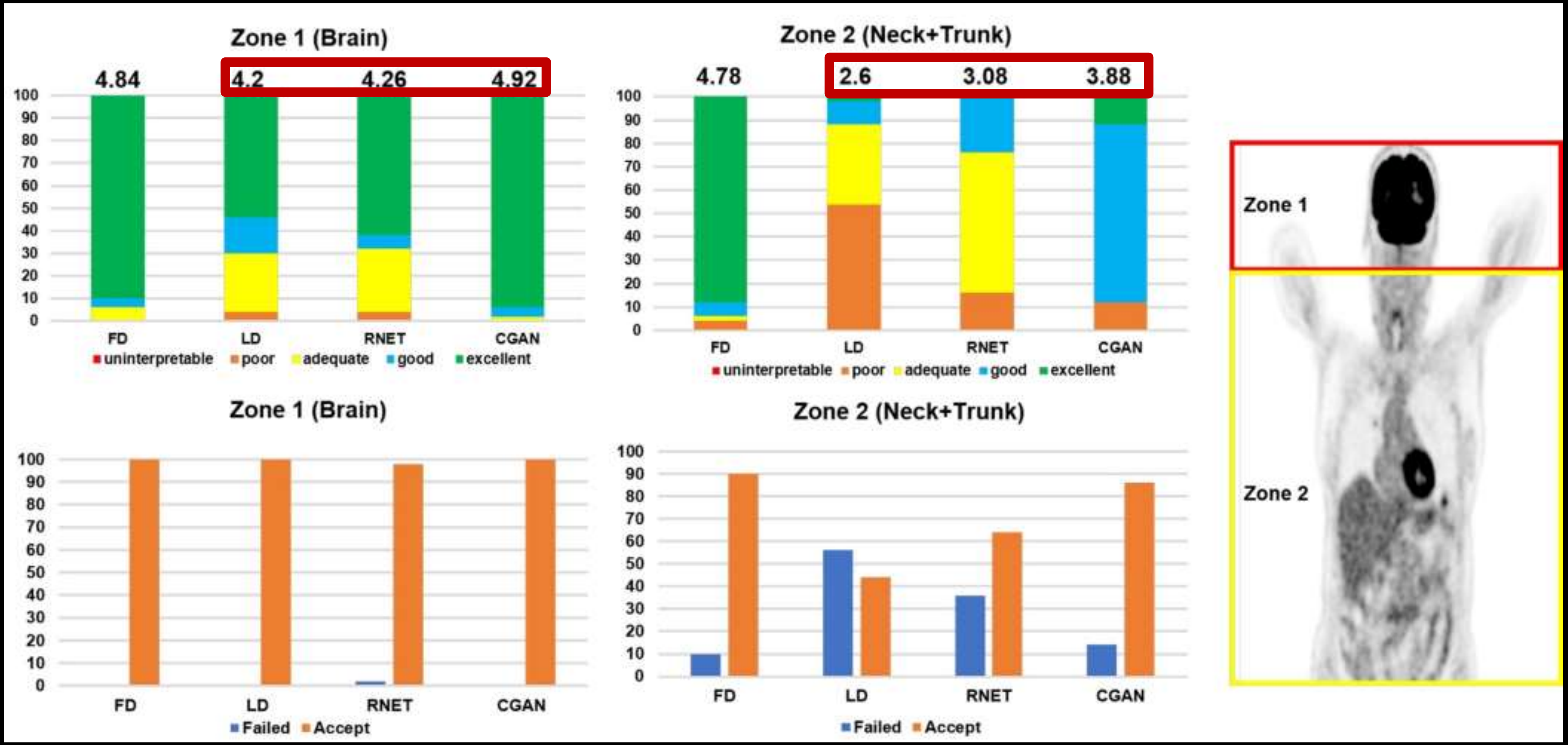



0.7 mm/s
(3 min/bed)

5 mm/s
(25 sec/bed)

Sanaat et al. (2021) *Eur J Nucl Med Mol Imaging*

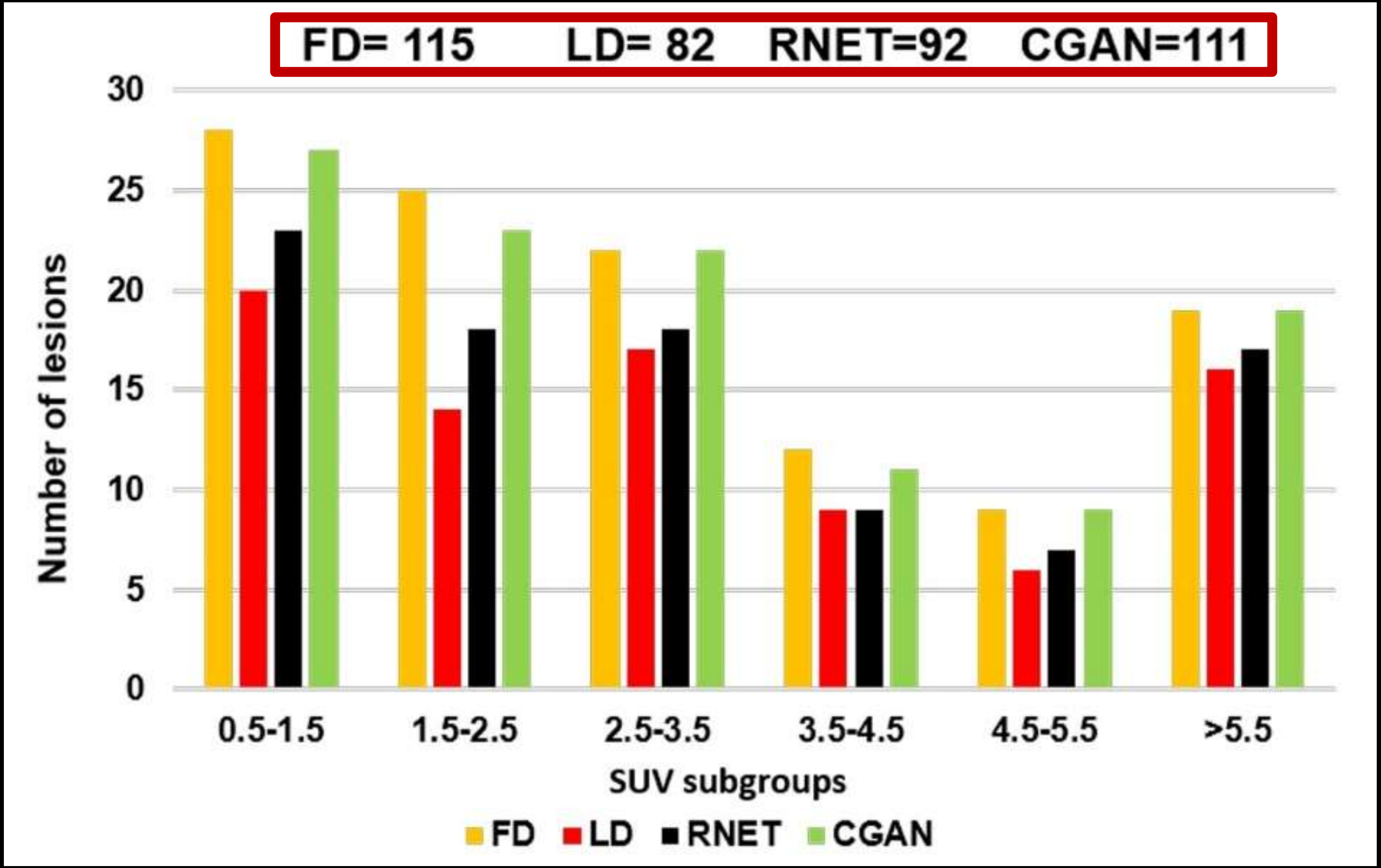
# Deep learning-guided low-dose PET imaging




**1 = uninterpretable** **2 = poor** **3 = adequate** **4 = good** **5 = excellent**

Sanaat et al. (2021) *Eur J Nucl Med Mol Imaging*

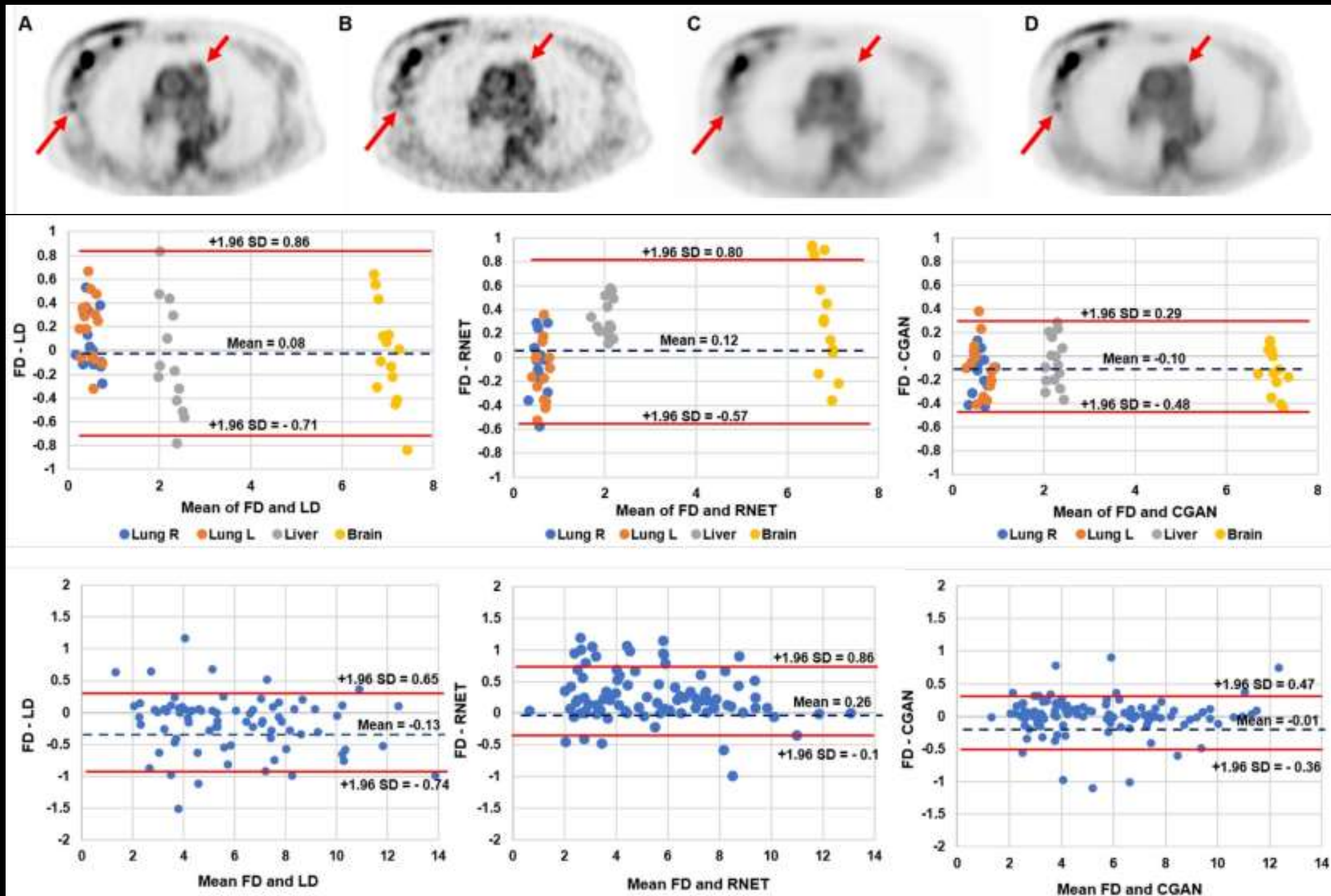
# Deep learning-guided low-dose PET imaging




Sanaat et al. (2021) *Eur J Nucl Med Mol Imaging*

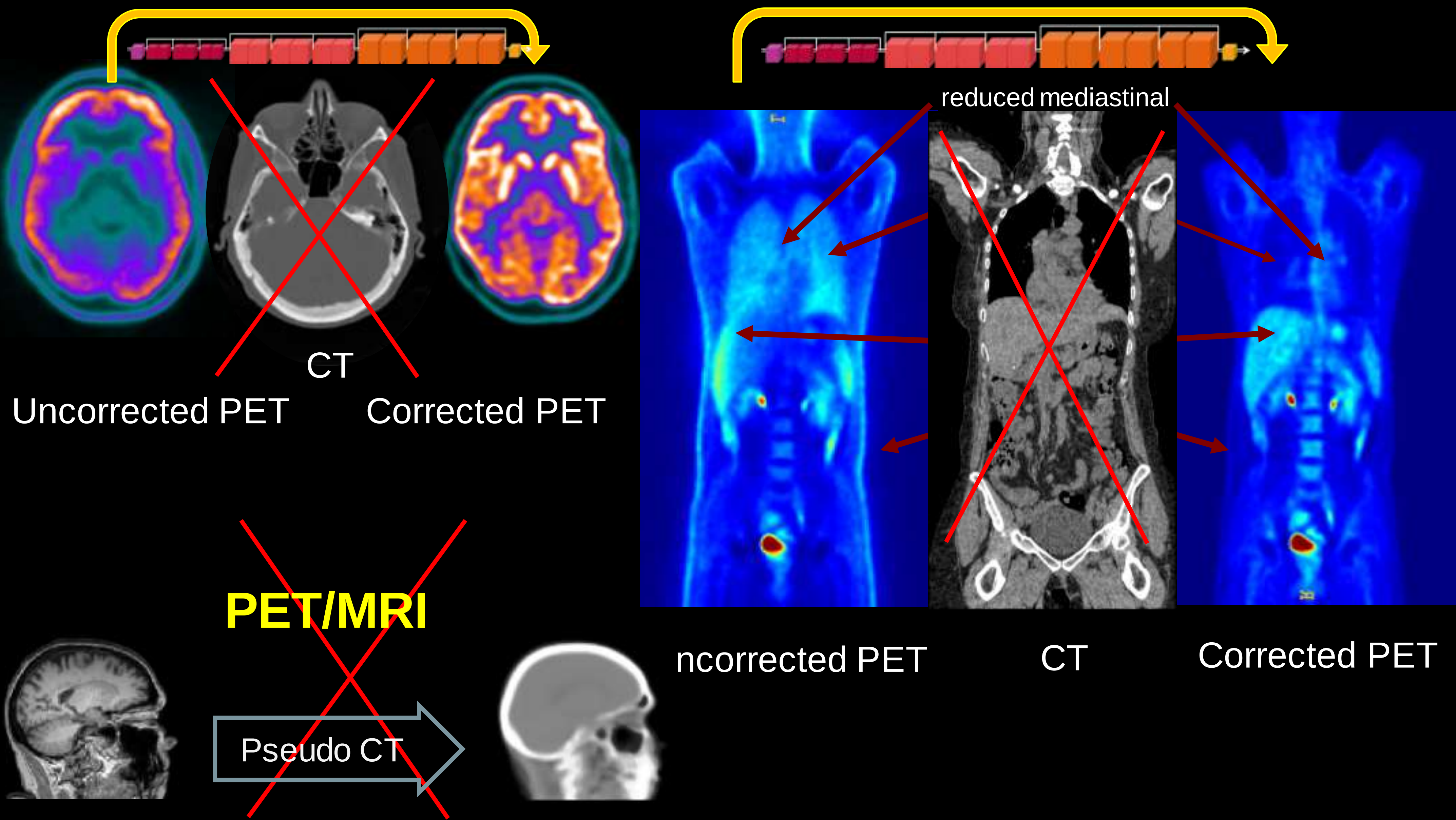
# *Deep learning-guided low-dose PET imaging*

**Full dose PET** **Low dose PET** **Pred. PET (RNET)** **Pred. PET (CGAN)**




Sanaat et al. (2021) *Eur J Nucl Med Mol Imaging*

# *CT-based attenuation correction (Reference)*



# MRI-guided AC in PET/MRI using deep learning

Hôpitaux Universitaires Genève

European Journal of Nuclear Medicine and Molecular Imaging (2019) 46:2746–2759
https://doi.org/10.1007/s00259-019-04380-x

ORIGINAL ARTICLE

Check for updates

## Novel adversarial semantic structure deep learning for MRI-guided attenuation correction in brain PET/MRI

Hossein Arabi[1] · Guodong Zeng[2] · Guoyan Zheng[2,3] · Habib Zaidi[1,4,5,6]

Received: 5 February 2019 / Accepted: 28 May 2019 / Published online: 1 July 2019



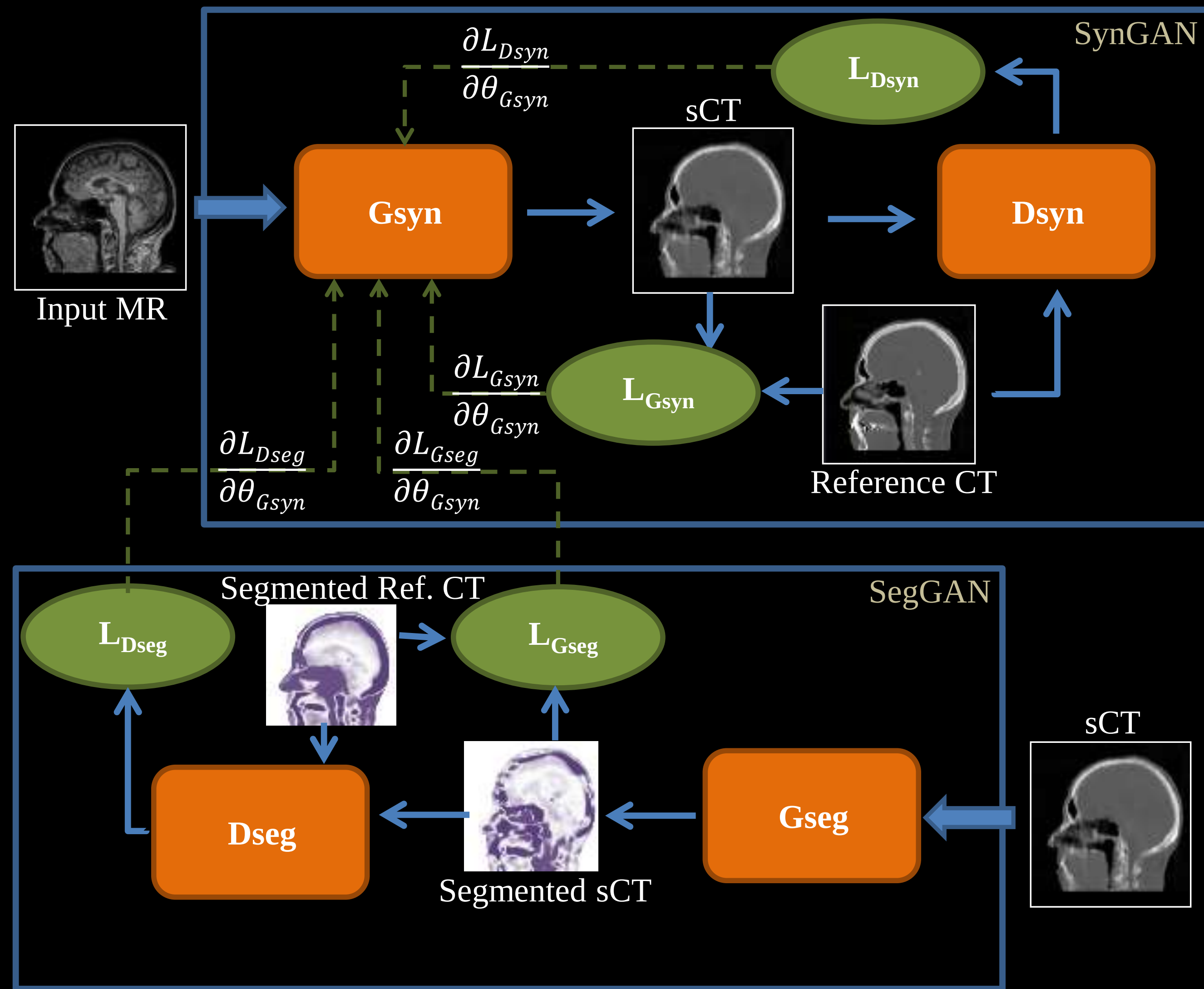
Arabi et al (2019) *Eur J Nucl Med Mol Imaging*

# Deep learning for MRI-guided AC in PET/MRI

Hôpitaux Universitaires Genève

## Proposed deep convolutional neural network

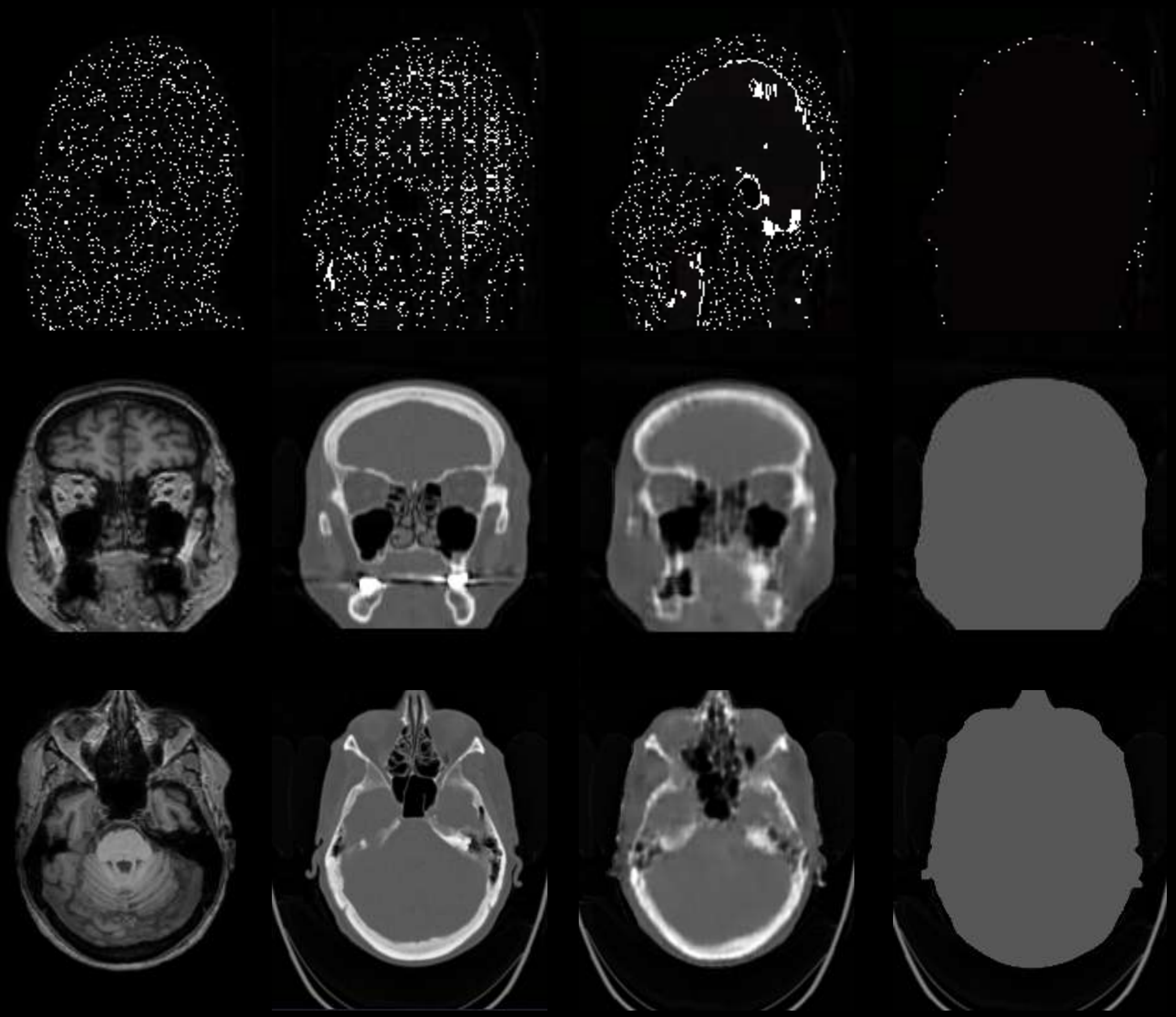
### Adversarial semantic structure learning (DL-AdvSS)




- Two generative adversarial cores for CT synthesis (SynGAN) and semantic structure extraction (SegGAN)
- L2-norm and cross-entropy loss functions
- SynGAN core contains 22 layers whereas SegGAN core 16 layers
- In total, DL-AdvSS involves 54,408,932 trainable parameters

Arabi et al (2019) *Eur J Nucl Med Mol Imaging*

# Deep learning for MRI-guided AC in PET/MRI




Arabi et al (2019) *Eur J Nucl Med Mol Imaging*

# Joint attenuation & scatter correction in PET

Hôpitaux Universitaires Genève

European Journal of Nuclear Medicine and Molecular Imaging
https://doi.org/10.1007/s00259-020-04852-5

ORIGINAL ARTICLE

Check for updates

## Deep-JASC: joint attenuation and scatter correction in whole-body $^{18}$F-FDG PET using a deep residual network

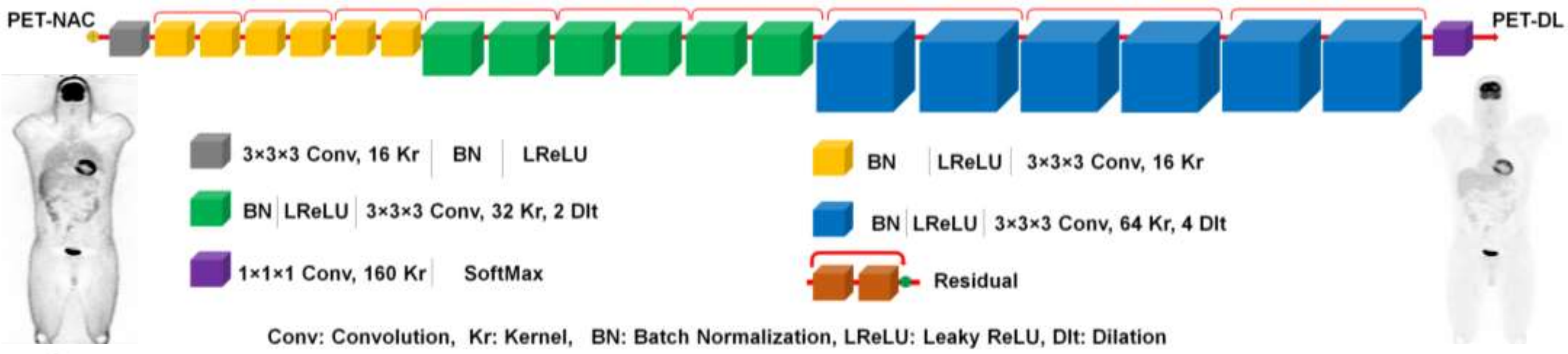
Isaac Shiri[1] • Hossein Arabi[1] • Parham Geramifar[2] • Ghasem Hajianfar[3] • Pardis Ghafarian[4,5] • Arman Rahmim[6,7] • Mohammad Reza Ay[8,9] • Habib Zaidi[1,10,11,12]

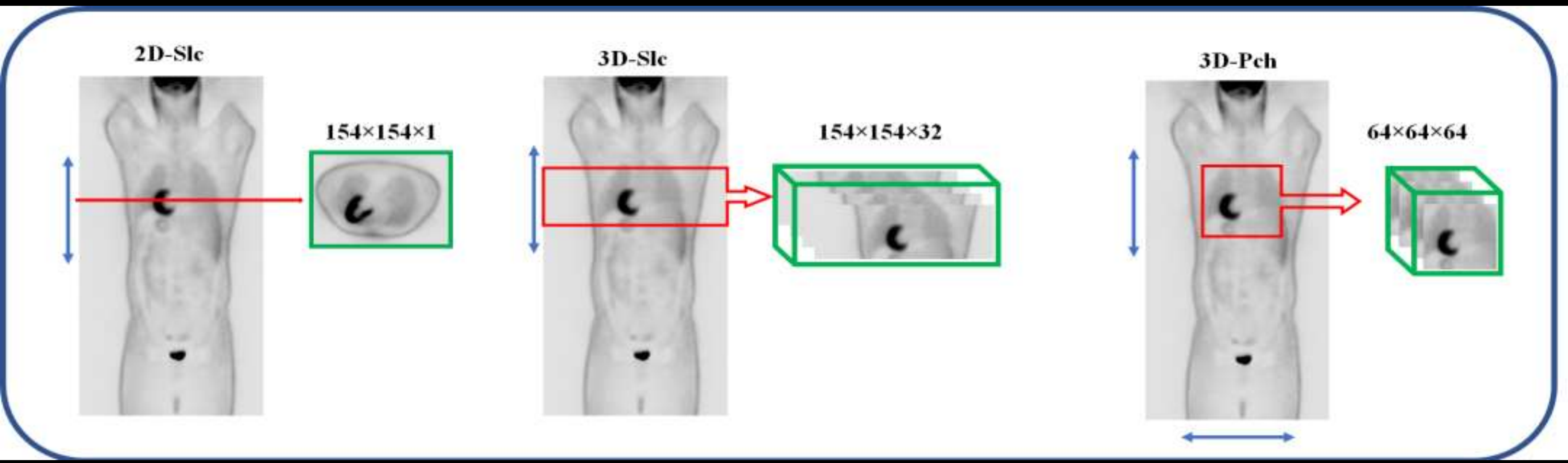
Received: 7 November 2019 / Accepted: 1 May 2020



Shiri et al. (2020) *Eur J Nucl Med Mol Imaging*

# Deep-JSAC: Implementation issues




Shiri et al. (2020) *Eur J Nucl Med Mol Imaging*

# Deep learning compensates motion artifacts

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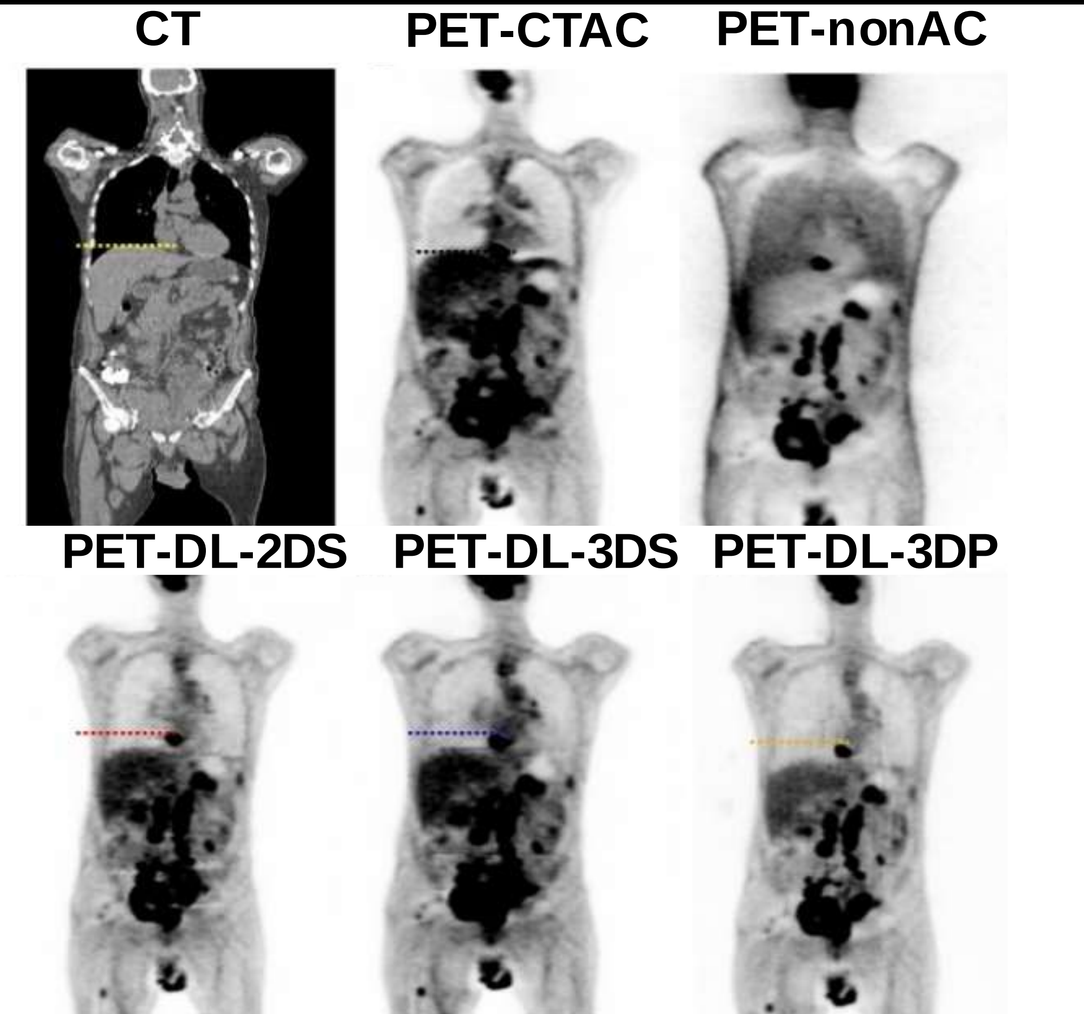
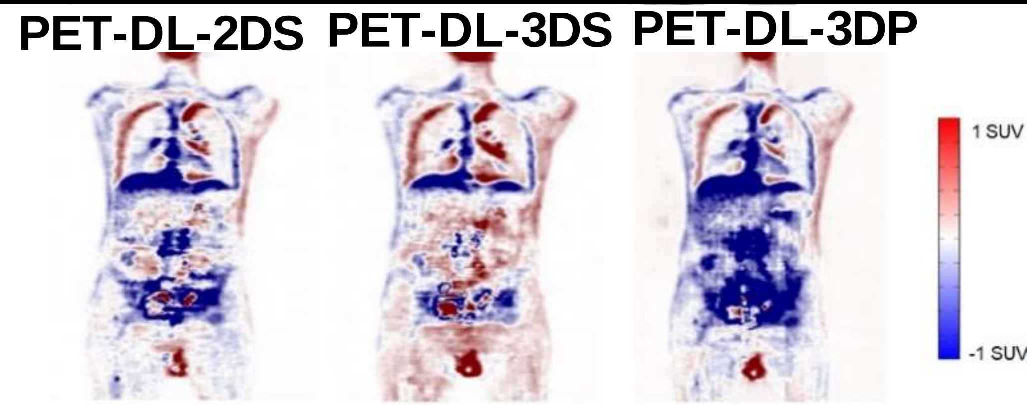
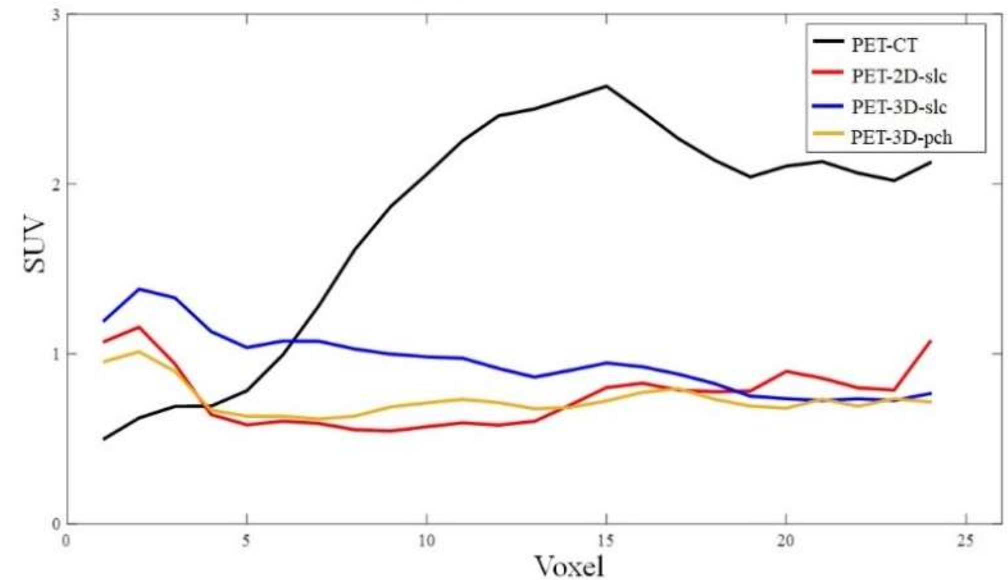



Difference images: PET-DL – PET-CTAC

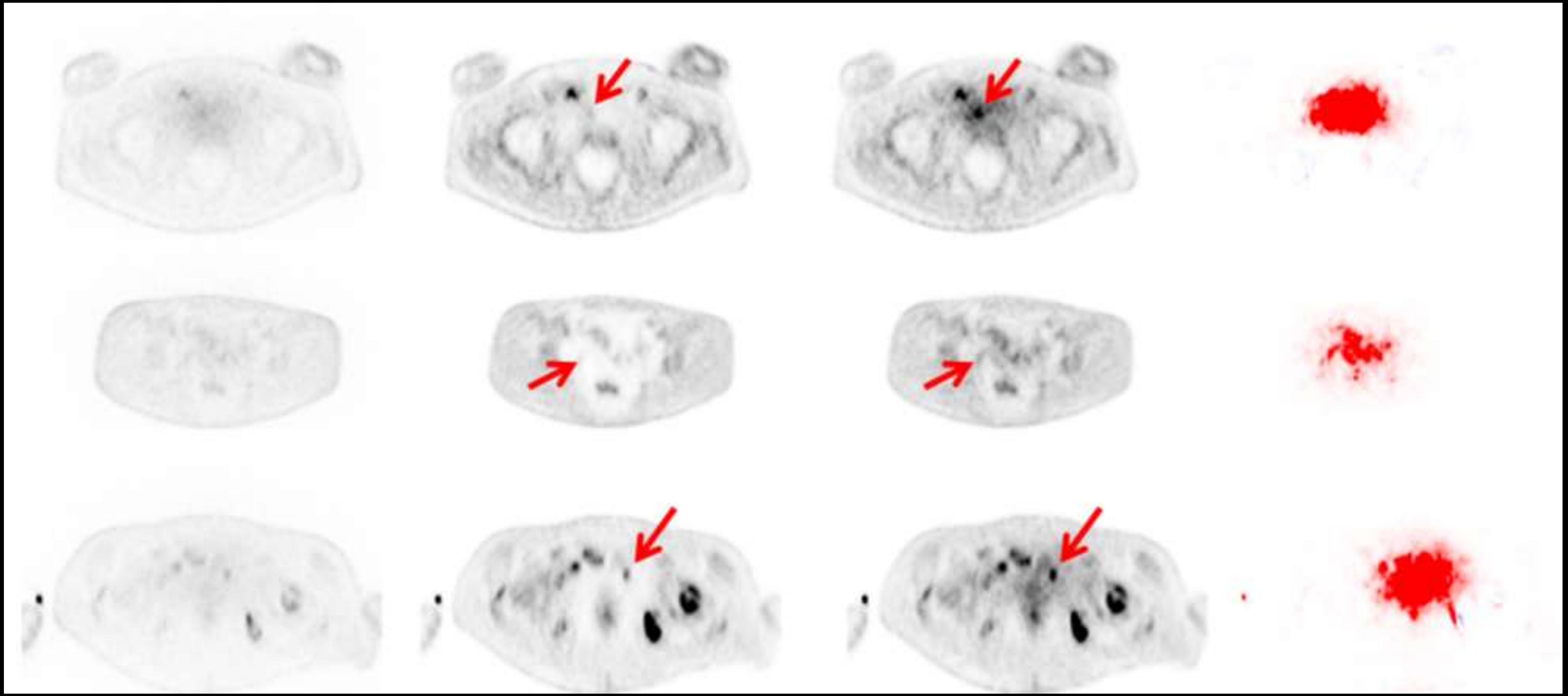



Shiri et al. (2020) *Eur J Nucl Med Mol Imaging*

# AI-based artifact disentanglement

| Non-ASC | CT-ASC | PET-QA-NET | PET-QA-NET - CT-ASC |
|---|---|---|---|



Halo Artifact

- Detectability
- Diagnostic confidence
- Quantification $SUV_{mean}$ = 3.7/2.2 in PET-QA-NET/CT-ASC

Shiri *et al.* (2023) *Clin Nucl Med*

# AI-based artifact disentanglement

Hôpitaux Universitaires Genève

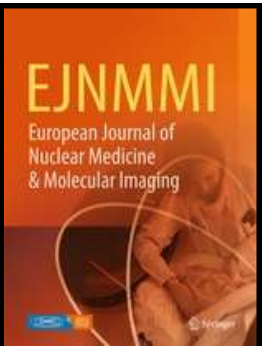
European Journal of Nuclear Medicine and Molecular Imaging
https://doi.org/10.1007/s00259-023-06418-7

ORIGINAL ARTICLE

Check for updates

## Differential privacy preserved federated transfer learning for multi-institutional $^{68}$Ga-PET image artefact detection and disentanglement

Isaac Shiri[1,2] · Yazdan Salimi[1] · Mehdi Maghsudi[3] · Elnaz Jenabi[4] · Sara Harsini[5] · Behrooz Razeghi[6] · Shayan Mostafaei[7,8] · Ghasem Hajianfar[1] · Amirhossein Sanaat[1] · Esmail Jafari[9] · Rezvan Samimi[10] · Maziar Khateri[11] · Peyman Sheikhzadeh[12] · Parham Geramifar[4] · Habibollah Dadgar[13] · Ahmad Bitrafan Rajabi[3,14] · Majid Assadi[9] · François Bénard[5,15] · Alireza Vafaei Sadr[16,17] · Slava Voloshynovskiy[6] · Ismini Mainta[1] · Carlos Uribe[15,18,19] · Arman Rahmim[15,19,20] · Habib Zaidi[1,21,22,23]

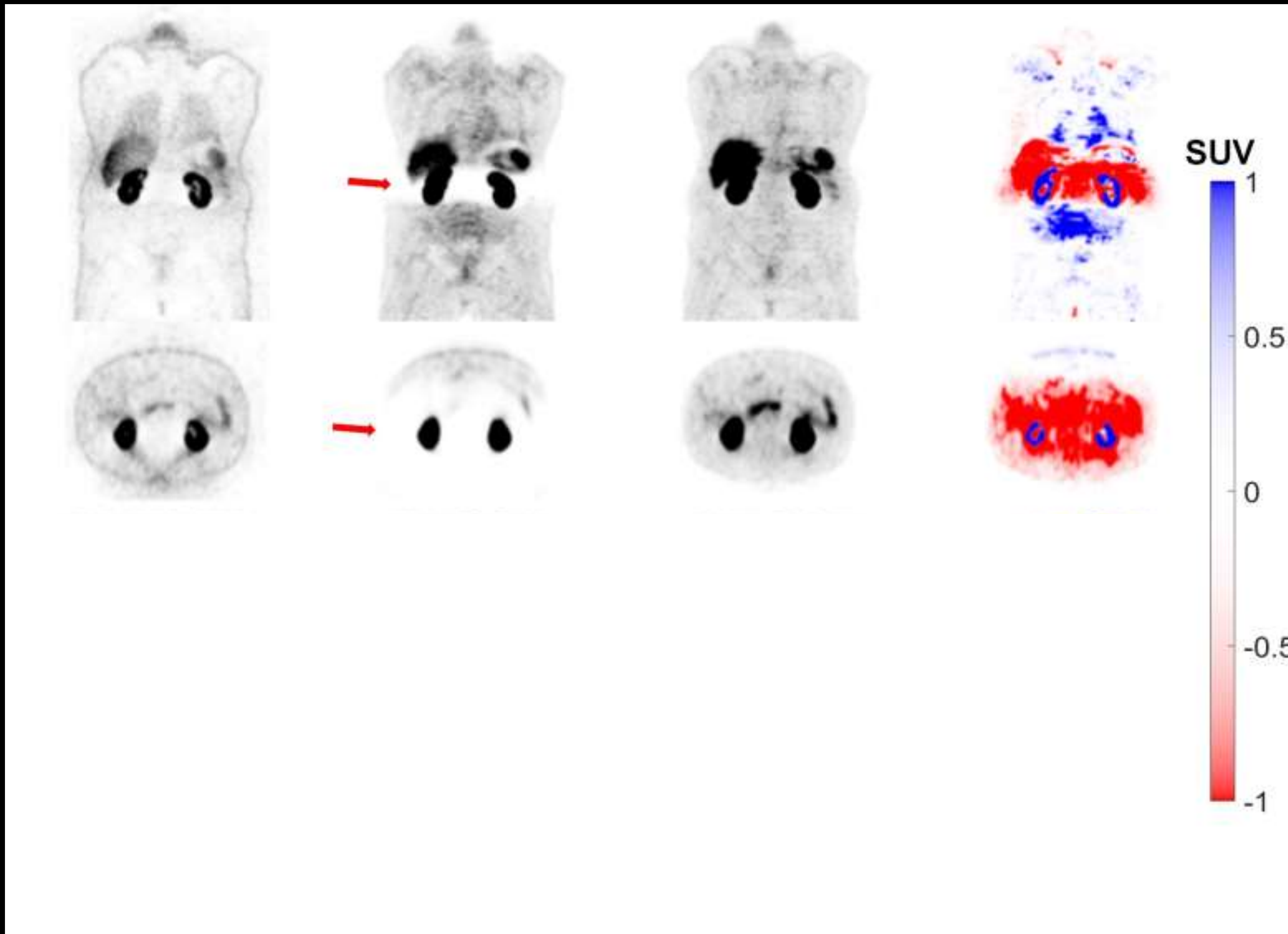



Shiri *et al. Eur J Nucl Med Mol Imaging* (2023)

# DPFL for PET/CT image artifact correction

Hôpitaux Universitaires Genève

Non-ASC CT-ASC FTL-ASC PET-QA-NET - CT-ASC




$^{68}$Ga-PSMA

Repeated scan

Shiri *et al. Eur J Nucl Med Mol Imaging* (2023)

# Deep learning-guided internal dosimetry

Hôpitaux Universitaires Genève

European Journal of Nuclear Medicine and Molecular Imaging
https://doi.org/10.1007/s00259-020-05013-4

ORIGINAL ARTICLE

Check for updates

## Whole-body voxel-based internal dosimetry using deep learning

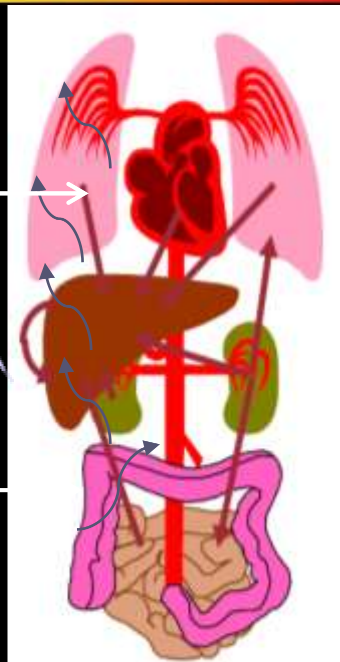
Azadeh Akhavanallaf[1] • Iscaac Shiri[1] • Hossein Arabi[1] • Habib Zaidi[1,2,3,4]

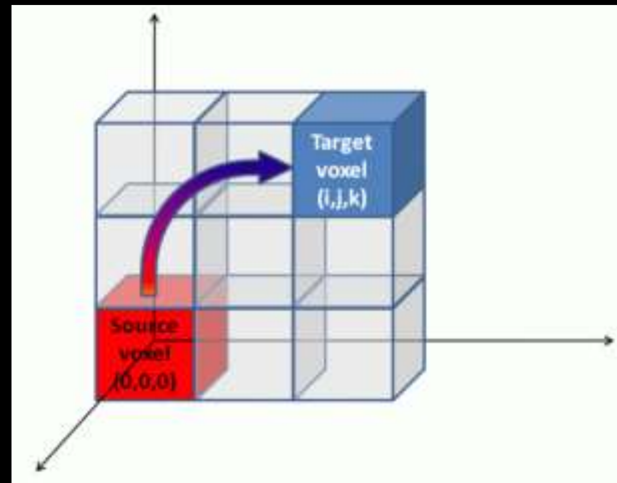
Received: 27 May 2020 / Accepted: 23 August 2020

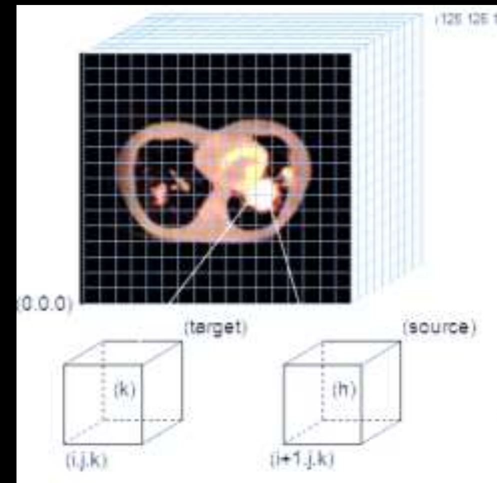


Akhavanallaf *et al.* (2020) *Eur J Nucl Med Mol Imaging*

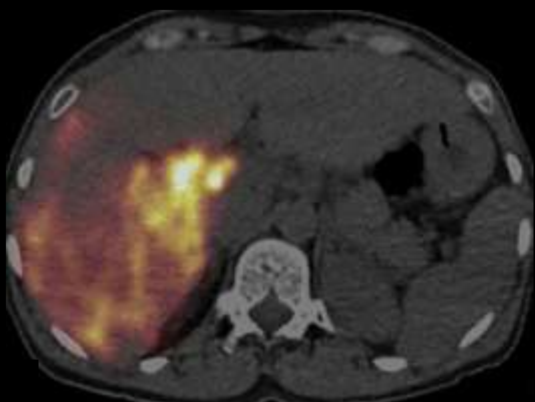
# *Voxel-based internal dosimetry (MIRD)*



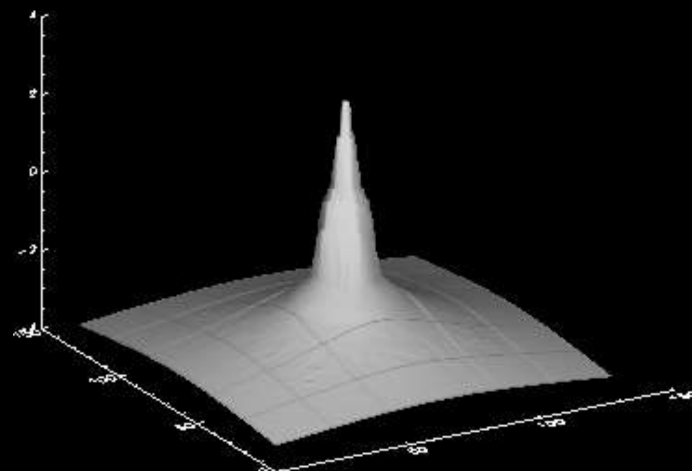




$$\bar{D}_{voxel_k} = \sum_{n=1}^{N} \tilde{A}_{voxel_n} . S(voxel_k \leftarrow voxel_n)$$



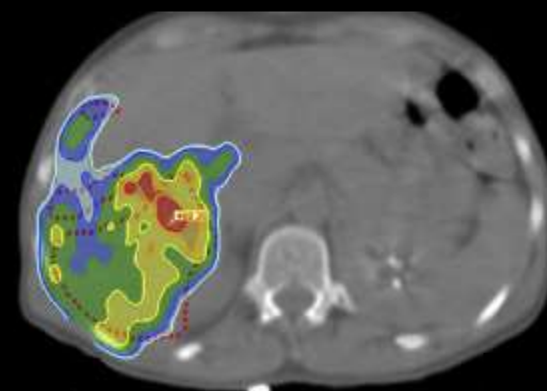
Activity map

*



Dose point kernel

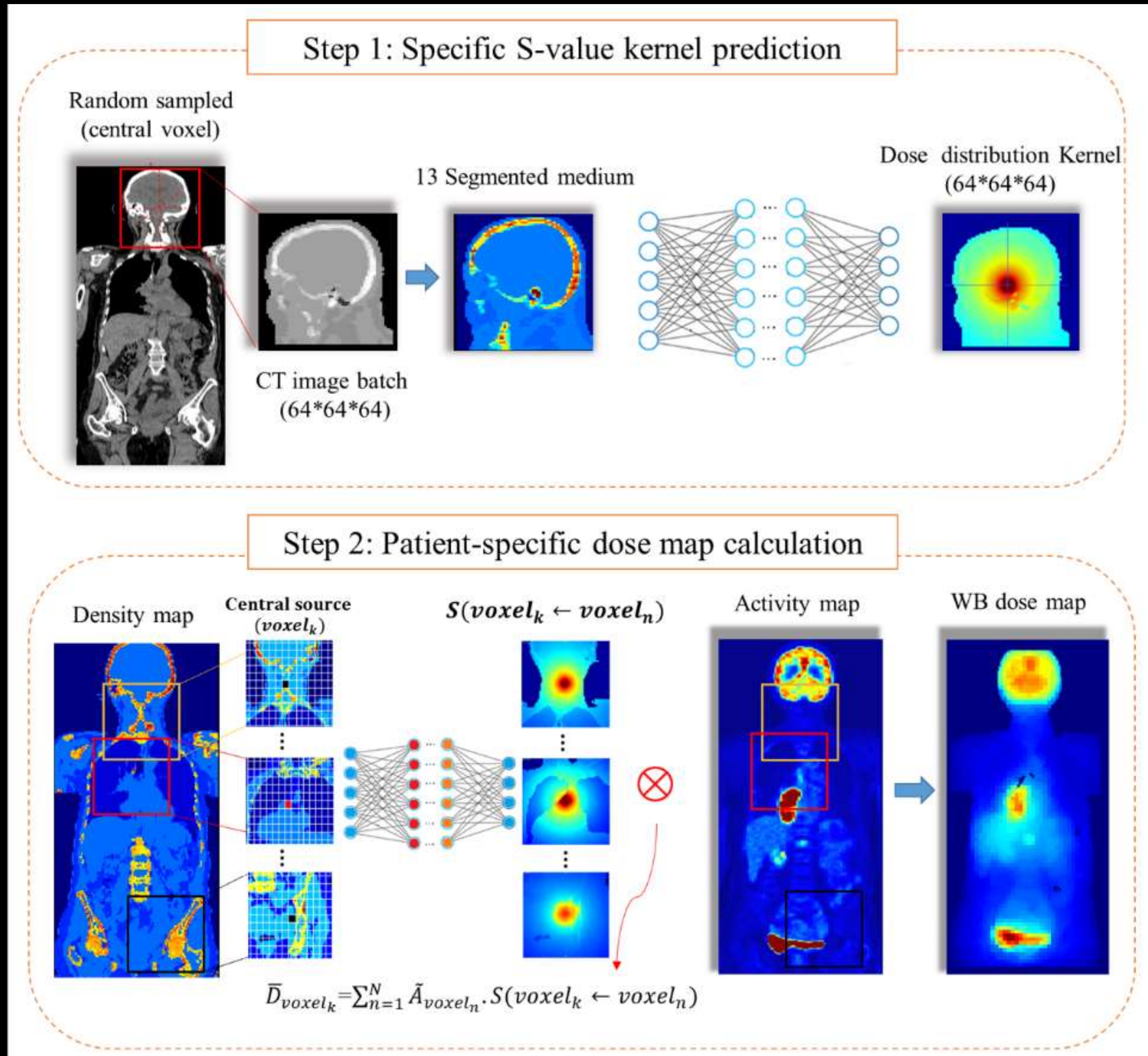
=



3D dose map

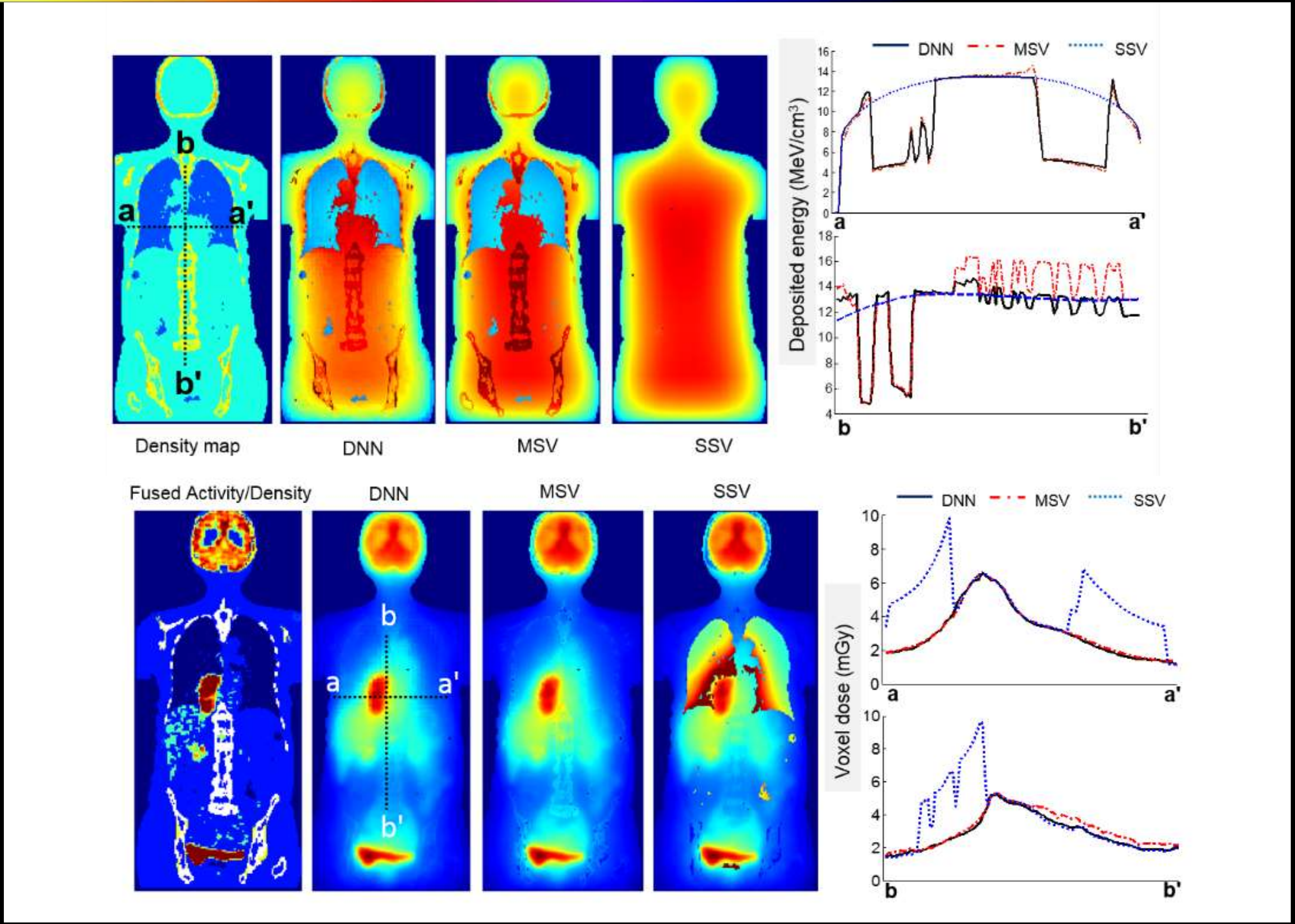
*Bolch et al. J Nucl Med (1999)*

# Deep learning-guided internal dosimetry




Akhavanallaf *et al.* (2020) *Eur J Nucl Med Mol Imaging*

# *Deep learning-guided internal dosimetry*




Akhavanallaf et al. (2020) *Eur J Nucl Med Mol Imaging*

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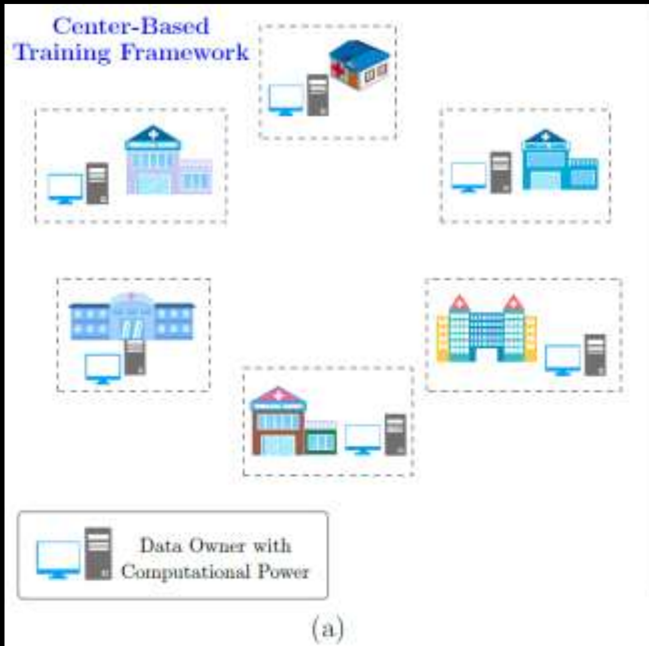
# *Federated learning in medical imaging*




| | Advantages | Disadvantages |
| --- | --- | --- |
| CB | Local control, utilization of centre-specific data and expertise | Generalizability, limited access to large datasets, infrastructure |

# Federated learning for PET AC/segmentation

Hôpitaux Universitaires Genève

ORIGINAL ARTICLE

## Decentralized Distributed Multi-institutional PET Image Segmentation Using a Federated Deep Learning Framework

Isaac Shiri, MSc,* Alireza Vafaei Sadr, MSc,†‡ Mehdi Amini, MSc,* Yazdan Salimi, MSc,* Amirhossein Sanaat, MSc,* Azadeh Akhavanallaf, MSc,* Behrooz Razeghi, PhD,§ Sohrab Ferdowsi, PhD,|| Abdollah Saberi, MSc,* Hossein Arabi, PhD,* Minerva Becker, MD,¶ Slava Voloshynovskiy, PhD,§ Deniz Gündüz, PhD,** Arman Rahmim, PhD,††‡‡ and Habib Zaidi, PhD*§§||||¶¶

European Journal of Nuclear Medicine and Molecular Imaging
https://doi.org/10.1007/s00259-022-06053-8

ORIGINAL ARTICLE

Check for updates

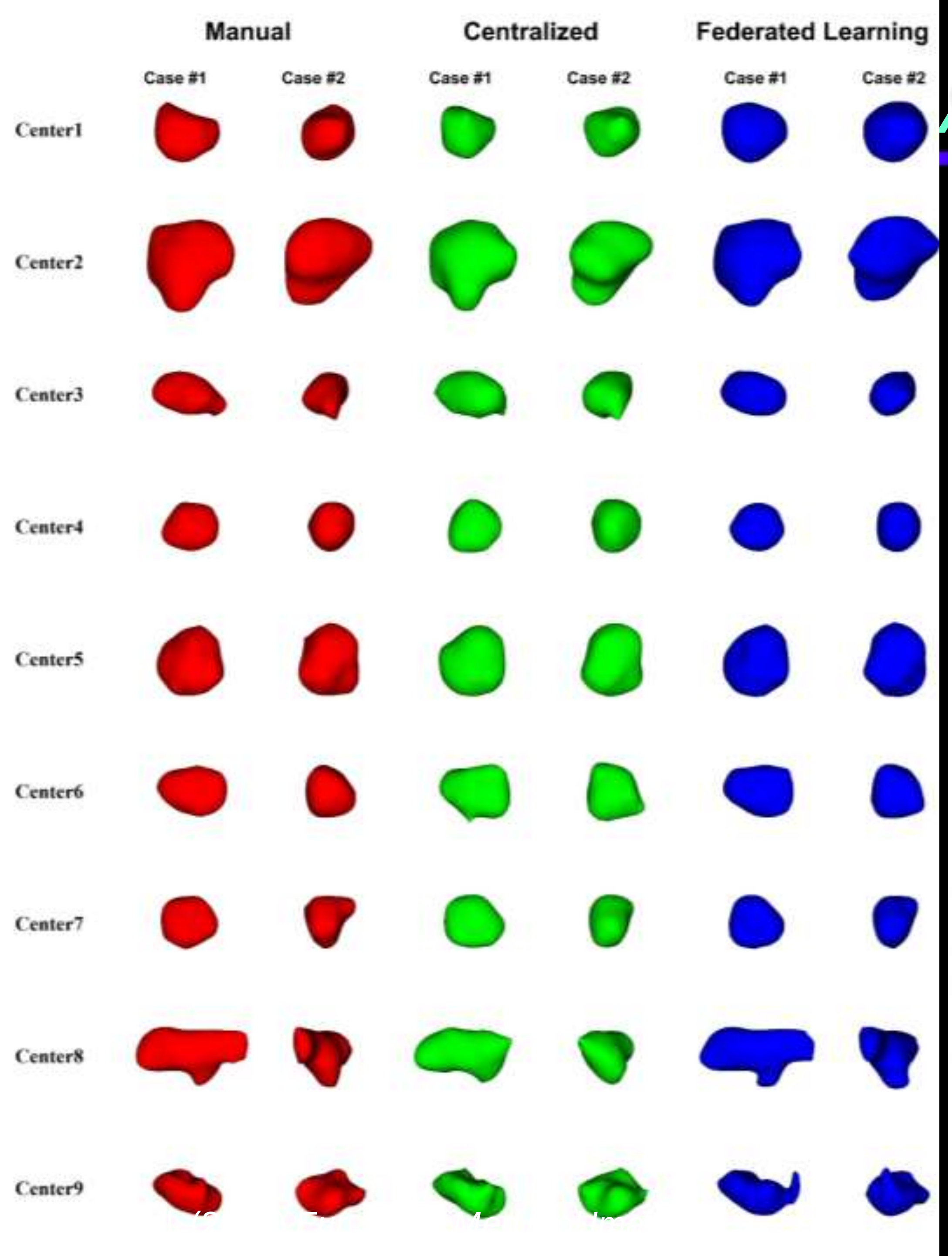
## Decentralized collaborative multi-institutional PET attenuation and scatter correction using federated deep learning

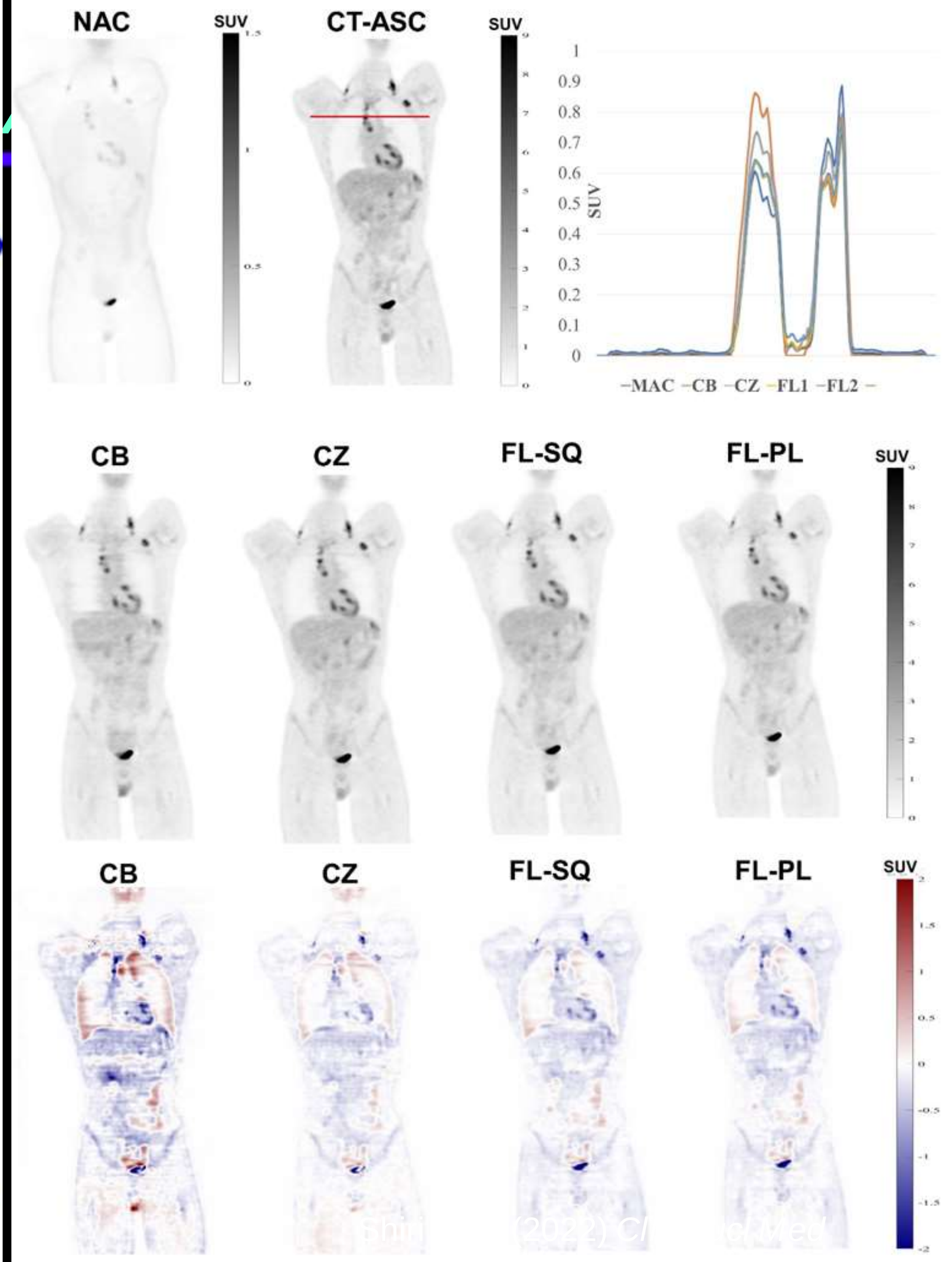
Isaac Shiri[1] · Alireza Vafaei Sadr[2,3] · Azadeh Akhavan[1] · Yazdan Salimi[1] · Amirhossein Sanaat[1] · Mehdi Amini[1] · Behrooz Razeghi[4] · Abdollah Saberi[1] · Hossein Arabi[1] · Sohrab Ferdowsi[5] · Slava Voloshynovskiy[4] · Deniz Gündüz[6] · Arman Rahmim[7,8] · Habib Zaidi[1,9,10,11]

Received: 13 August 2022 / Accepted: 18 November 2022


Shiri et al. (2023) *Eur J Nucl Med Mol Imaging*

Shiri et al. (2022) *Clin Nucl Med*


Manual
Centralized
Federated Learning
Case #1
Case #2
Case #1
Case #2
Case #1
Case #2
Center1
Center2
Center3
Center4
Center5
Center6
Center7
Center8
Center9


NAC
SUV
CT-ASC
SUV
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
SUV
—MAC —CB —CZ —FL1 —FL2
CB
CZ
FL-SQ
FL-PL
SUV
CB
CZ
FL-SQ
FL-PL
SUV

# *Summary*

Hôpitaux Universitaires Genève

- Imaging biomarkers are a major component of Big Data driven medical knowledge and decision making
- Nuclear medicine physicians/Radiologists/Medical physicists who use AI and deep learning will replace those who don't …
- AI/deep learning are producing challenges in terms of validation/adoption in clinical setting, but also plenty of research opportunities.
- Is there a future for AI/deep learning in medical imaging? **YES**
- If artificial intelligence is possible, so is artificial stupidity …
- Wide and specific participation by industry and research communities, planning for long term sustainability.

# *Take home message …*

"*Machine learning works very well, and we don't know why it works so well. I consider that a challenge for mathematicians is to understand it better. I believe if something works, there is a reason. We have to find the reason*"

Prof. Ingrid Daubechies, Duke University

# *On the horizon …*

## The Wave…

## … of the Future…

*"Prediction is very difficult, especially if it is about the future"*
*Niels Bohr (1885–1962)*

# Distinguished professor at Óbuda University

Hôpitaux Universitaires Genève

# *Potential collaborations (themes)*

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- High performance computing (Monte Carlo simulations, algorithmic developments, optimization, …).
- Advanced signal & medical image analysis and processing
- Biomedical imaging instrumentation
- Novel neural network architectures and applications
- Applications of artificial intelligence in healthcare (other than medical imaging, e.g. radiation therapy, modeling, …)
- Clinical diagnosis, prognostic modeling, outcome prediction, …
- Any research requiring expertise in imaging, AI, modeling, computing…

# Thank you!

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European Commission
krebsforschung schweiz
recherche suisse contre le cancer
ricerca svizzera contro il cancro
swiss cancer research
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European Workshop on Visual Information Processing
Hôpitaux Universitaires Genève
EUVIP 2024
Geneva, 8-11 Sep 2023
Main topics : visual information processing, analysis/interpretation and representation/coding;
Applications: Multimedia, Medical imaging, Augmented and virtual reality, Biometrics, forensics, trust/security
Geneva University Hospital

*Thank you!*

*Thanks to all my colleagues, too many to mention, who have participated in the formulation process of the ideas behind this presentation*

*"Scientists are very happy people because their job is also their hobby"*

*Prof. Abdus Salem*
*1979 Nobel Laureate - Physics*