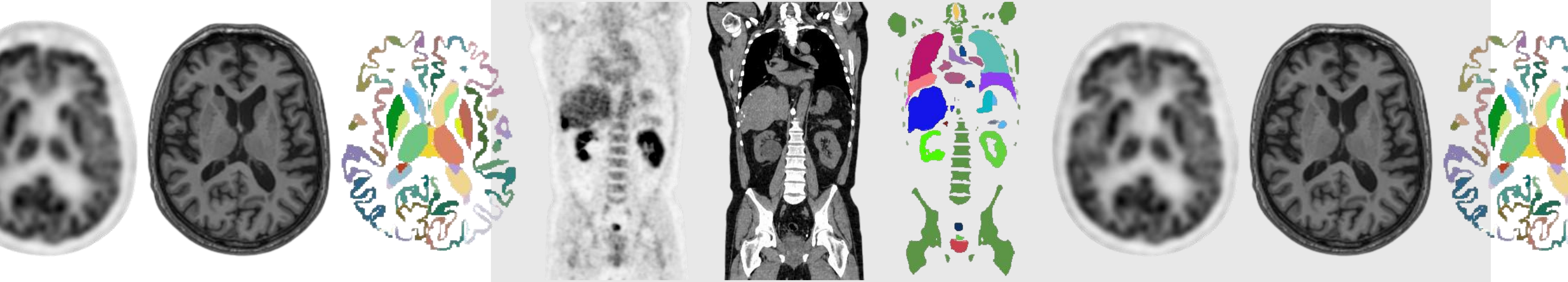


Medical Image Processing and **Segmentation** (with **3D Slicer**)

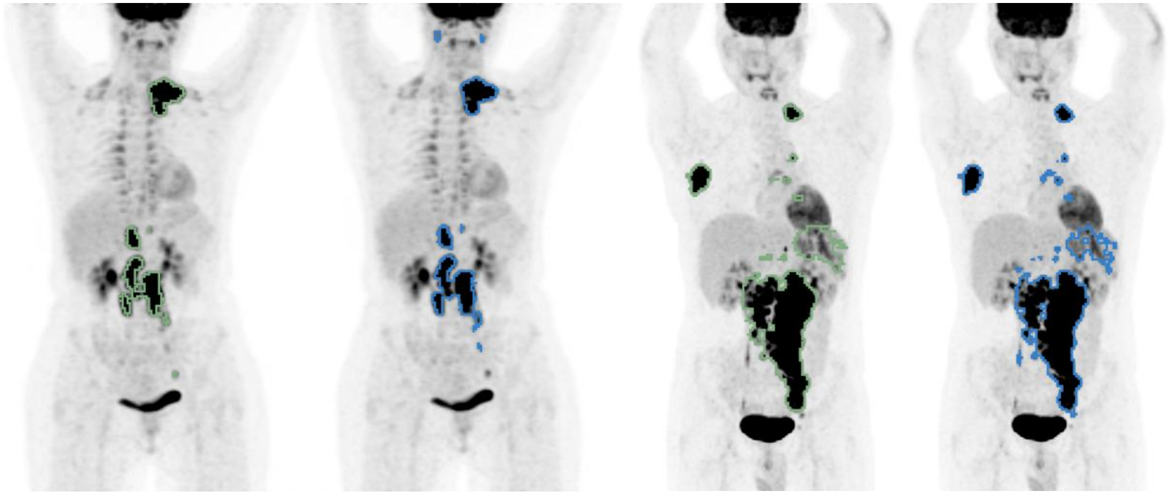
Luísa CastelBranco Silva
Biomedical engineer, researcher @ MN-Rf

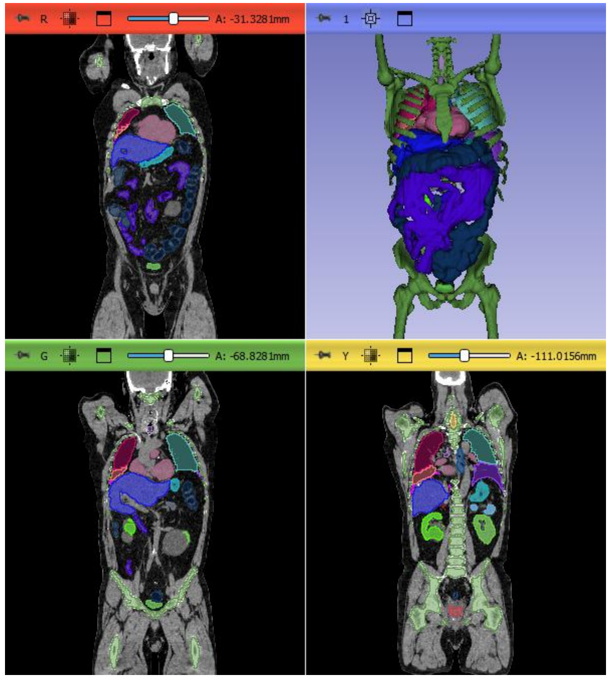
Champalimaud Foundation

Our work @ Champalimaud Foundation

Automatic **segmentation**

- Manual segmentation by physicians is **time-consuming** and subject to **inter-reader variability** and **depends on experience**
- **AI** (in particular, deep learning – deep convolutional neural networks) allows for automatic segmentation – of tumors/lesions, organs, etc.

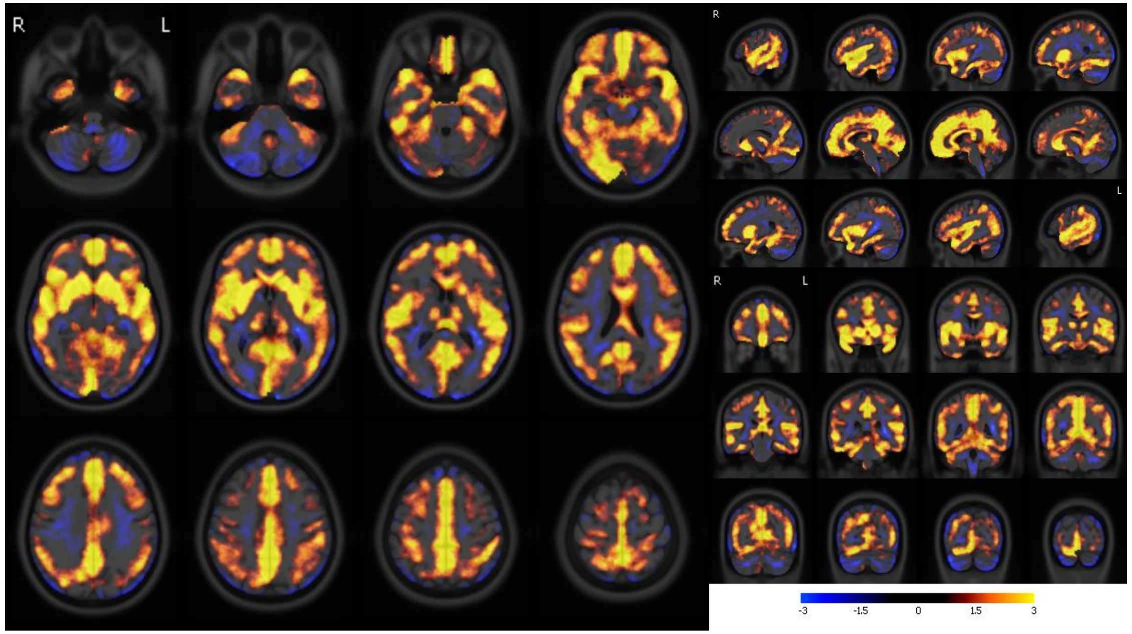




Our work @ Champalimaud Foundation

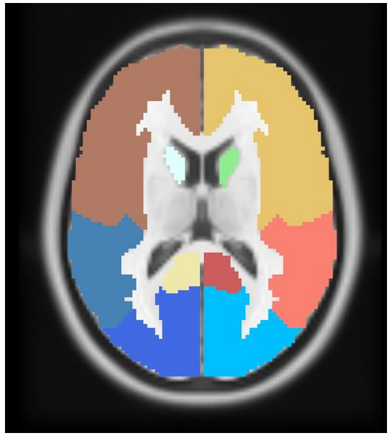
Image **quantification**

- Functional imaging modalities, such as PET and SPECT, allow for **interpretation in terms of function/activity**
- **Quantification in regions of interest** provides a **robust aid for interpretation**
- **Machine learning classifiers** based on quantitative measures **assist diagnosis**



Z-scores sobrepostos no atlas MNI (MRI T1).
Normalização pela captação média na ponte.

Região	Doente (MeanSUVR)	Doente (MeanZscore)	Normal (MeanSUVR)
Frontal_esquerdo	1.39	1.32	1.12
Frontal_direito	1.43	1.32	1.15
Parietal_esquerdo	1.40	1.26	1.09
Parietal_direito	1.40	1.33	1.10
Ocipital_esquerdo	1.34	0.89	1.16
Ocipital_direito	1.34	1.11	1.13
Temporal_esquerdo	1.41	1.69	1.08
Temporal_direito	1.40	1.52	1.11
Putamen_esquerdo	1.84	4.75	1.08
Putamen_direito	1.89	4.61	1.13



Machine learning classifier: amyloid* positive

* Alzheimer's disease biomarker

Our work @ Champalimaud Foundation

Workflow **optimization**

- Reducing **acquisition duration** – medical image acquisition usually takes (a long) time!!
- **AI**-based **post-processing** allows for faster acquisitions:
    - **more patients** per day
    - **lower burden** for the patient
    - **lower susceptibility** for motion artifacts

10 s acquisition
(x 10 bed positions)

10 s acquisition
(x 10 bed positions)
+ **AI**

Our work @ Champalimaud Foundation

Research → Clinic

Identification of a **problem** or an **unmet need**

Development and **validation** of hypothesis (ideas)

Implementation into clinical workflow

Biomedical engineers 🤝 **Doctors**

(**Translational** research)

Download **3D Slicer**

https://download.slicer.org/

3D Slicer image computing platform

Download | Documentation | Developers

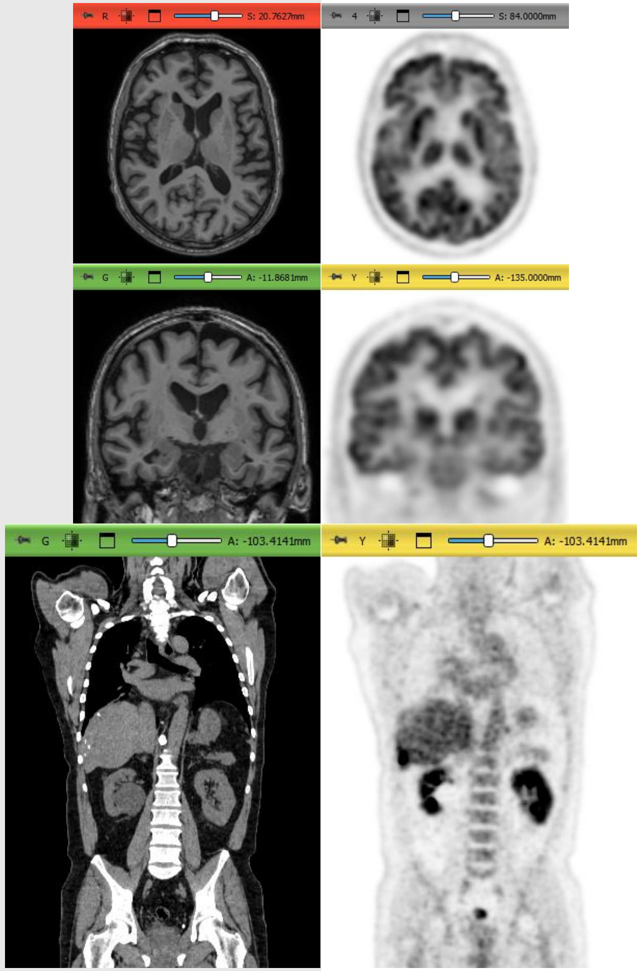
Training | Forum | LinkedIn

3D Slicer is a **free**, **open source** software for visualization, processing, segmentation, registration, and analysis of medical, biomedical, and other 3D images and meshes; and planning and navigating image-guided procedures.

Structural vs. **Functional** Imaging

Structural Imaging
E.g.: MRI, CT

- Provides **structural/spatial** information
- ↑ **spatial resolution** for visualizing anatomical details
- ↓ **functional/temporal** information

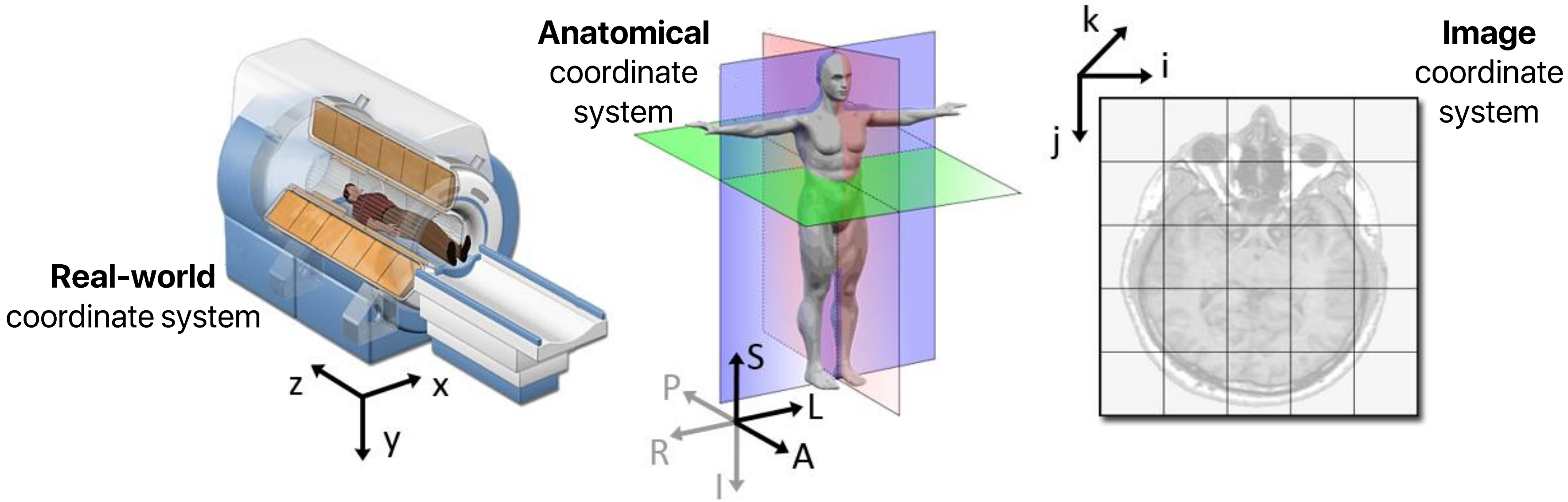


Functional Imaging
E.g.: PET, SPECT, fMRI

- Provides **functional** information (e.g. metabolic activity)
- ↑ **functional/temporal** information for translating tissue function/activity
- ↓ **spatial resolution**

Medical Image **Basics**

- Medical images are more than just an array!!!
- Each **point in the image** is mapped to a **location in the real world**:



How? By defining **origin**, **spacing**, **size** and **direction matrix**

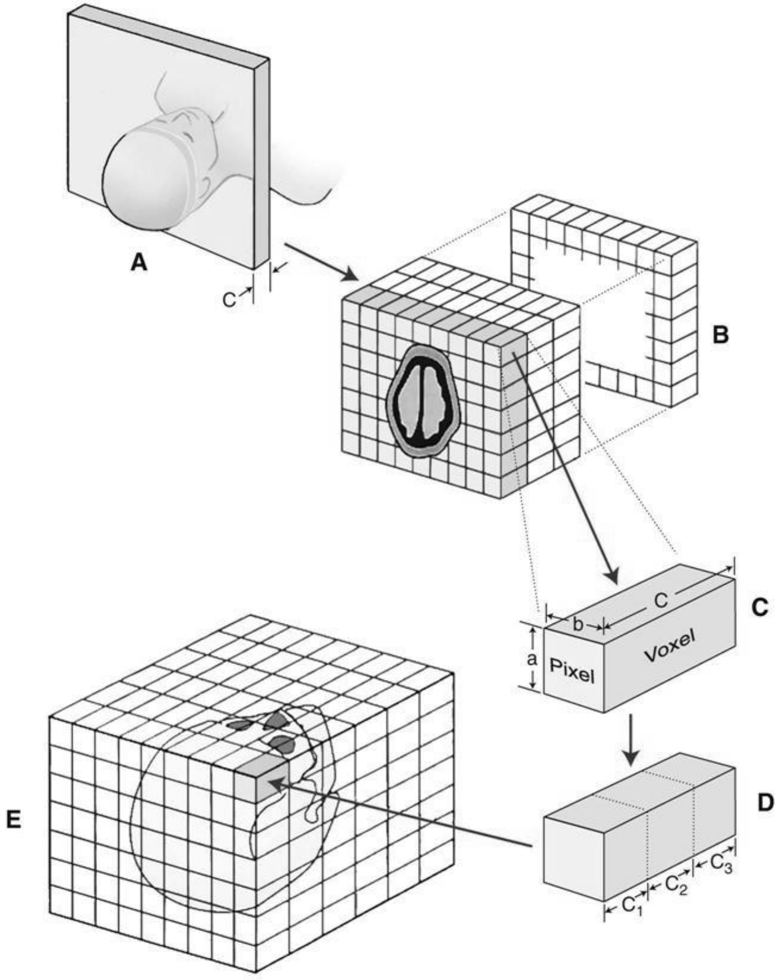
Medical Image **Basics**

Origin: location in the world coordinate system of the voxel with all zero indexes in the image coordinate system – e.g. (0, 0, 0) for 3D space.

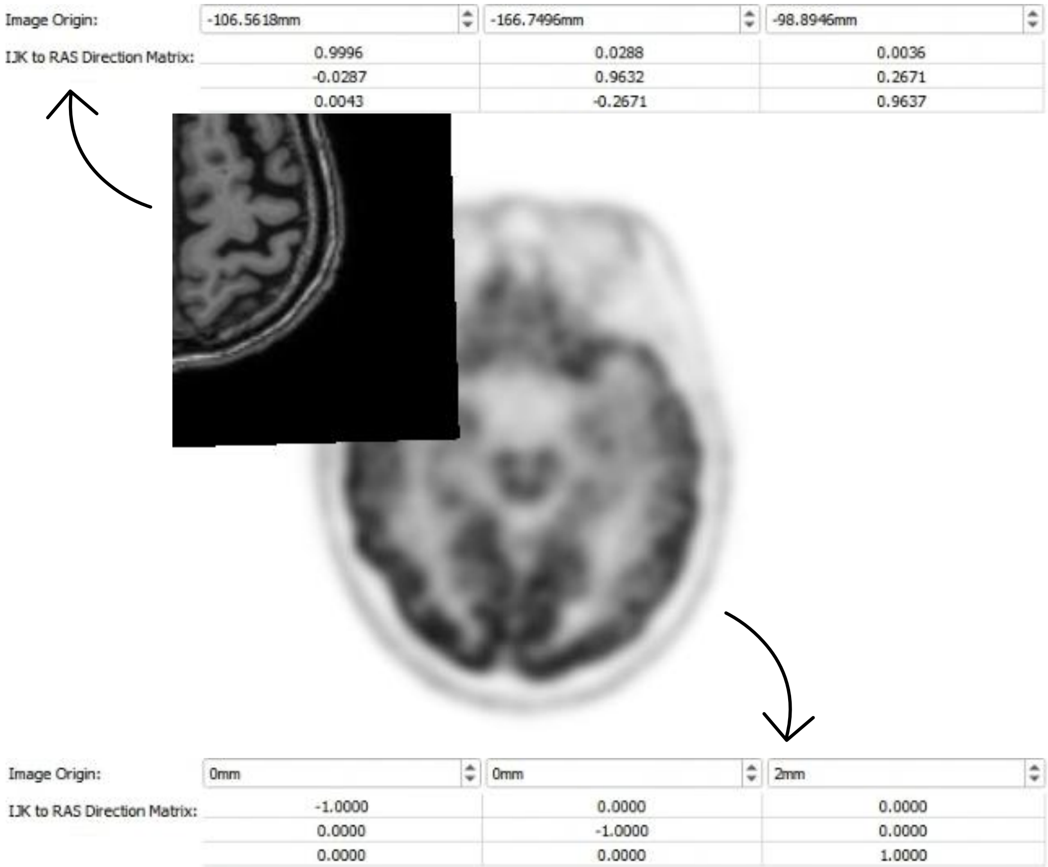
Spacing: real-world distance between pixels/voxels along each of the dimensions.

Size: number of pixels/voxels in each dimension.

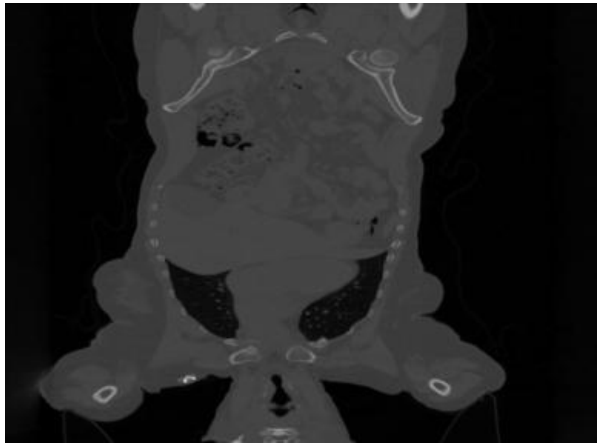
Direction cosine matrix: orientation of the image coordinate system relative to a reference coordinate system (real-world coordinates).



Medical Image **Basics**

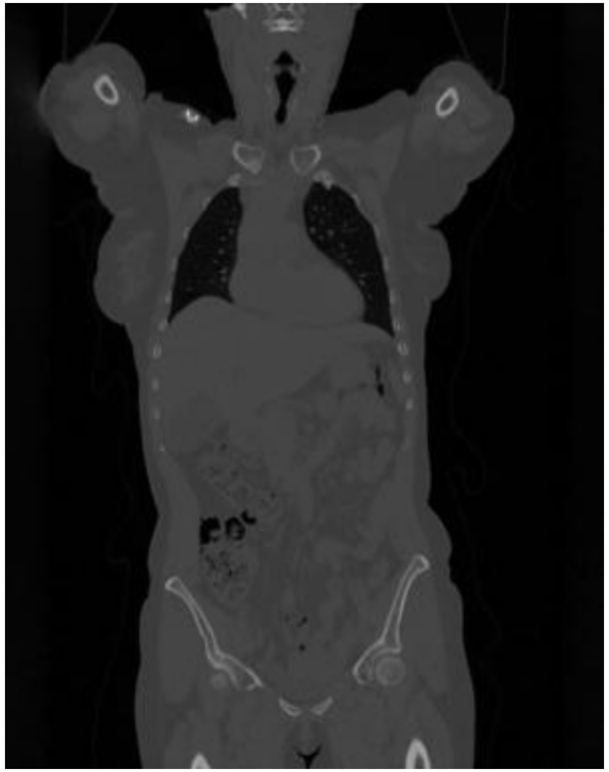


Different **origins** and **direction matrices**



Wrong **spacing** and **direction matrix**

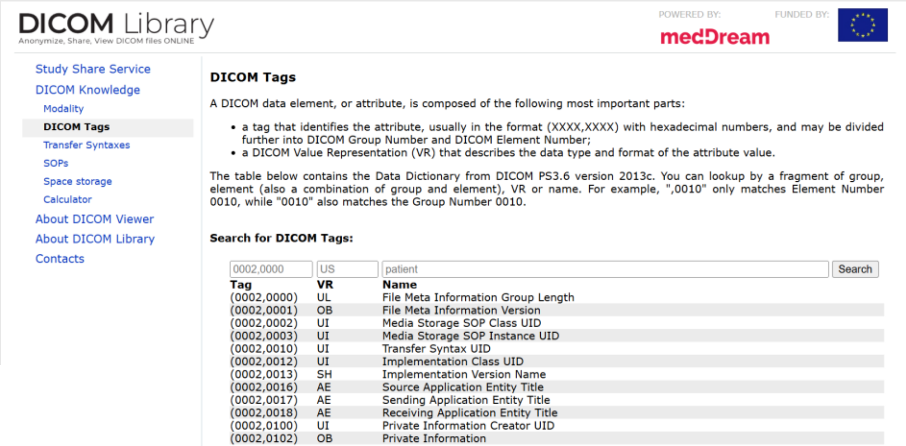
corrected



DICOM (Digital Imaging and Communications in Medicine)

- Globally adopted standard for the **digital storage** and **transmission** of medical images and other clinical information.
- Stores **metadata** – like **patient information** (name, sex, weight, etc.) but also **image acquisition parameters**:

How? Each information field is attributed a **hexadecimal tag** (e.g. (0010,0010) for patient name) – which is used by **all manufacturers**


DICOM Library
Anonymize, Share, View DICOM files ONLINE
POWERED BY: medDream
FUNDED BY:

Study Share Service
DICOM Knowledge
Modality
DICOM Tags
Transfer Syntaxes
SOPs
Space storage
Calculator
About DICOM Viewer
About DICOM Library
Contacts

DICOM Tags

A DICOM data element, or attribute, is composed of the following most important parts:

- a tag that identifies the attribute, usually in the format (XXXX,XXXX) with hexadecimal numbers, and may be divided further into DICOM Group Number and DICOM Element Number;
- a DICOM Value Representation (VR) that describes the data type and format of the attribute value.

The table below contains the Data Dictionary from DICOM PS3.6 version 2013c. You can lookup by a fragment of group, element (also a combination of group and element), VR or name. For example, ",0010" only matches Element Number 0010, while "0010" also matches the Group Number 0010.

Search for DICOM Tags:

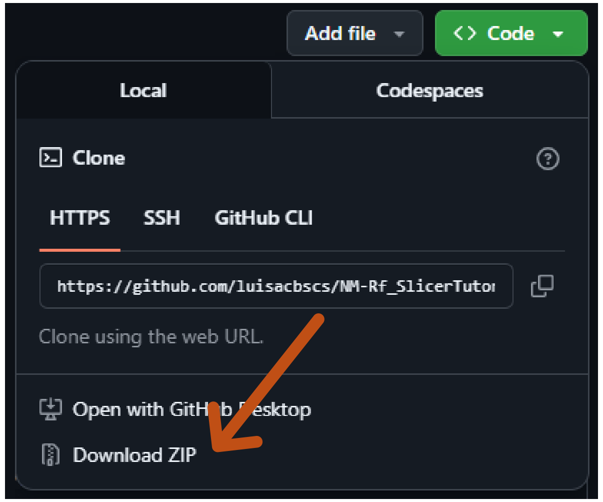
0002,0000 | US | patient | Search

Tag	VR	Name
(0002,0000)	UL	File Meta Information Group Length
(0002,0001)	OB	File Meta Information Version
(0002,0002)	UI	Media Storage SOP Class UID
(0002,0003)	UI	Media Storage SOP Instance UID
(0002,0010)	UI	Transfer Syntax UID
(0002,0012)	UI	Implementation Class UID
(0002,0013)	SH	Implementation Version Name
(0002,0016)	AE	Source Application Entity Title
(0002,0017)	AE	Sending Application Entity Title
(0002,0018)	AE	Receiving Application Entity Title
(0002,0100)	UI	Private Information Creator UID
(0002,0102)	OB	Private Information

(0010,0020)	PatientID	005_S_0221
(0010,0040)	PatientSex	M
(0018,0000)	GenericGroupLength	54
(0018,0050)	SliceThickness	2.42500
(0018,1020)	SoftwareVersions	72
(0018,1210)	ConvolutionKernel	Ramp
(0018,1242)	ActualFrameDuration	1800000
(0020,0000)	GenericGroupLength	252
(0020,000d)	StudyInstanceUID	1.3.6.1.4.1.13856.242000.1.2.5057.2.624698184470.2
(0020,000e)	SeriesInstanceUID	1.3.6.1.4.1.13856.242000.1.2.5057.3.624698184493.2
(0020,0010)	StudyID	
(0020,0011)	SeriesNumber	
(0020,0013)	InstanceNumber	1
(0020,0032)	ImagePositionPatient	[3] 0.0, 0.0, 2.42490
(0020,0037)	ImageOrientationPatient	[6] 1, 0, 0, 0, 1, 0
(0020,0052)	FrameOfReferenceUID	1.3.6.1.4.1.13856.242000.1.2.5057.4.624698184494.2
(0020,1040)	PositionReferenceIndicator	
(0028,0000)	GenericGroupLength	146
(0028,0002)	SamplesPerPixel	1
(0028,0004)	PhotometricInterpretation	MONOCHROME2
(0028,0010)	Rows	128
(0028,0011)	Columns	128
(0028,0030)	PixelSpacing	[2] 2.05941, 2.05941
(0028,0100)	BitsAllocated	16
(0028,0101)	BitsStored	16

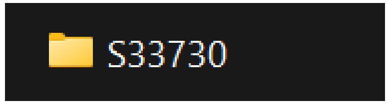
Hands-on tutorial: **Whole-body** Imaging

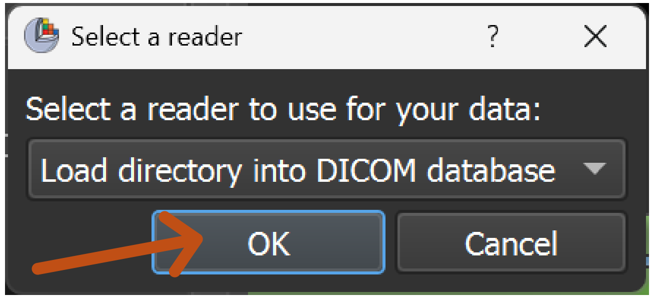
1. Open **3D Slicer**
2. Download the images (DICOM series) from GitHub

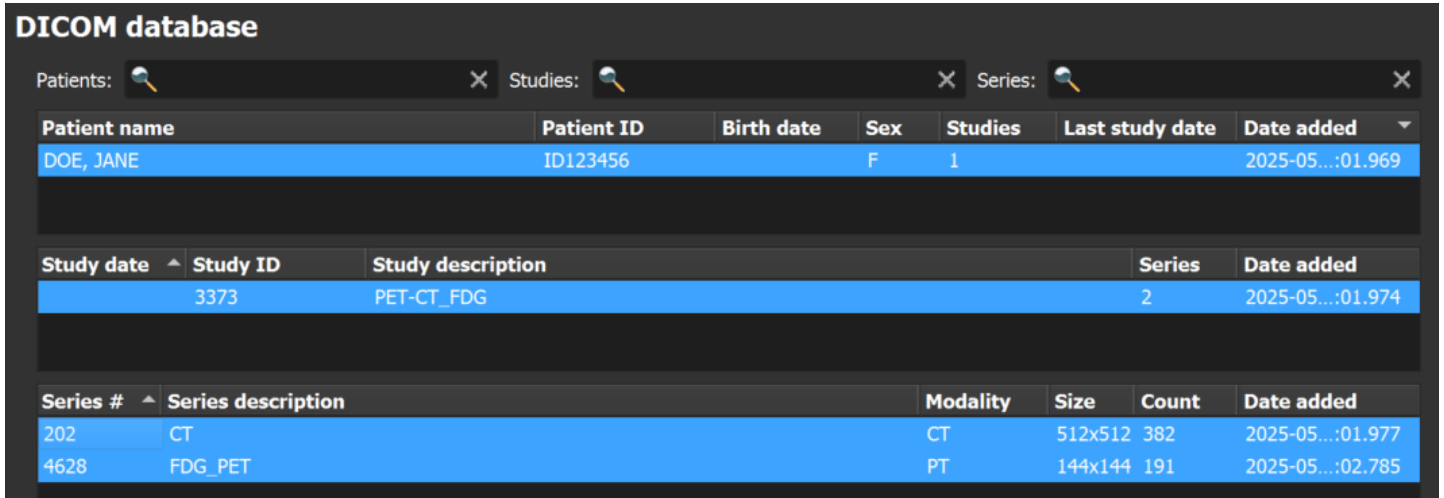


You can **download the entire folder** for the tutorial:
https://github.com/luisacbscs/NM-Rf_SlicerTutorial

3. Drag the **DICOM series** (S33730) **folder into 3D Slicer**



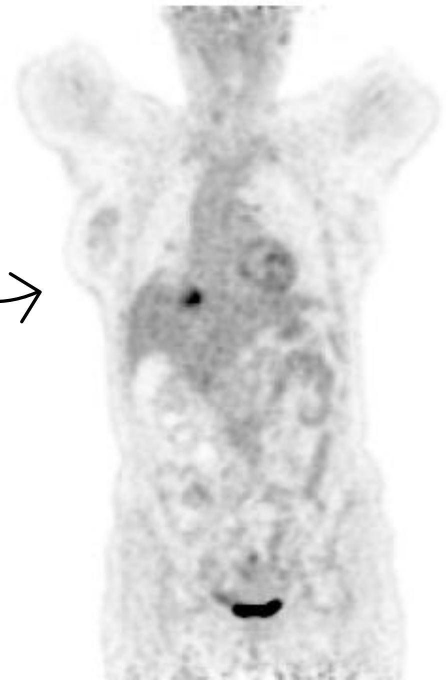




[^{18}F]**FDG PET/CT**

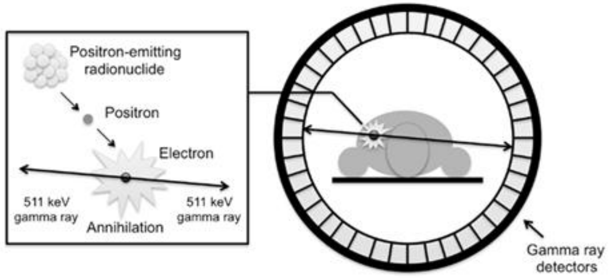
In **Positron Emission Tomography (PET)** Imaging, a **target molecule** labelled with a **radioisotope** is administered to the patient – this allows us to see the **biodistribution of that molecule in the body**.

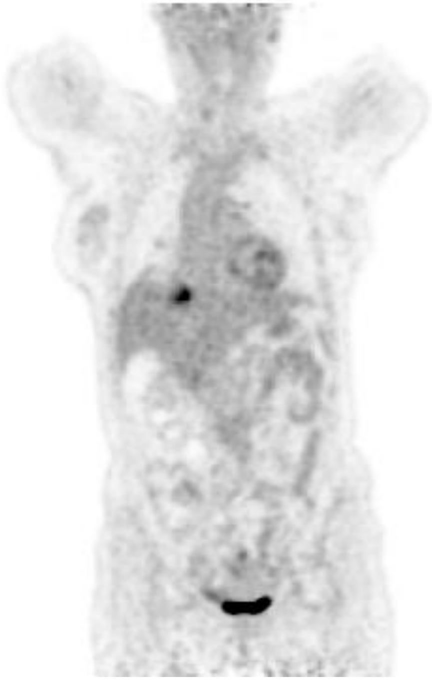
- **[^{18}F]FDG** – analog of glucose labelled with fluorine-18: we can see the **metabolic activity in the body**!
- **Cancer cells** are characterized by **uncontrolled growth/proliferation**, requiring **more energy** (**glucose**!) than normal healthy cells → tumor lesions with glucose avidity can be observed in [^{18}F]FDG PET.



[^{18}F]**FDG PET/CT**

In **Positron Emission Tomography (PET)** Imaging, a **target molecule** labelled with a **radioisotope** is administered to the patient – this allows us to see the **biodistribution of that molecule in the body**.





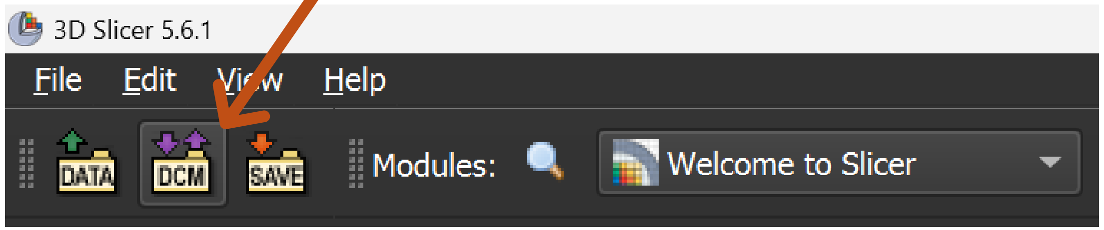
- The PET scanner's detectors count **how many radioactive decays occur** in a given volume in space (voxel).
- The image is, thus, provided in **activity concentration**, i.e. radioactive decays per unit of volume (Bq/mL) – this highly depends on **patient weight** and the "**amount**" **injected**...

Converting PET image to **SUV** (standardized uptake value):
normalizing images with respect to weight and administered activity

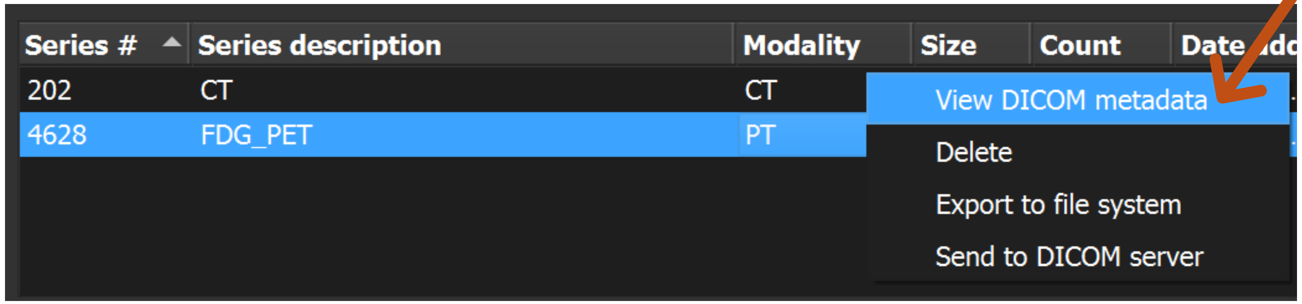
Converting PET image to **SUV** (standardized uptake value): normalizing images with respect to weight and administered activity

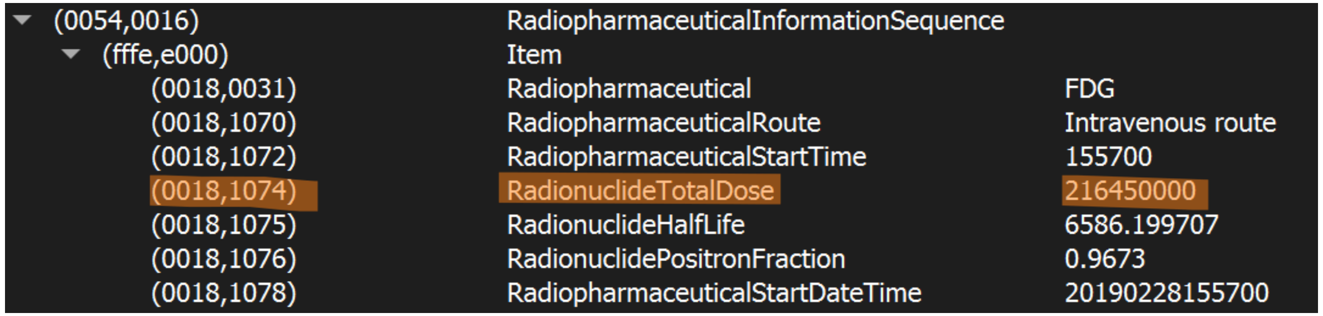
$$\textbf{SUV conversion factor} = \frac{\text{administered activity [Bq]}}{\text{weight [g]}}$$

1



2





3

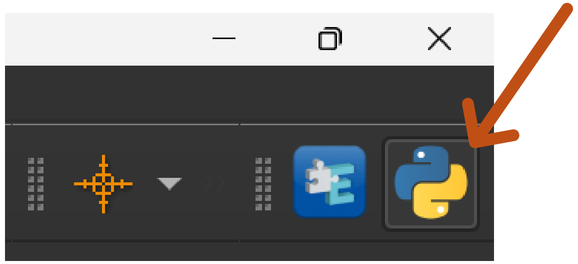
$$\textbf{SUV conversion factor} = \\ = \frac{216450000\ \text{[Bq]}}{\text{????}\ \text{[g]}}$$

Converting PET image to **SUV** (standardized uptake value): normalizing images with respect to weight and administered activity

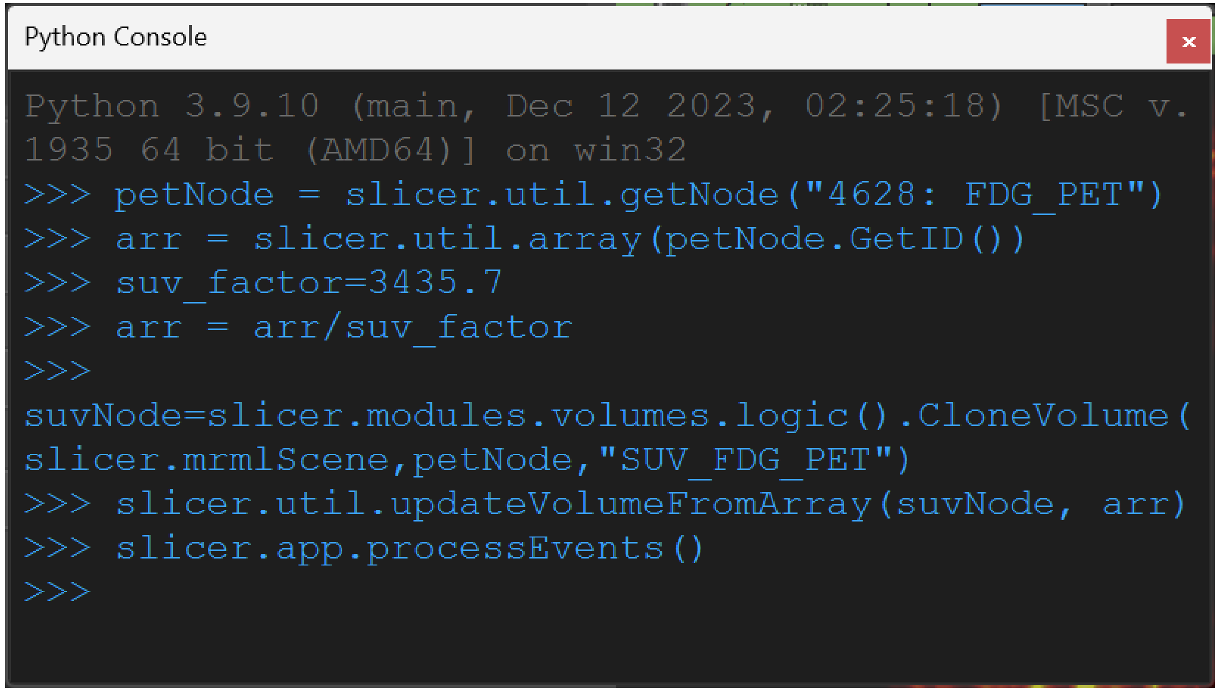
$$\textbf{SUV conversion factor} = \frac{\text{administered activity [Bq]}}{\text{weight [g]}}$$

$$= \frac{216450000\ [\text{Bq}]}{63000\ [\text{g}]} \approx 3435.7\ [\text{Bq/g}]$$

4



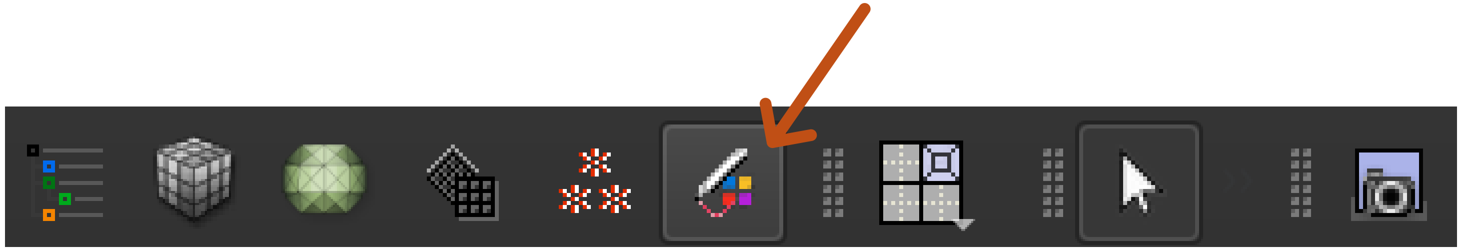
5

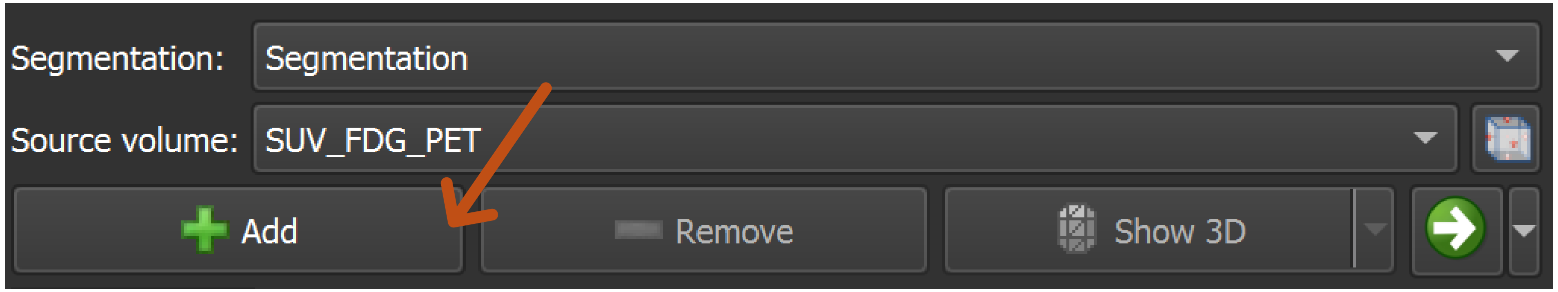


```
Python 3.9.10 (main, Dec 12 2023, 02:25:18) [MSC v.1935 64 bit (AMD64)] on win32
>>> petNode = slicer.util.getNode("4628: FDG_PET")
>>> arr = slicer.util.array(petNode.GetID())
>>> suv_factor=3435.7
>>> arr = arr/suv_factor
>>> suvNode=slicer.modules.volumes.logic().CloneVolume(slicer.mrmlScene,petNode,"SUV_FDG_PET")
>>> slicer.util.updateVolumeFromArray(suvNode, arr)
>>> slicer.app.processEvents()
>>>
```

Or copy+paste from the .txt file on GitHub

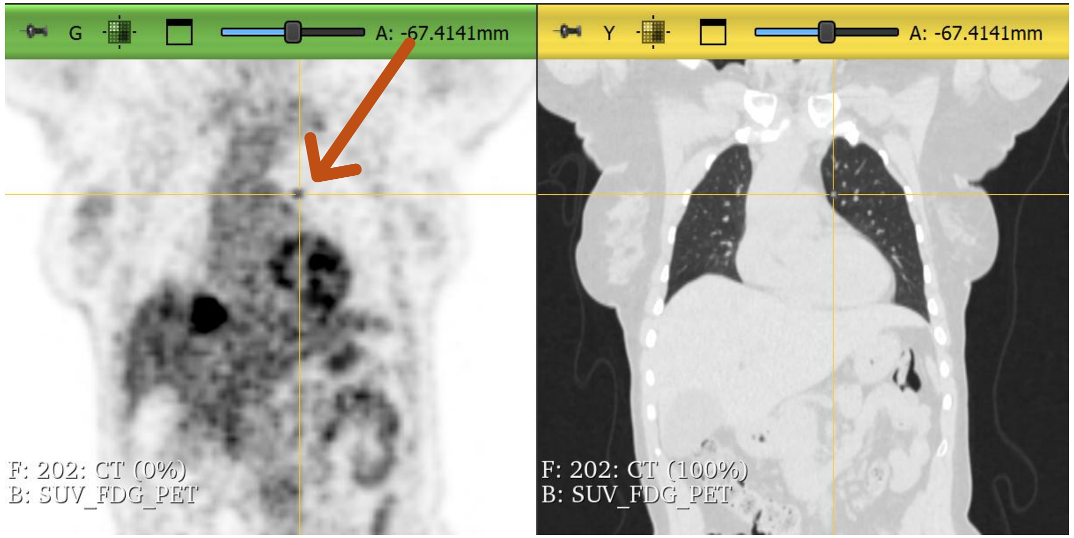
convert_to_SUV_3DSlicer.txt

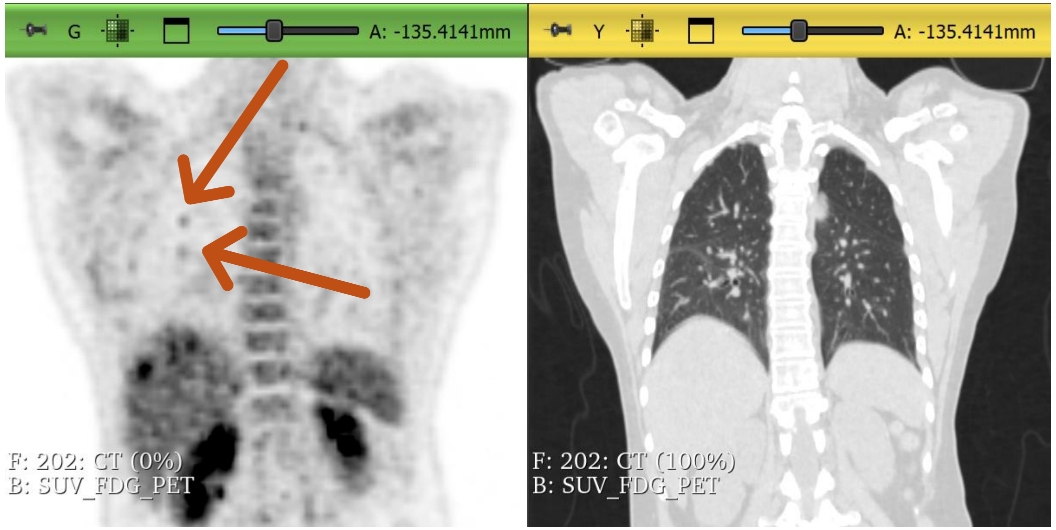


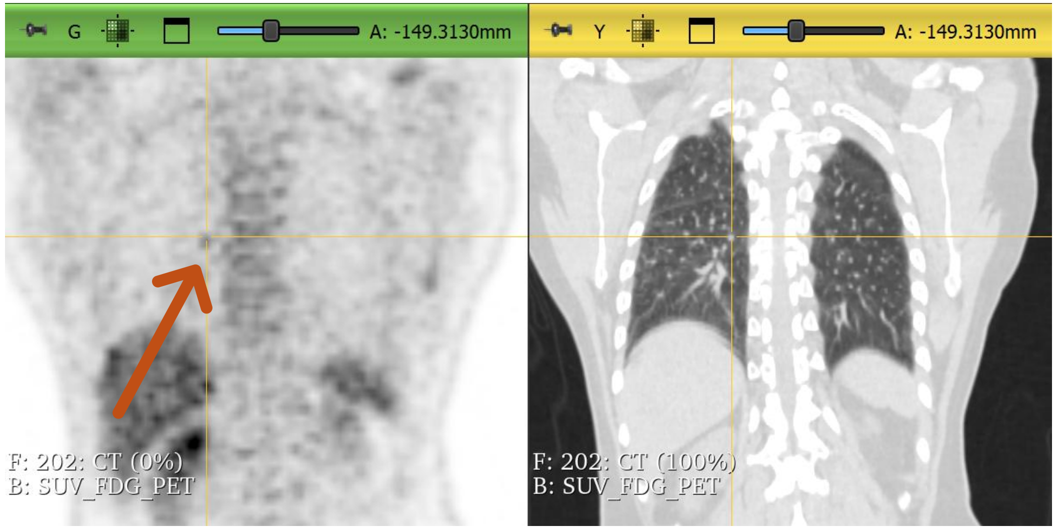


Add a new segment every time you change labels – i.e. every time you start a new lesion segmentation!

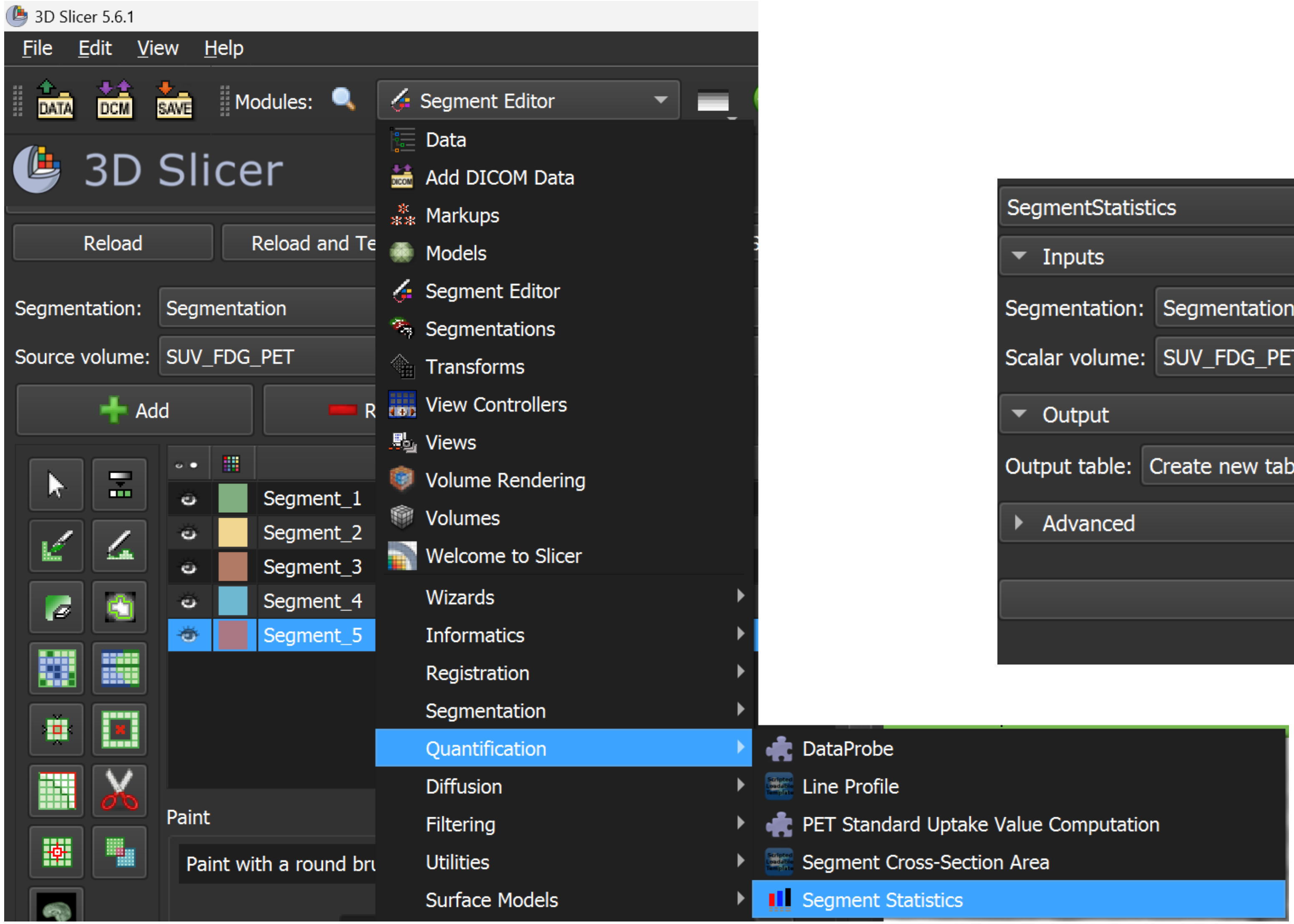
1. **Hands-on** tutorial: **Whole-body** Imaging
1.3. Segmentation

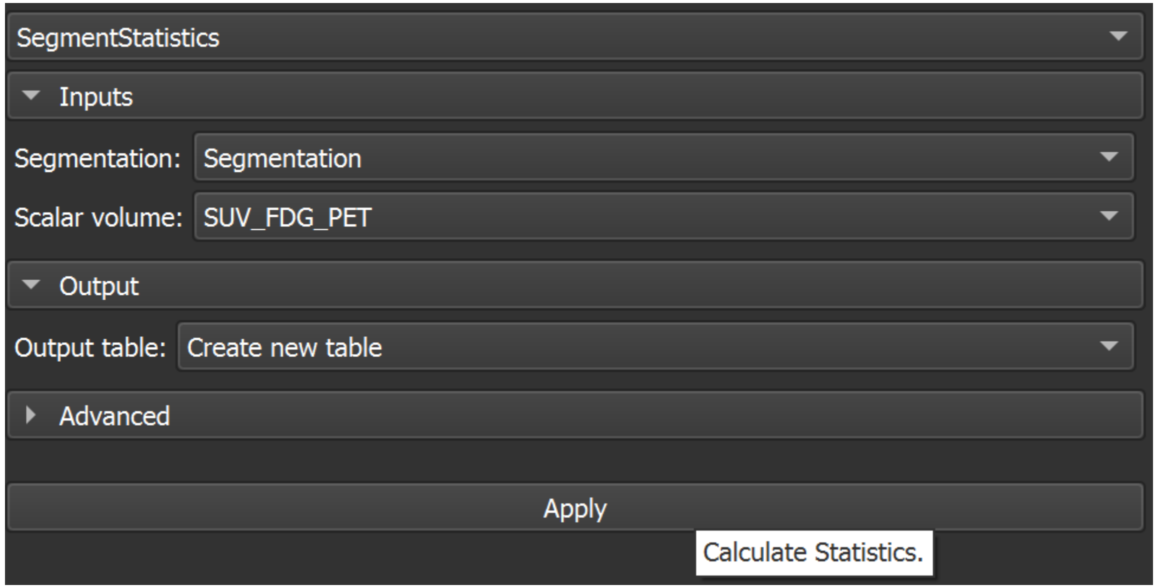






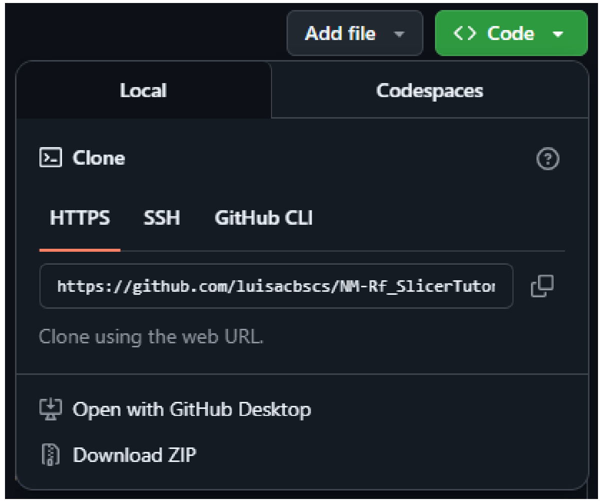
Add a new segment every time you change labels – i.e. every time you start a new lesion segmentation!





Which is the **most metabolically active** lesion?

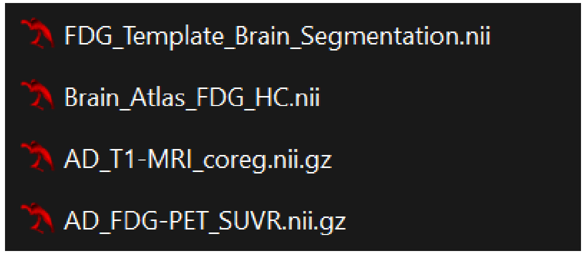
Hands-on tutorial: **Brain** Imaging

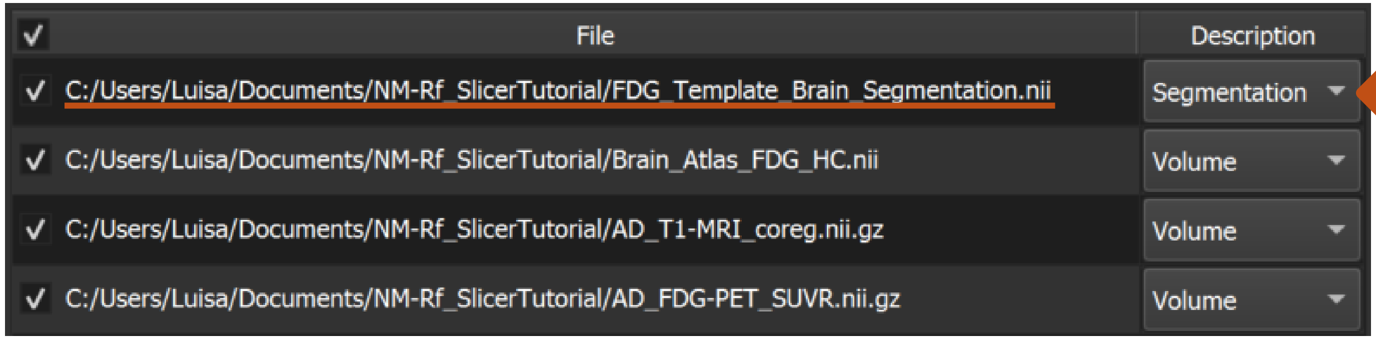


1. Open **3D Slicer**
2. Download the images from GitHub

You can **download the entire folder** for the tutorial:
https://github.com/luisacbscs/NM-Rf_SlicerTutorial

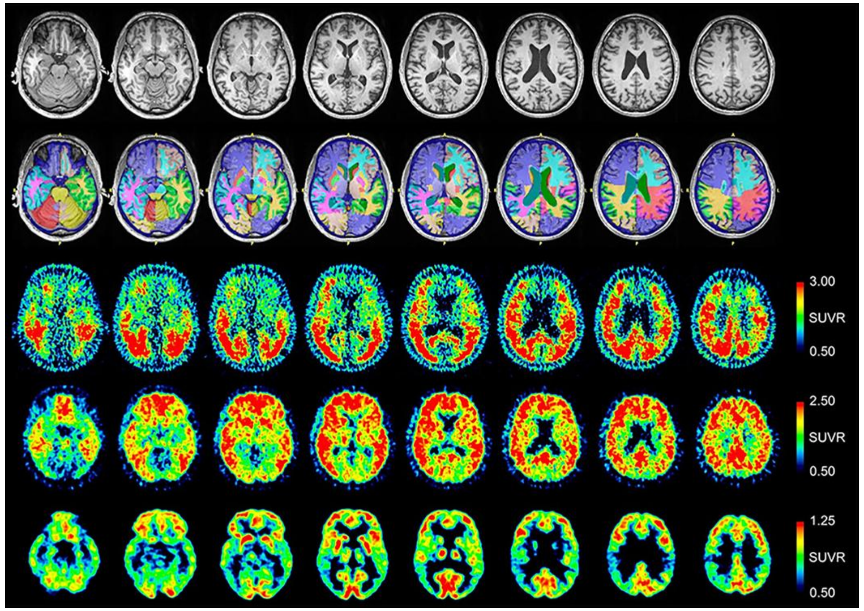
3. Drag the **images** (and mask) **into 3D Slicer**





Brain PET

Brain PET is a non-invasive imaging technique that uses a radioactive tracer to assess **brain function and metabolism**. Different radiopharmaceuticals are used to assess different functions/biodistributions:

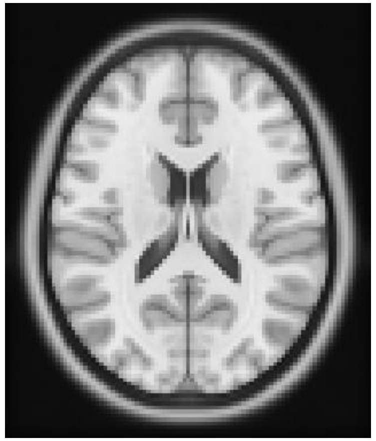


- **[^{18}F]FDG** – Specific patterns of **hypometabolism** (decreased activity) and **hypermetabolism** (increased activity) are used to distinguish different types of dementia.
- **Amyloid PET** (e.g. **[^{18}F]FBB**, **[^{18}F]FBP**, **[^{11}C]PiB**) – Amyloid **deposits**, particularly those of **amyloid beta (Aβ) protein**, are a key characteristic of Alzheimer's disease (AD) and other dementias.
- **Tau PET** (e.g. **[^{18}F]FTP**) – Similar to amyloid PET but for the **Tau protein**, another biomarker of AD and other tauopathies.

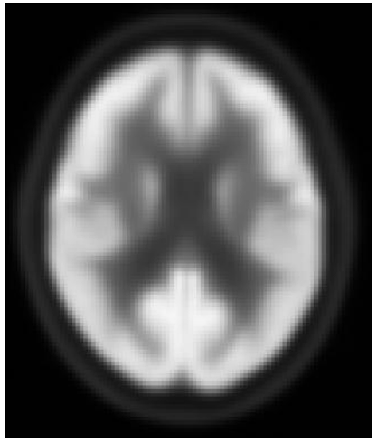
Brain PET

Brain PET is a non-invasive imaging technique that uses a radioactive tracer to assess **brain function and metabolism**. Different radiopharmaceuticals are used to assess different functions/biodistributions.

- To assess **if the biodistribution in different brain regions is altered**, it should be **compared with a healthy brain**.
- **Brain atlases** correspond to the **average of the brain across multiple subjects** (in this case, healthy controls) and are used as a benchmark for comparison.



MRI brain atlas: average of multiple brain MRIs of healthy subjects

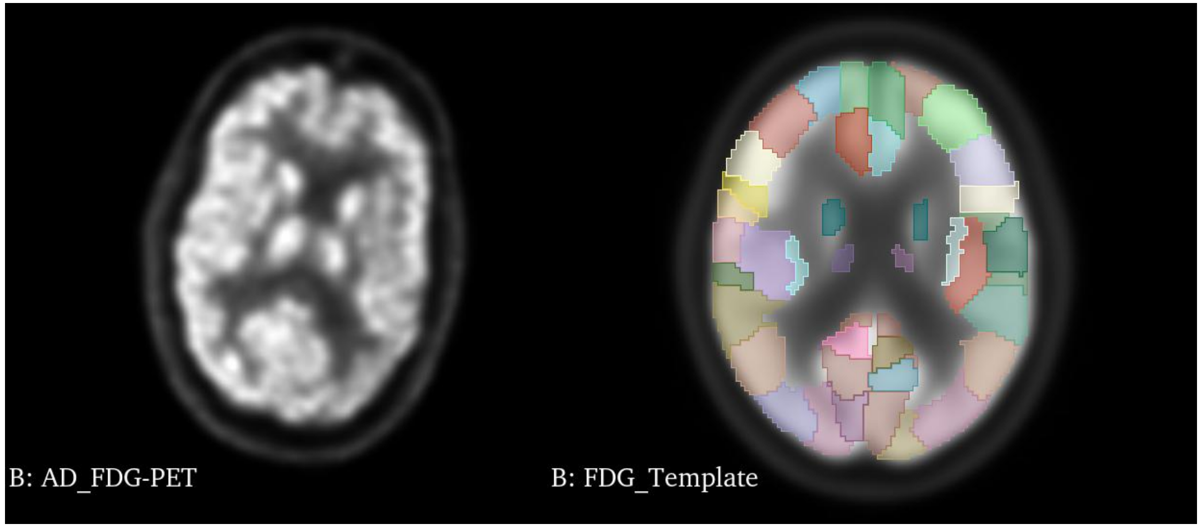


FDG PET brain atlas: average of multiple brain [18F]FDG PET of healthy subjects

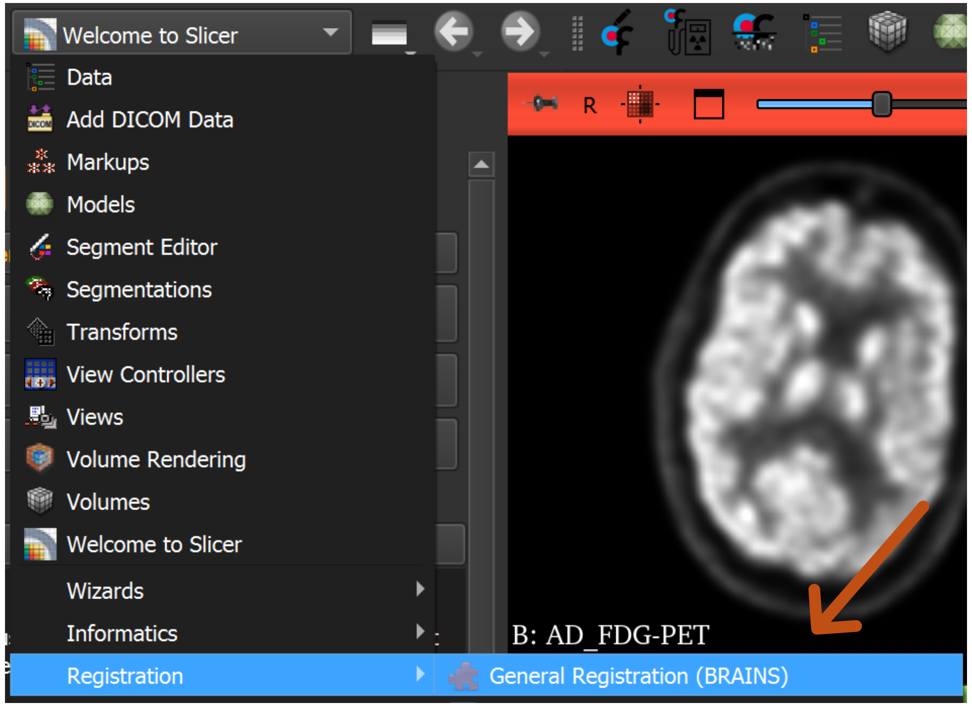
The **brain PET study of the patient** must be **deformed into the corresponding atlas**, so we can assess regional differences in radiopharmaceutical uptake.

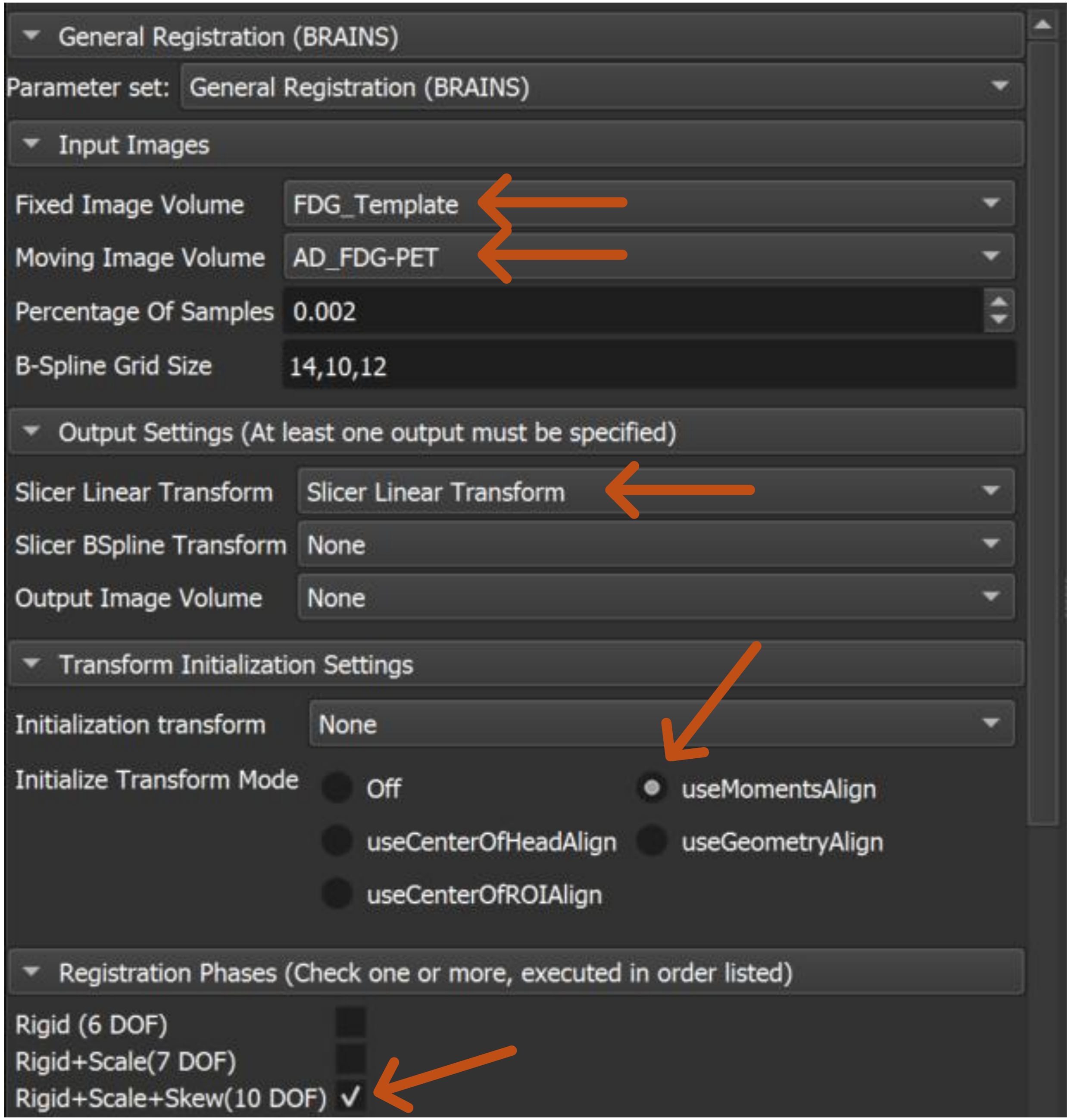
The **brain PET study of the patient** must be **deformed into the corresponding atlas**, so we can assess regional differences in radiopharmaceutical uptake.

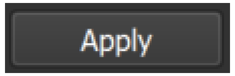
This is called **registration**.



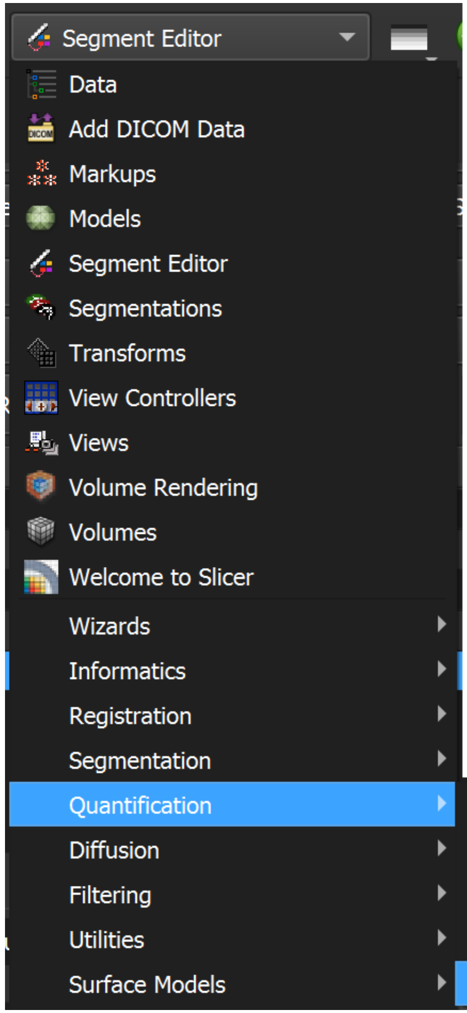
We need to make these two brains – the patient's (left) and the atlas (right) – **overlap**, so the **anatomical regions coincide**.

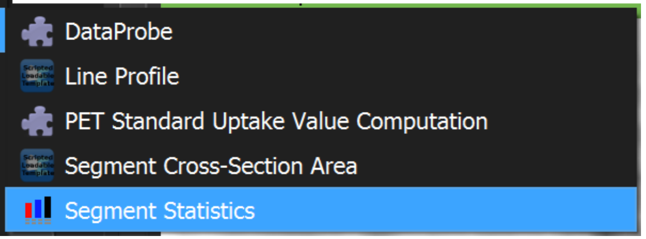




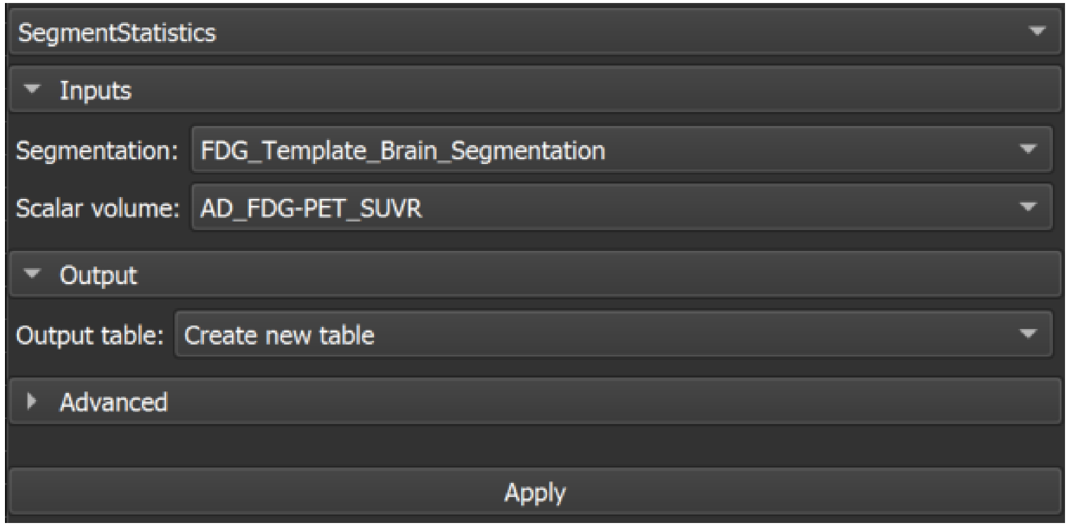


After **registration** is done, you'll see that the patient's brain (AD_FDG-PET) now overlaps with the FDG PET brain atlas!





Let’s perform **regional brain quantification** – as was done before!



In patients with **Alzheimer's Disease**, FDG PET scans typically reveal a characteristic pattern of **hypometabolism** (**decreased glucose uptake**) in specific brain regions, particularly in the parietotemporal cortex - **inferior parietal lobule** and **middle temporal gyrus**.

Labels **61** and **62** (left and right, respectively)

Labels **85** and **86** (left and right, respectively)

FDG uptake in the **brain atlas** – **healthy** controls

Label	Region	Mean Uptake
61	Parietal_Inf_L	1.31715
62	Parietal_Inf_R	1.22215
85	Temporal_Mid_L	1.35607
86	Temporal_Mid_R	1.38914

Given the **healthy uptake values** in the regions of interest for Alzheimer’s disease (AD), is the **metabolic pattern in the patient’s brain** FDG PET **in agreement with a diagnosis of AD**?

Thank you!

Luísa CastelBranco Silva
Biomedical engineer, researcher @ MN-Rf
luisa.silva@research.fchampalimaud.org

Champalimaud Foundation