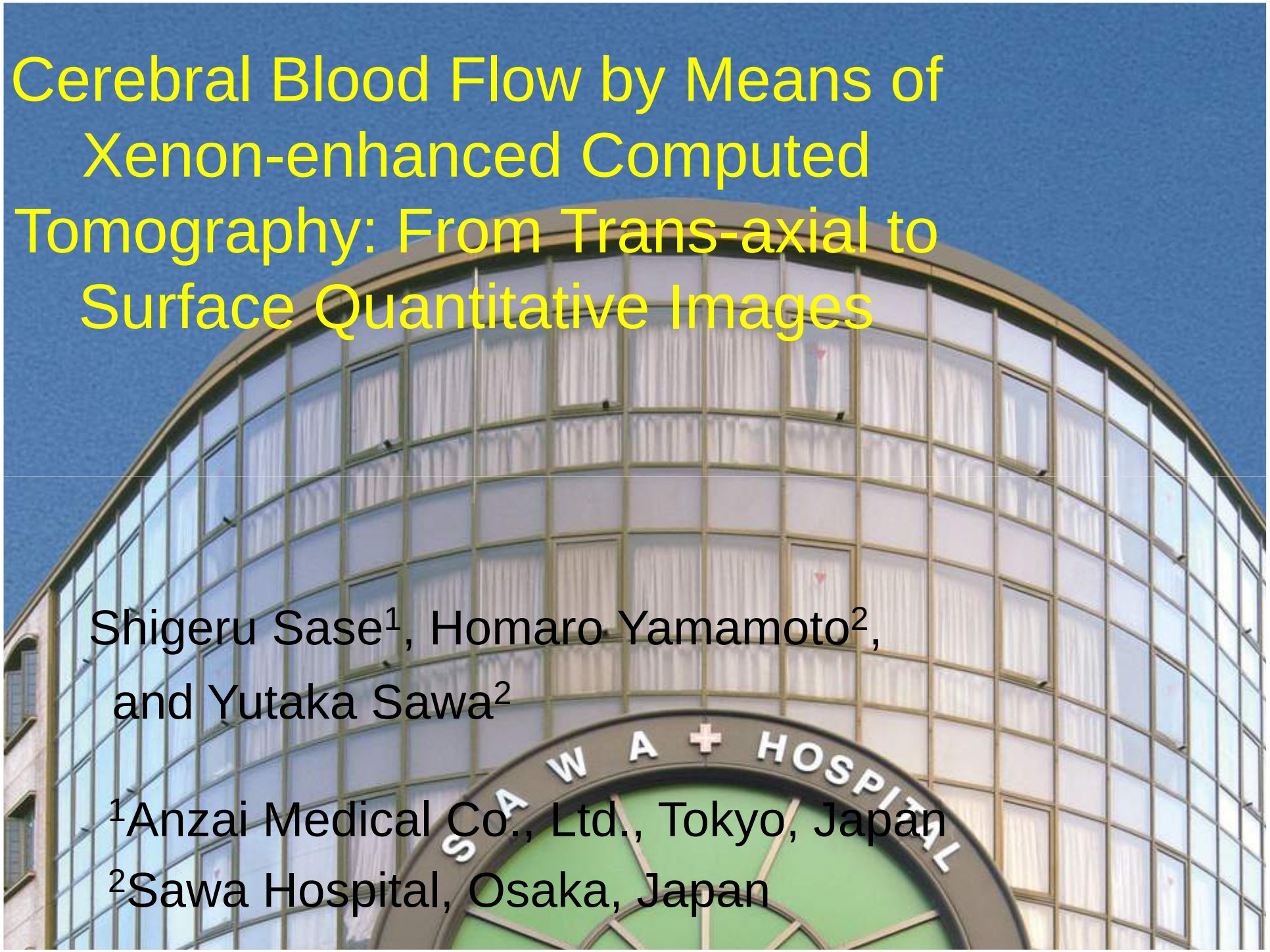
Cerebral Blood Flow by Means of Xenon-enhanced Computed Tomography: From Trans-axial to Surface Quantitative Images



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[Purpose]

- To create brain surface images by stacking thin tomographic images obtained by xenon-enhanced computed tomography (Xe-CT).
- To demonstrate usefulness of layer-by-layer spherical analysis of blood flow and lambda for patients with dementia.

What is Xenon？

① Xe is an inert gas and not metabolized in human body.

② Goes through blood-brain barrier.

③ Soluble in blood and brain tissue.

④ Radiopaque substance due to large atomic weight.

Ideal substance as blood-flow tracer using CT.

Blood flow measurement using Xe gas

Requirements

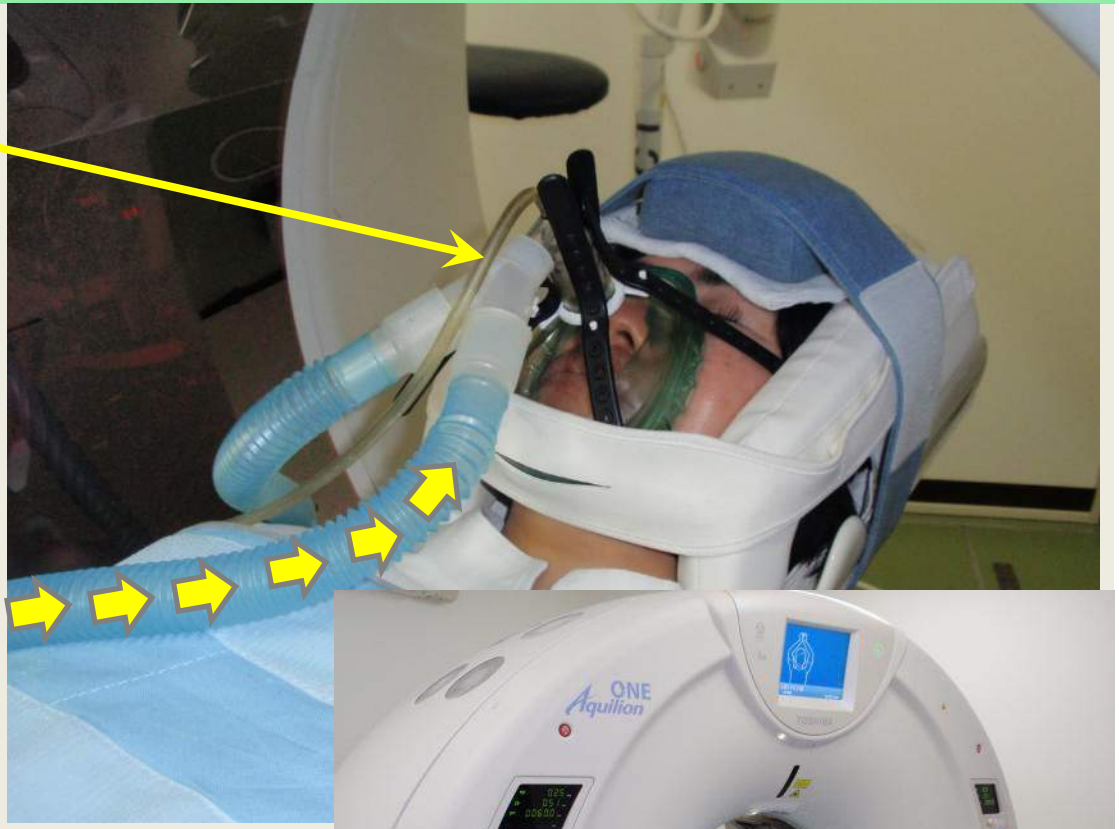
CT System

Xe gas Inhalator

Workstation for
Image Processing

Blood flow measurement using Xe gas

Measurement of respiratory Xe concentration, which is used as a surrogate of arterial Xe.

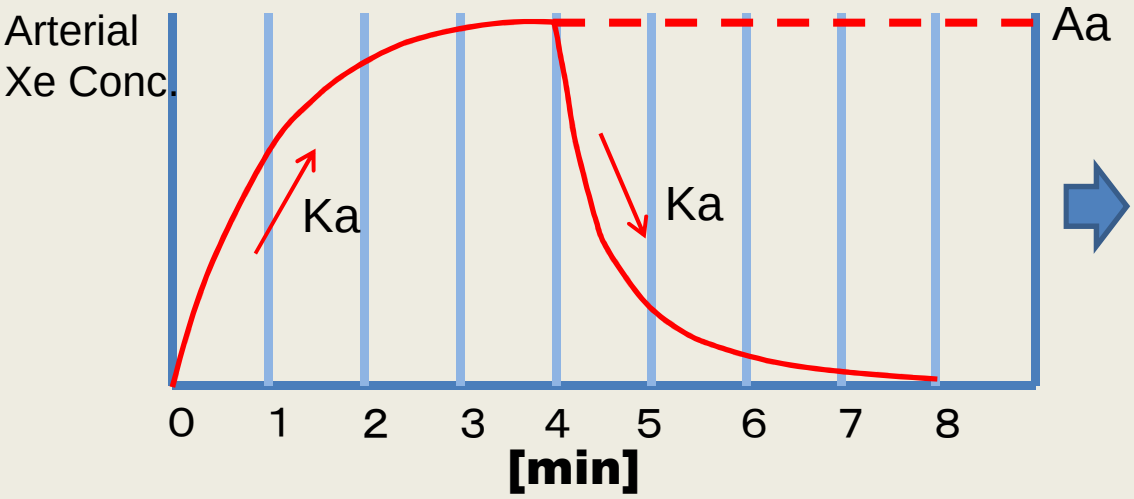


Inhale 30% Xe for 4 min.

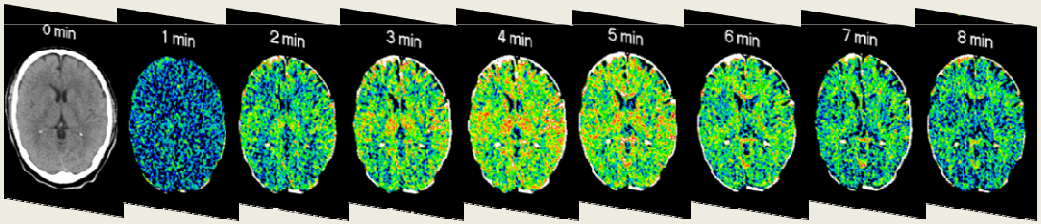
Then, inhale air for 4 min.

Meanwhile, CT scanning
at 1-min intervals.

Blood flow measurement using Xe gas



Saturation speed (Ka) and saturation concentration(Aa) of Xe in arterial blood.

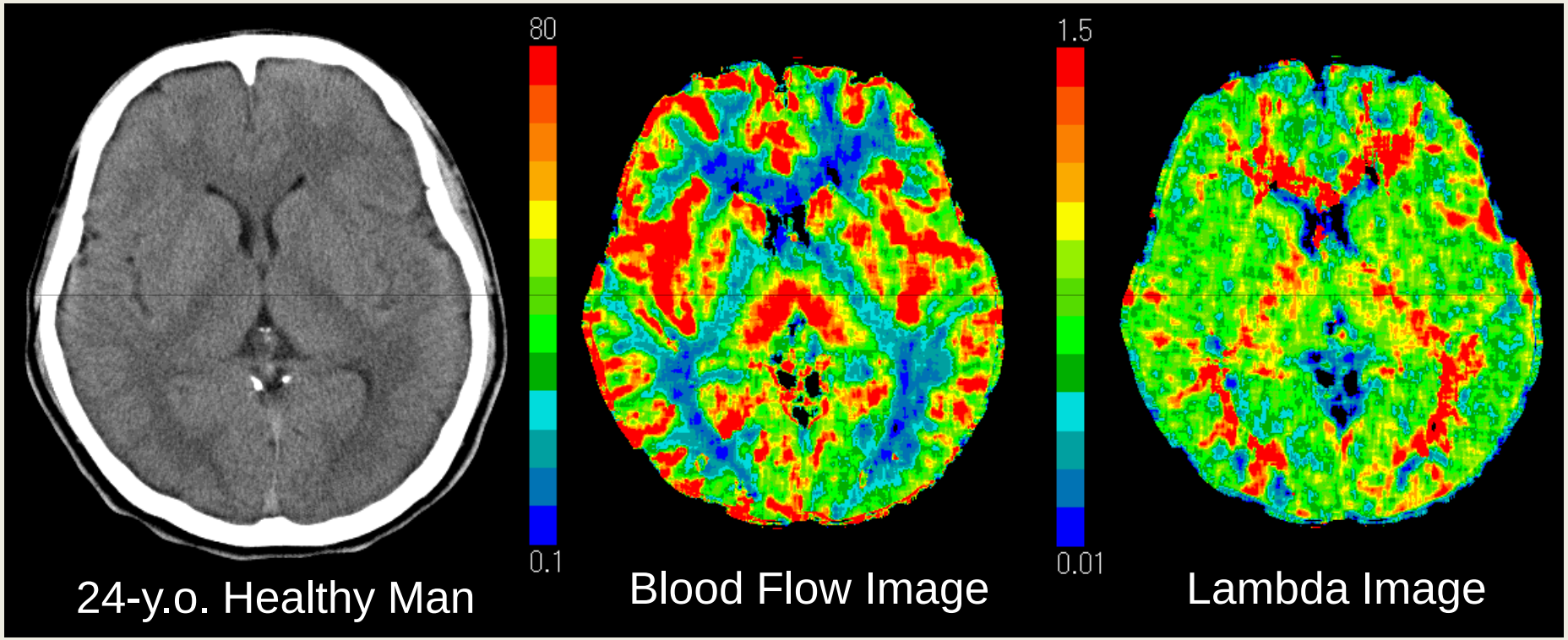


Time course of Xe concentration [**C(t)**]in brain tissue

$$\frac{dC(t)}{dt} = \frac{f}{100} \cdot \left[Aa \cdot \left(1 - e^{-Ka \cdot t} \right) - \frac{C(t)}{\lambda} \right]$$ (Fick's Law)

Blood flow (f) and lambda (λ) can be calculated pixel by pixel using Ka, Aa and C(t).

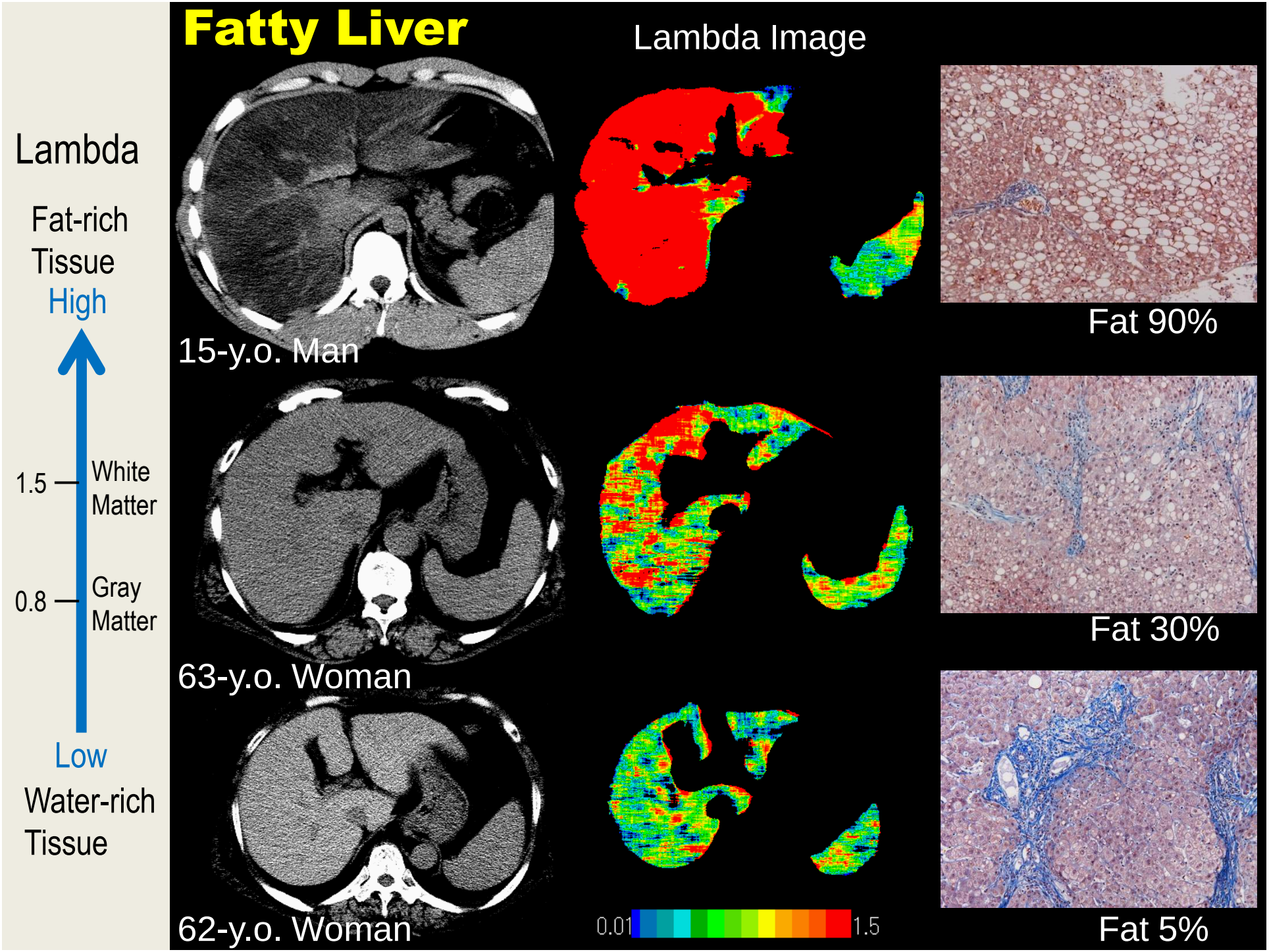
Blood Flow and Lambda Images obtained by Xe-CT



[mL/100 g tissue/min]

Xe Solubility Coefficient

$$= \frac{\text{Xe Solubility in Tissue}}{\text{Xe Solubility in Blood}}$$


Fatty Liver
Lambda Image
Lambda
Fat-rich Tissue
High
1.5
White Matter
0.8
Gray Matter
Low
Water-rich Tissue
15-y.o. Man
63-y.o. Woman
62-y.o. Woman
0.01
1.5
Fat 90%
Fat 30%
Fat 5%

[Methods]

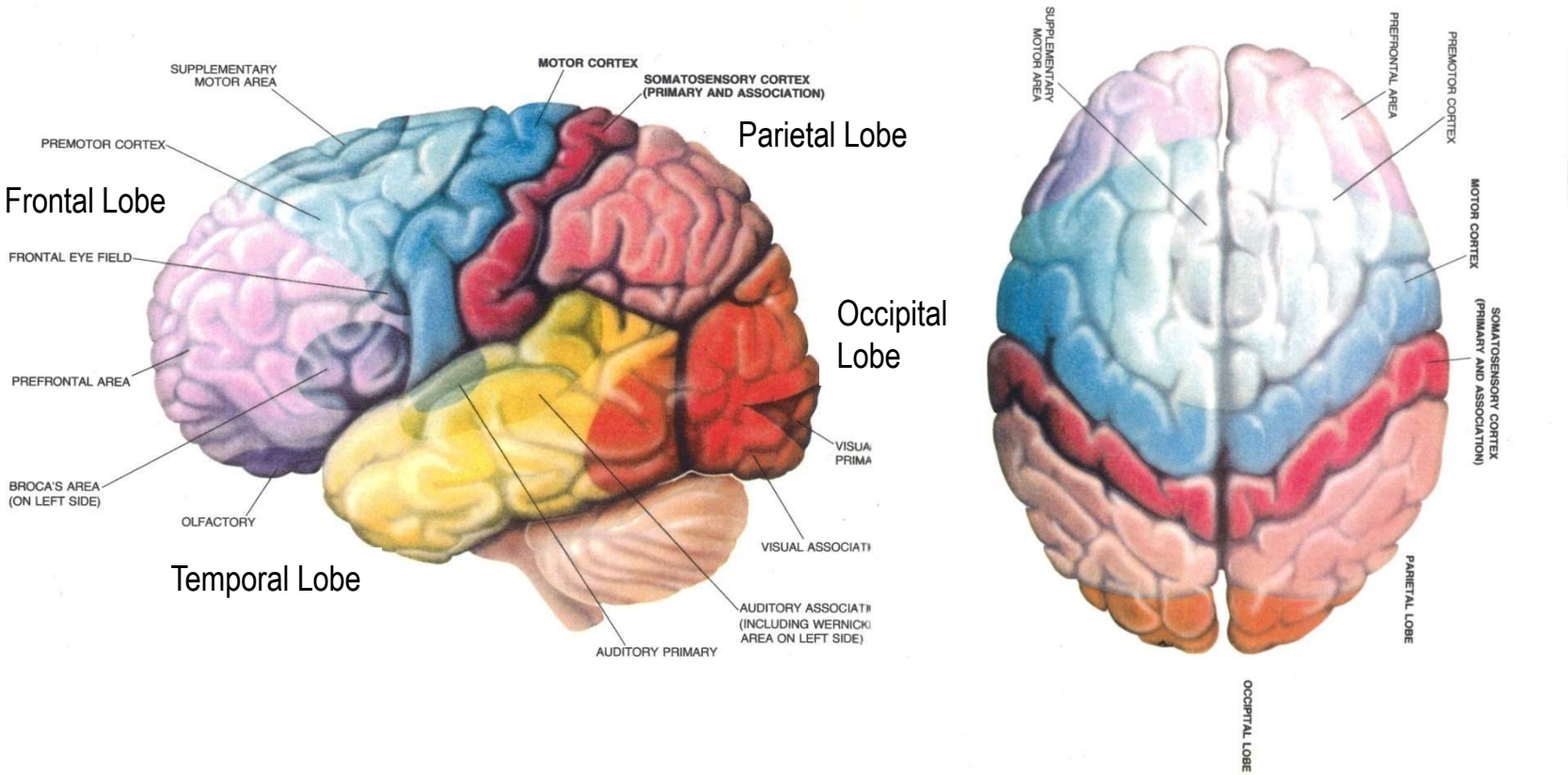
- CT: Aquilion ONE (Toshiba, Japan): Area-detector CT capable of volume scan of the brain.
- Xe gas inhalator: AZ-725 (Anzai Medical, Japan).
- Subjects: Patients with dementia, Age-matched healthy controls.
- Creation of brain surface images, and layer-by-layer analyses (layer thickness: 5mm)

Installed CT Scanner

Toshiba Medical Systems corporation

- The coverage of Detector: 160mm （320-row＊896ch）
- Slice Thickness: 0.5mm （The thinnest in the

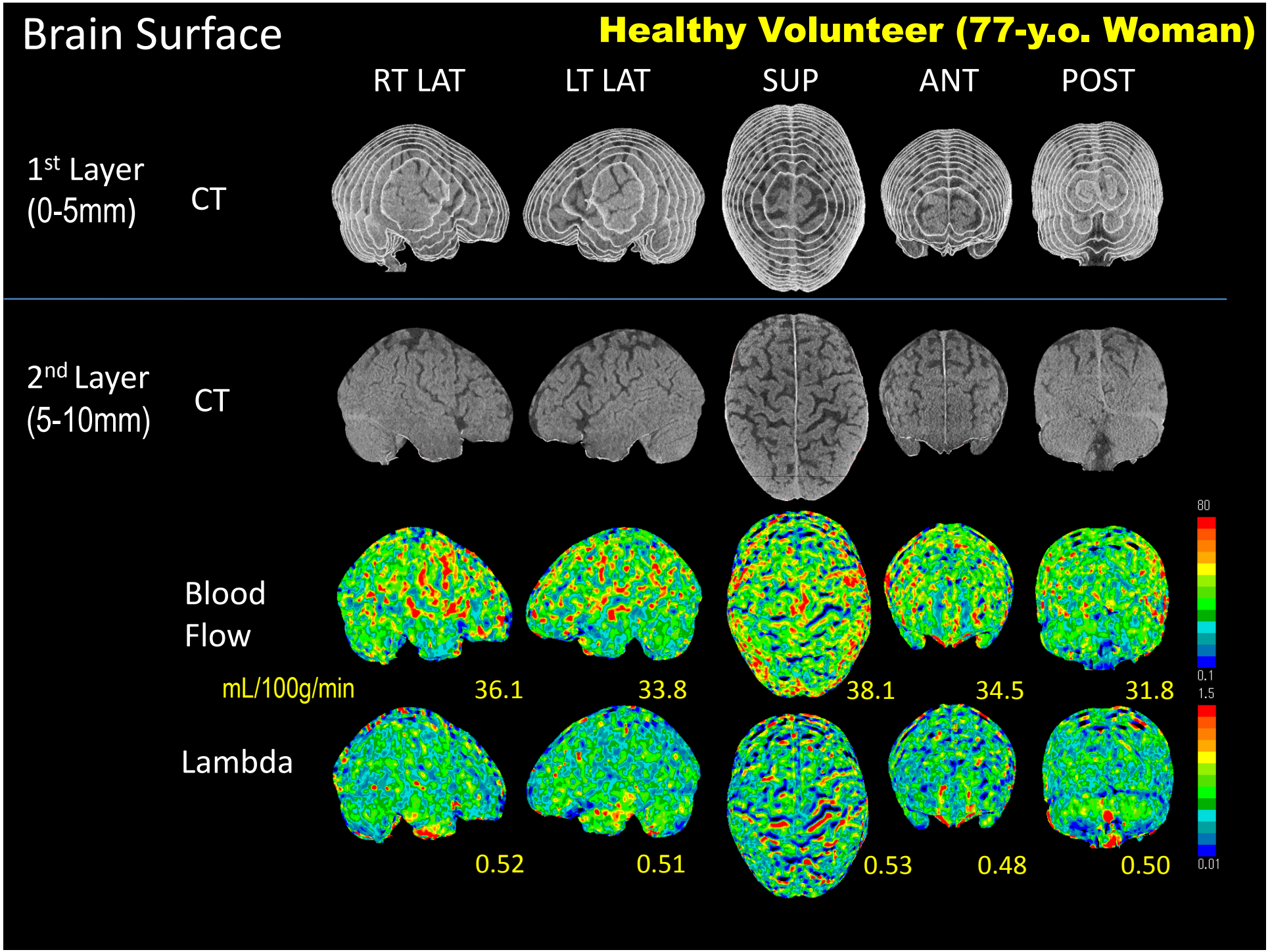
Functional maps of human cerebral cortex



Cortices of frontal, parietal, occipital and temporal lobes

[Results]

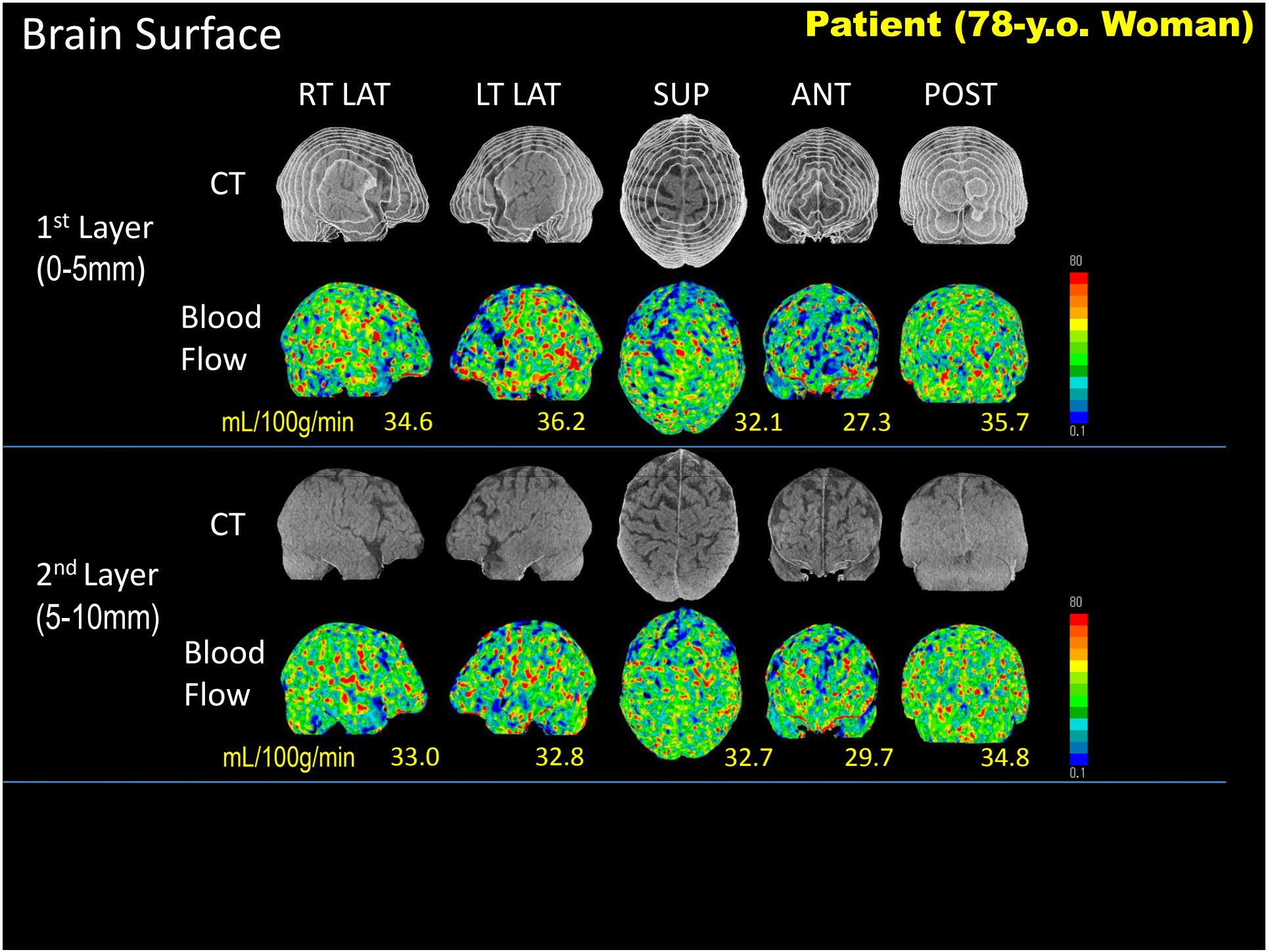
- Surface images of blood flow and lambda for healthy volunteer

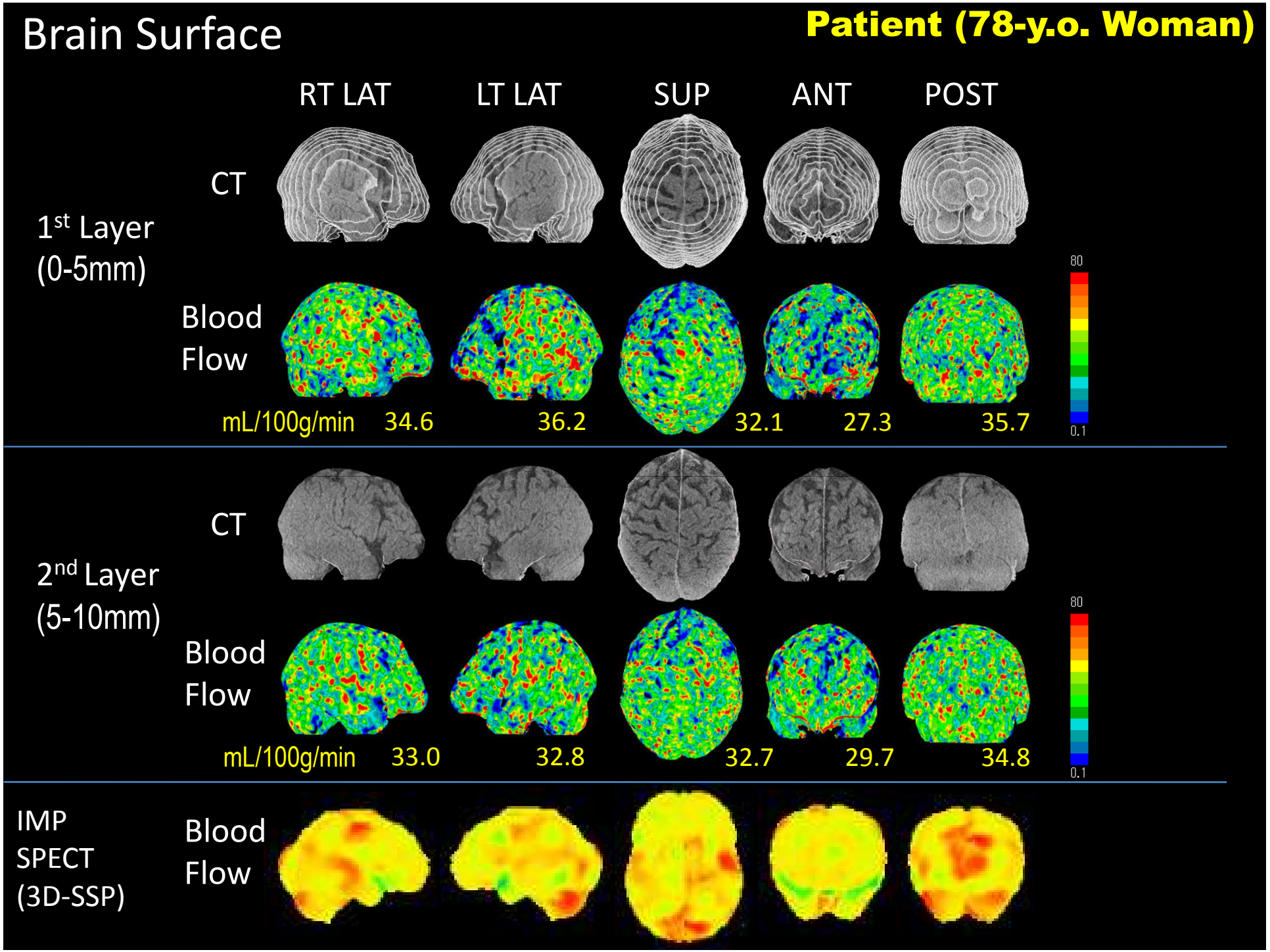

Brain Surface
Healthy Volunteer (77-y.o. Woman)
RT LAT
LT LAT
SUP
ANT
POST
1st Layer (0-5mm)
CT
2nd Layer (5-10mm)
CT
Blood Flow
mL/100g/min
36.1
33.8
38.1
34.5
31.8
Lambda
0.52
0.51
0.53
0.48
0.50
80
0.1
1.5
0.01

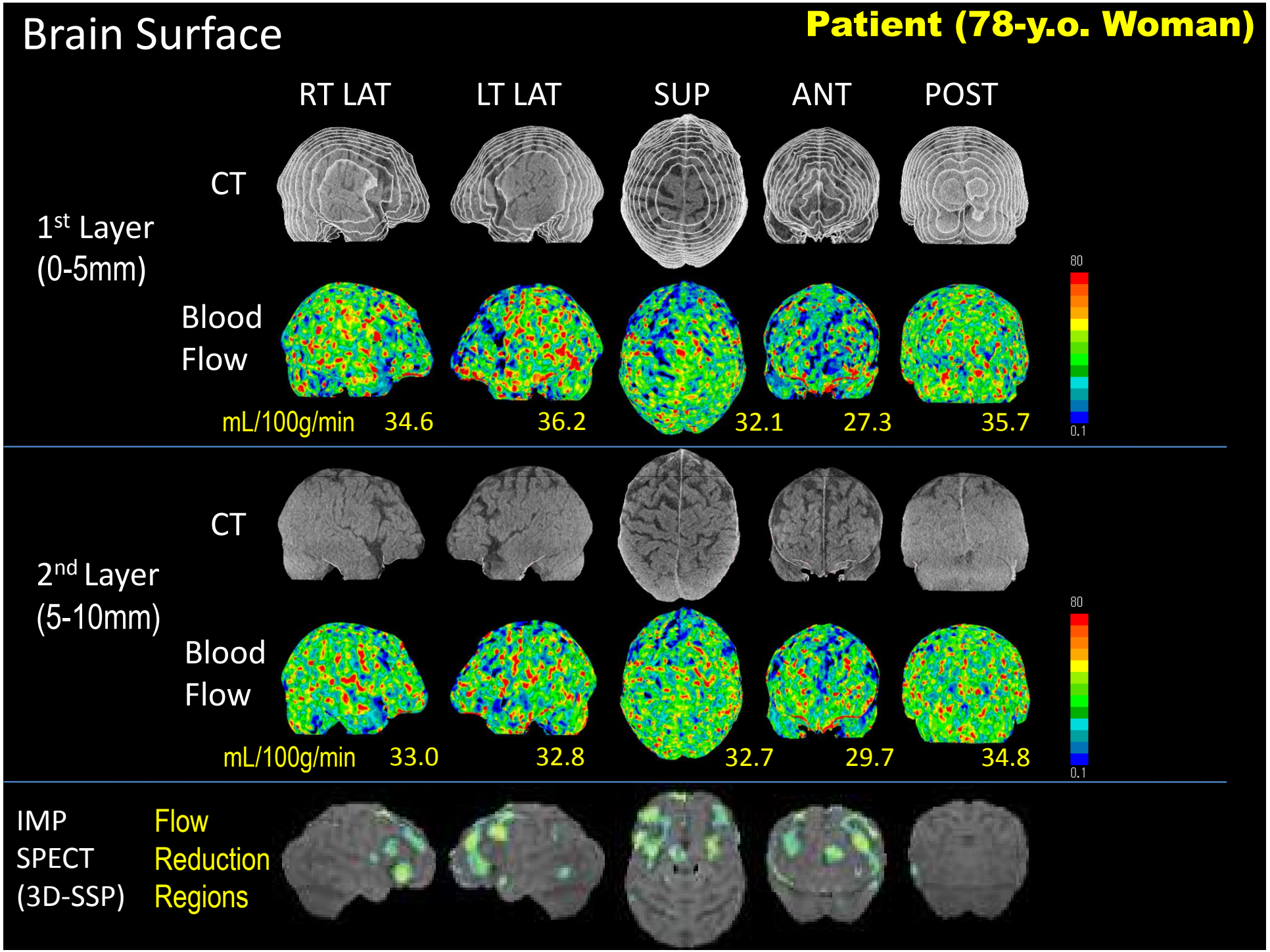
- Comparison of Xe-CT and SPECT

Brain Surface

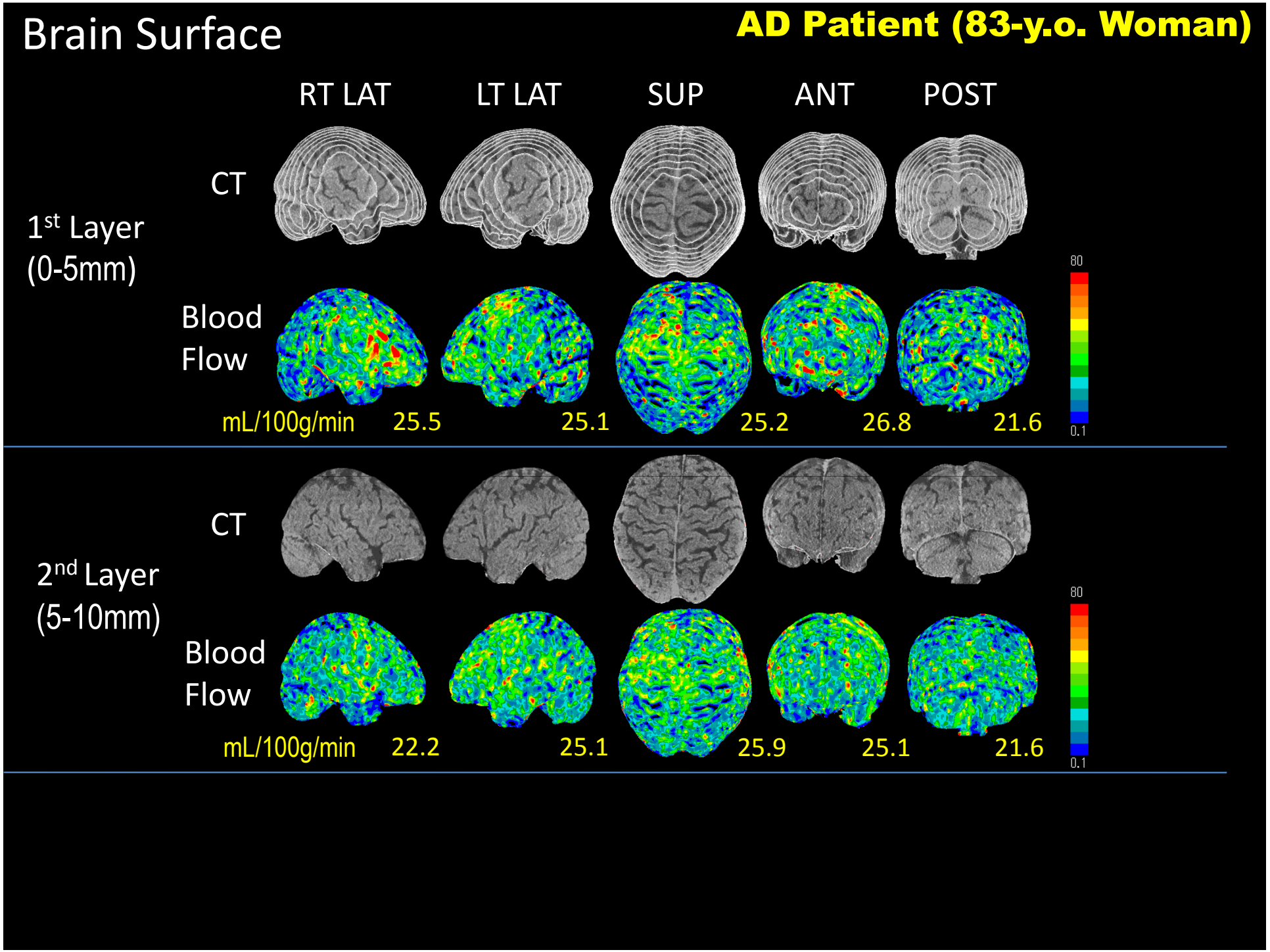
Patient (78-y.o. Woman)

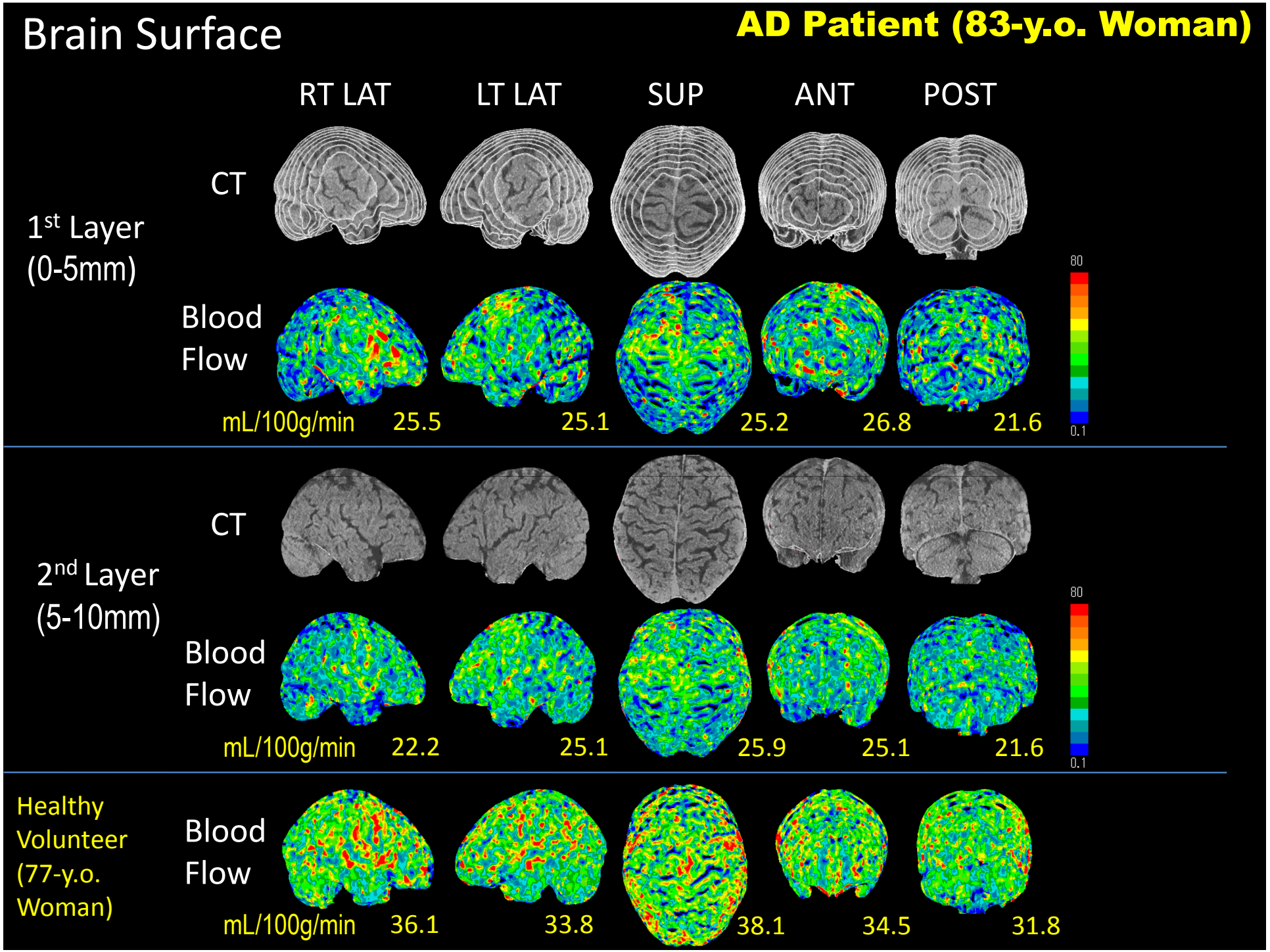



Brain Surface
Patient (78-y.o. Woman)
RT LAT
LT LAT
SUP
ANT
POST
1st Layer
(0-5mm)
CT
Blood
Flow
mL/100g/min
34.6
36.2
32.1
27.3
35.7
80
0.1
2nd Layer
(5-10mm)
CT
Blood
Flow
mL/100g/min
33.0
32.8
32.7
29.7
34.8
80
0.1
IMP
SPECT
(3D-SSP)
Blood
Flow

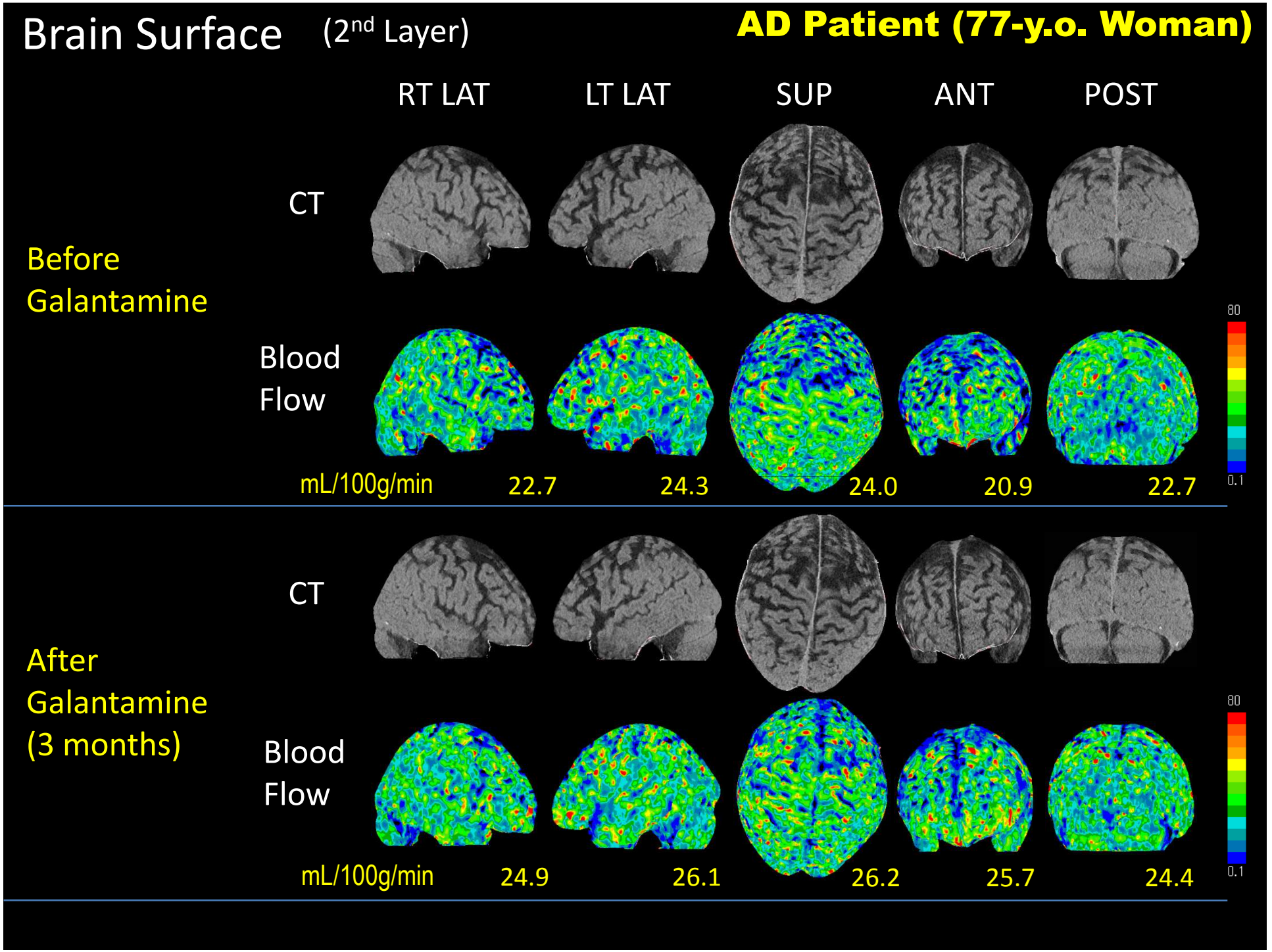

Brain Surface
Patient (78-y.o. Woman)
RT LAT
LT LAT
SUP
ANT
POST
CT
1st Layer
(0-5mm)
Blood
Flow
80
0.1
mL/100g/min
34.6
36.2
32.1
27.3
35.7
CT
2nd Layer
(5-10mm)
Blood
Flow
80
0.1
mL/100g/min
33.0
32.8
32.7
29.7
34.8
IMP
SPECT
(3D-SSP)
Flow
Reduction
Regions

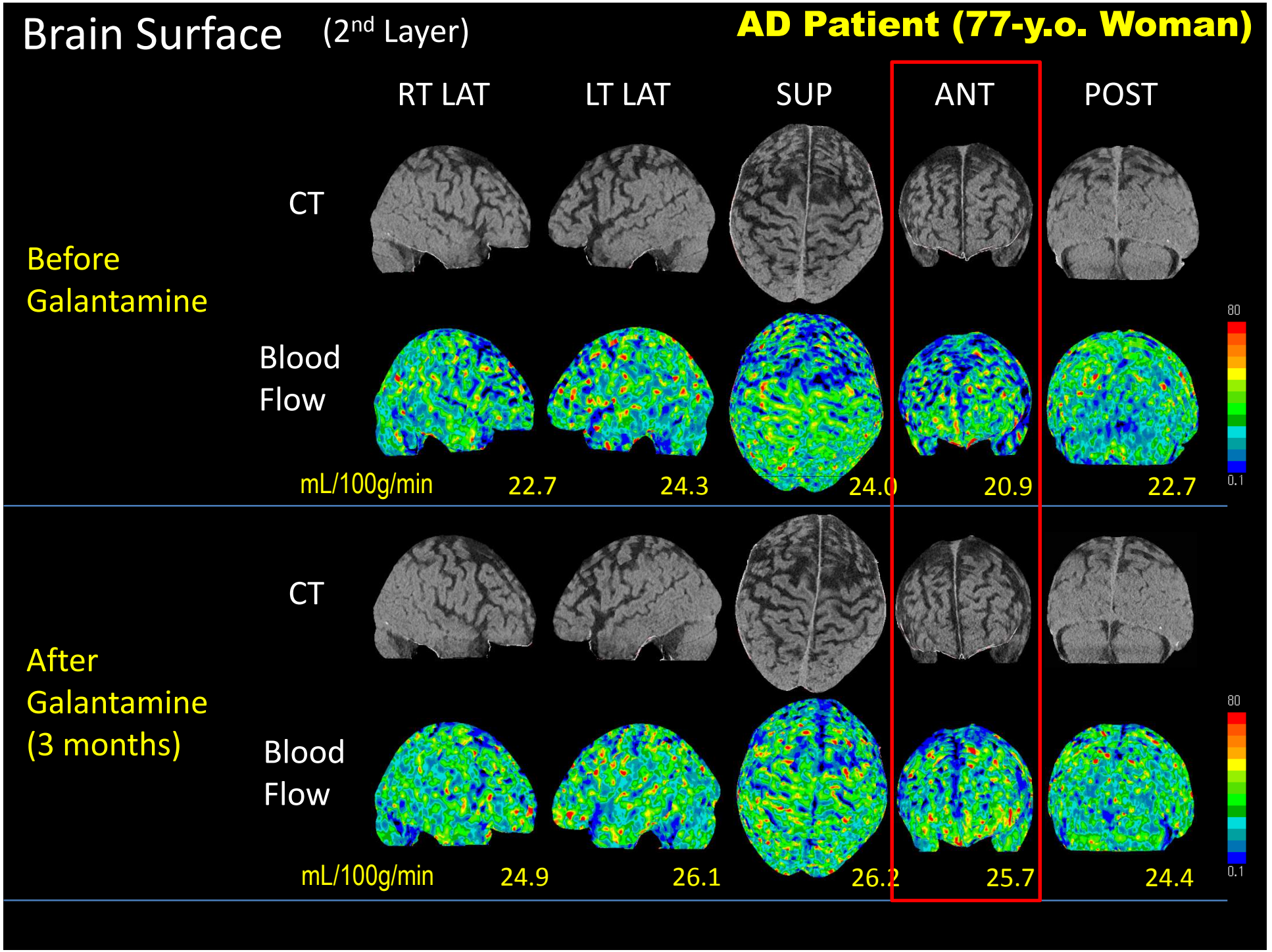
- Comparison of AD patient and healthy volunteer


Brain Surface
AD Patient (83-y.o. Woman)
RT LAT
LT LAT
SUP
ANT
POST
CT
1st Layer
(0-5mm)
Blood
Flow
mL/100g/min
25.5
25.1
25.2
26.8
21.6
80
0.1
CT
2nd Layer
(5-10mm)
Blood
Flow
mL/100g/min
22.2
25.1
25.9
25.1
21.6
80
0.1

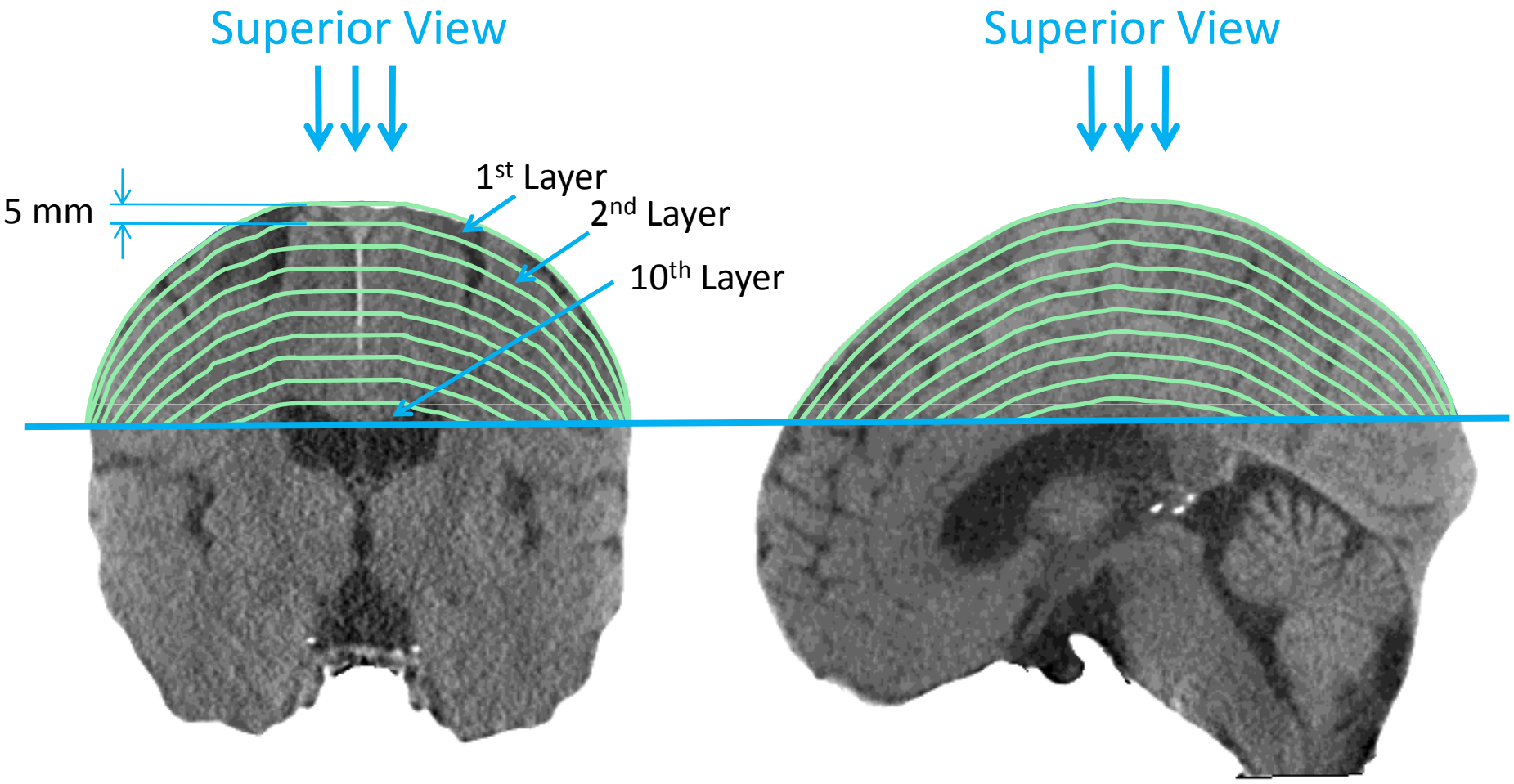

Brain Surface
AD Patient (83-y.o. Woman)
RT LAT
LT LAT
SUP
ANT
POST
1st Layer (0-5mm)
CT
Blood Flow
mL/100g/min
25.5
25.1
25.2
26.8
21.6
80
0.1
2nd Layer (5-10mm)
CT
Blood Flow
mL/100g/min
22.2
25.1
25.9
25.1
21.6
80
0.1
Healthy Volunteer (77-y.o. Woman)
Blood Flow
mL/100g/min
36.1
33.8
38.1
34.5
31.8

- Effect of drug administration to AD patient

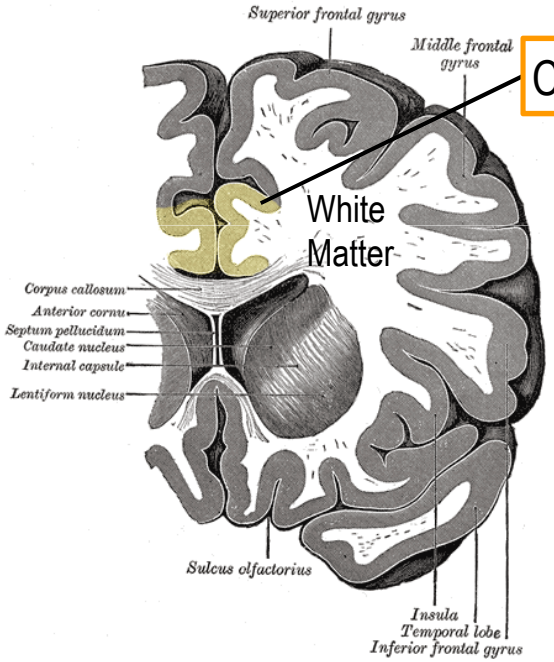

Brain Surface (2nd Layer)
AD Patient (77-y.o. Woman)
RT LAT
LT LAT
SUP
ANT
POST
Before Galantamine
CT
Blood Flow
mL/100g/min
22.7
24.3
24.0
20.9
22.7
80
0.1
After Galantamine (3 months)
CT
Blood Flow
mL/100g/min
24.9
26.1
26.2
25.7
24.4
80
0.1


Brain Surface (2nd Layer)
AD Patient (77-y.o. Woman)
RT LAT
LT LAT
SUP
ANT
POST
CT
Before Galantamine
Blood Flow
mL/100g/min
22.7
24.3
24.0
20.9
22.7
80
0.1
CT
After Galantamine (3 months)
Blood Flow
mL/100g/min
24.9
26.1
26.2
25.7
24.4
80
0.1

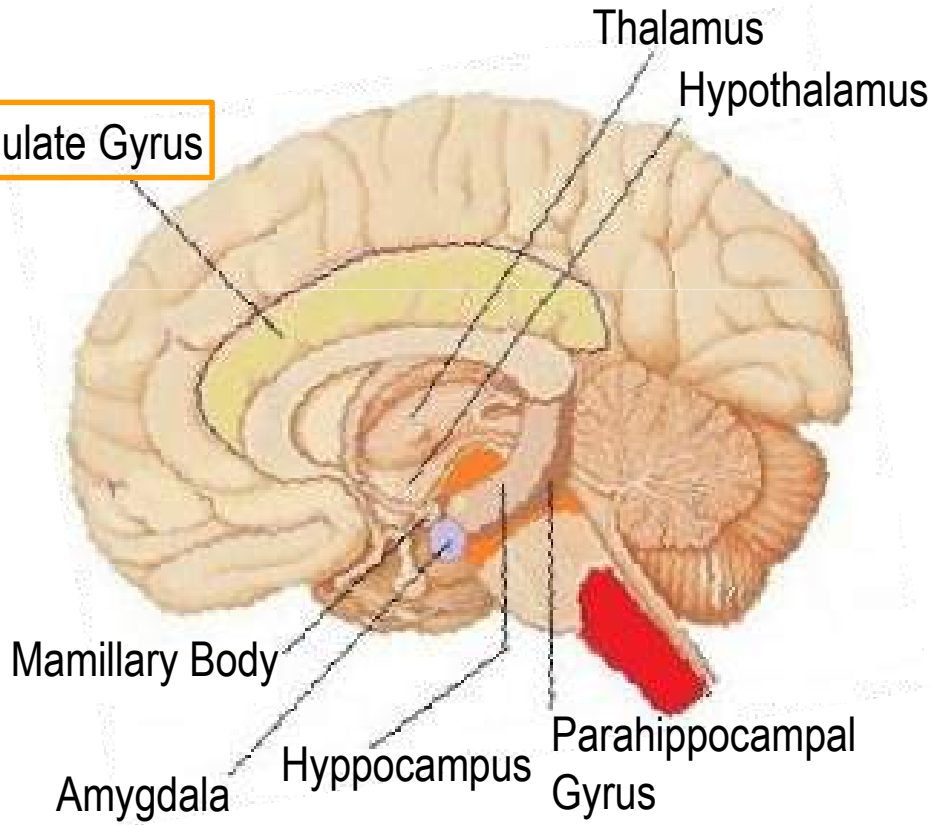
• 1st to 10th layer images



Limbic System



(From Wikipedia)

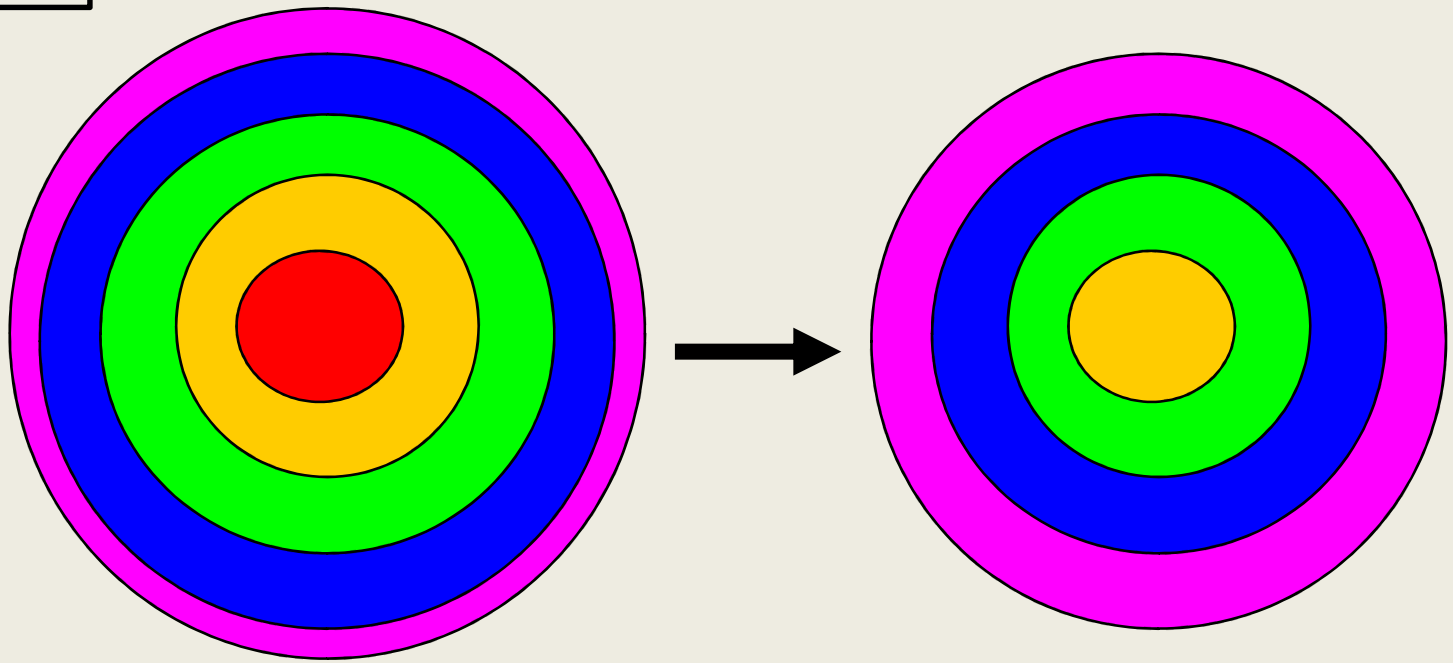


Schematic Diagram

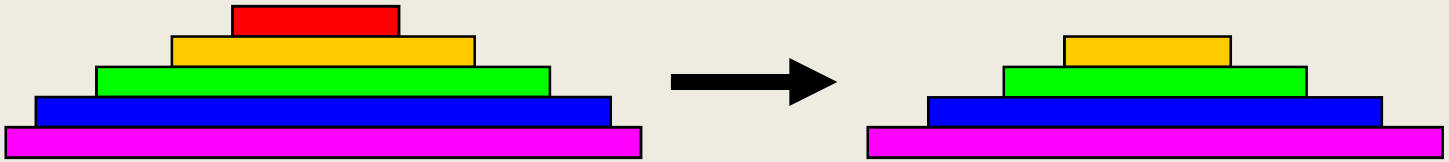
Superior View Images

1st Layer

2nd Layer



Side View



Remove white areas in the figure.

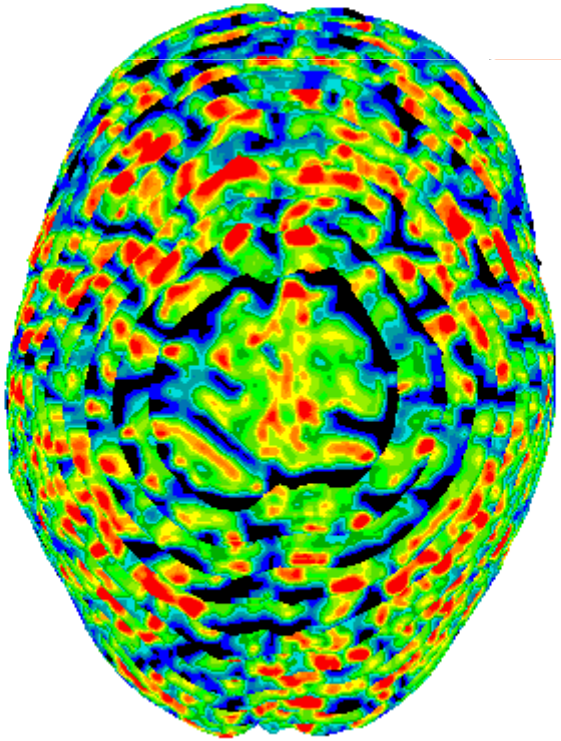
- Comparison of healthy volunteer and AD patient

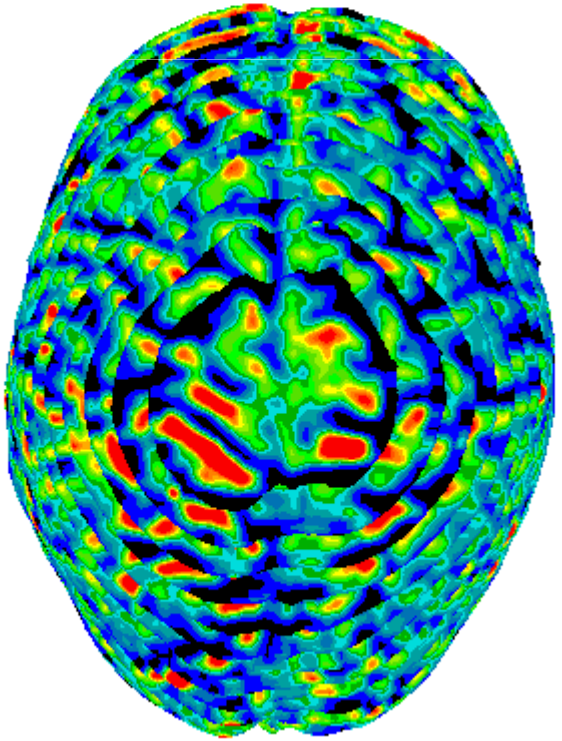
Healthy Volunteer
(77-y.o. Woman)

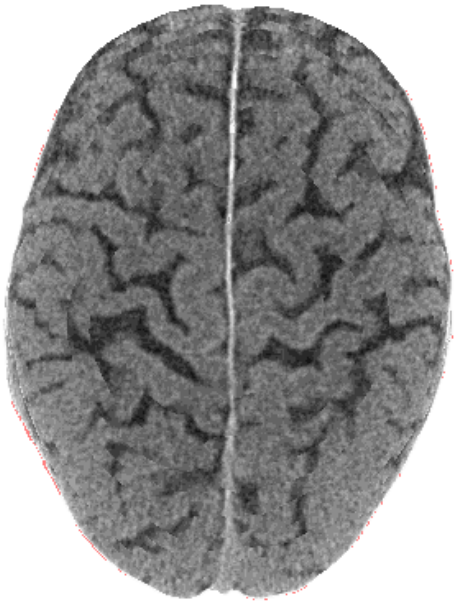
Blood Flow

Lambda

1st Layer





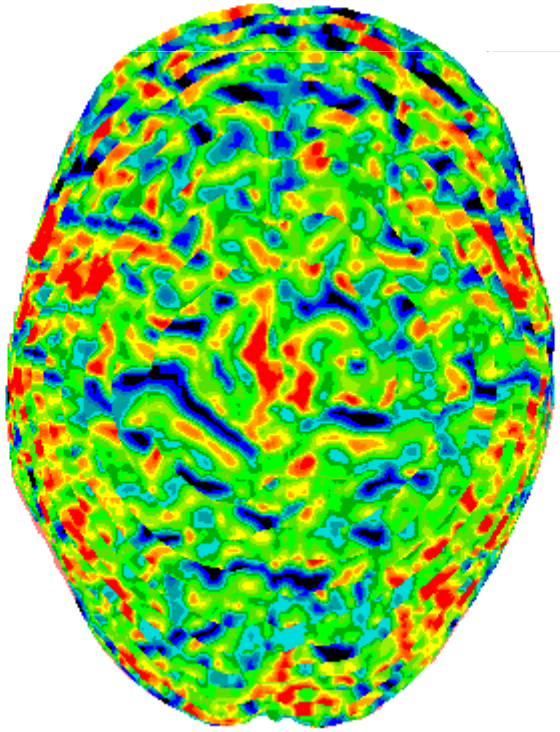


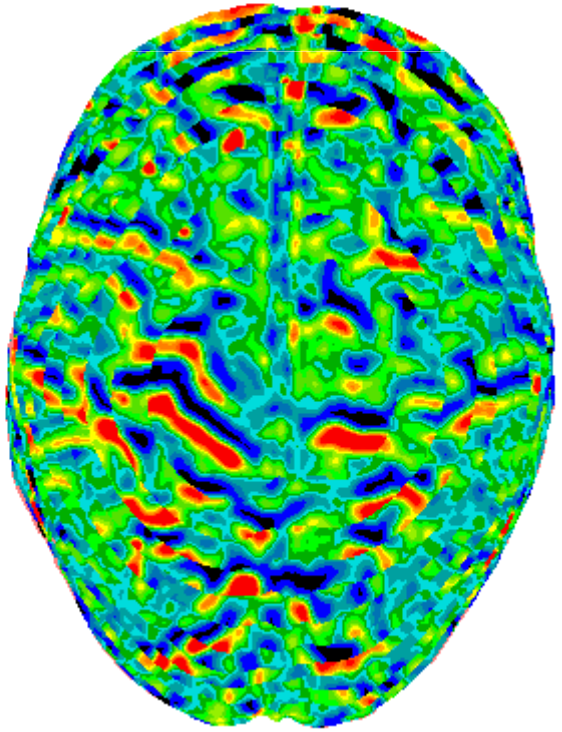
Healthy Volunteer
(77-y.o. Woman)

Blood Flow

Lambda

2nd Layer



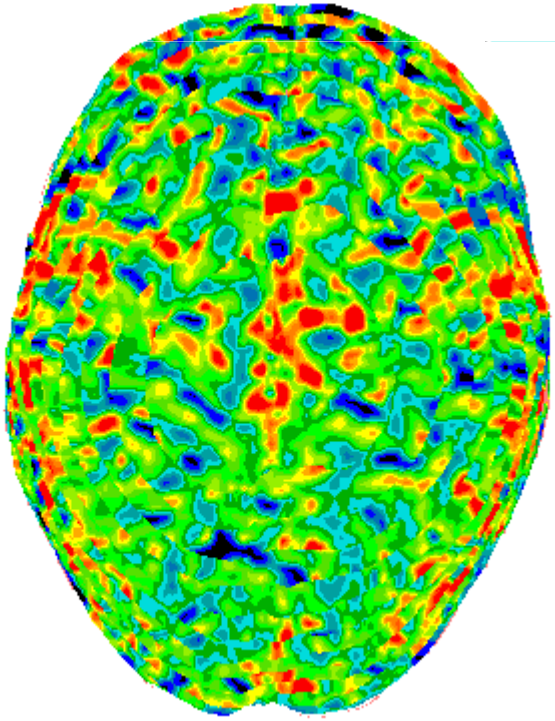


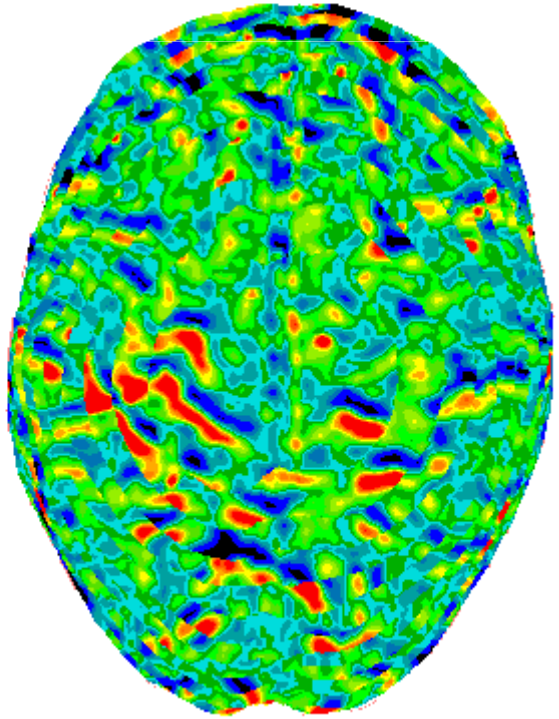
Healthy Volunteer
(77-y.o. Woman)

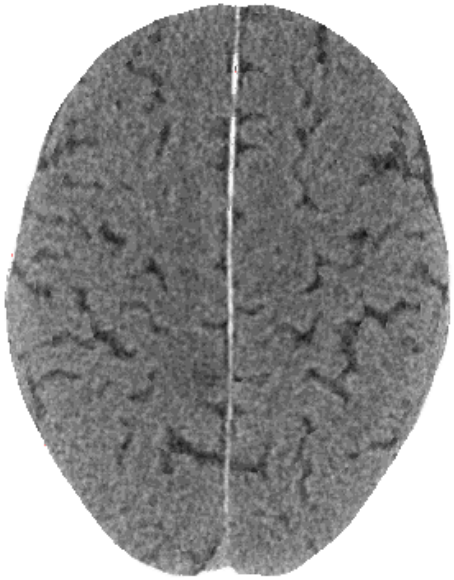
Blood Flow

Lambda

3rd Layer





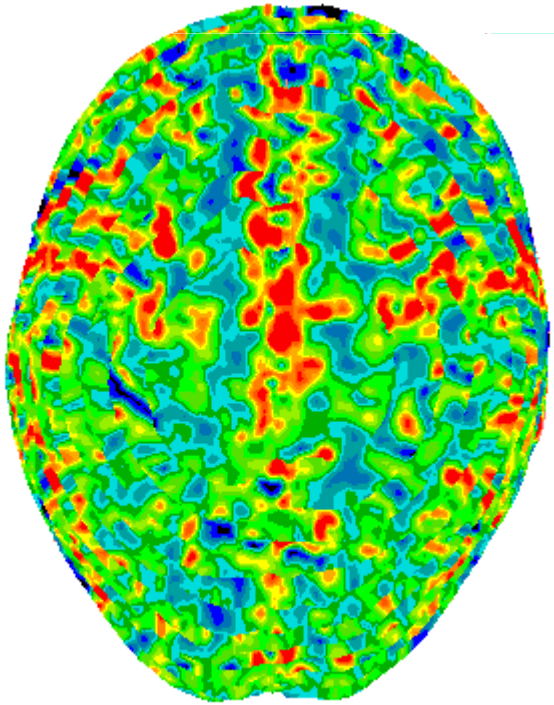


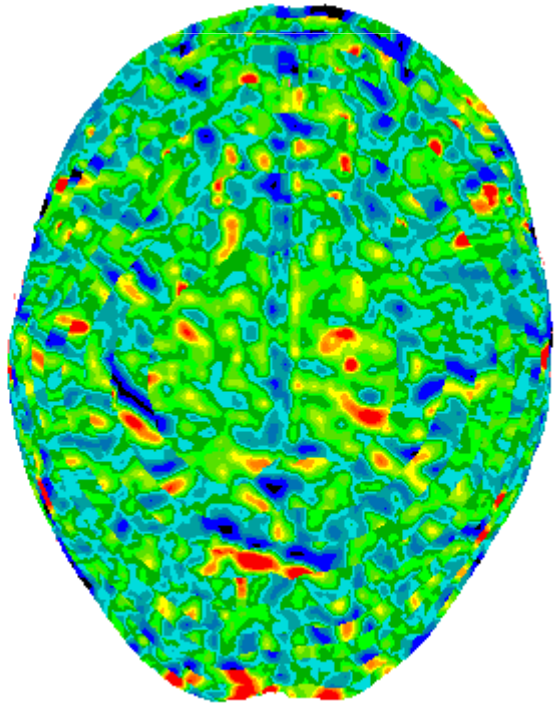
Healthy Volunteer
(77-y.o. Woman)

Blood Flow

Lambda

4th Layer



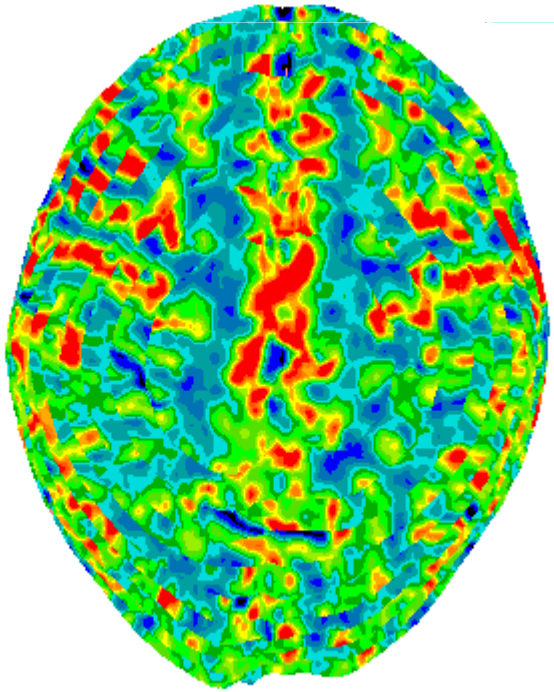


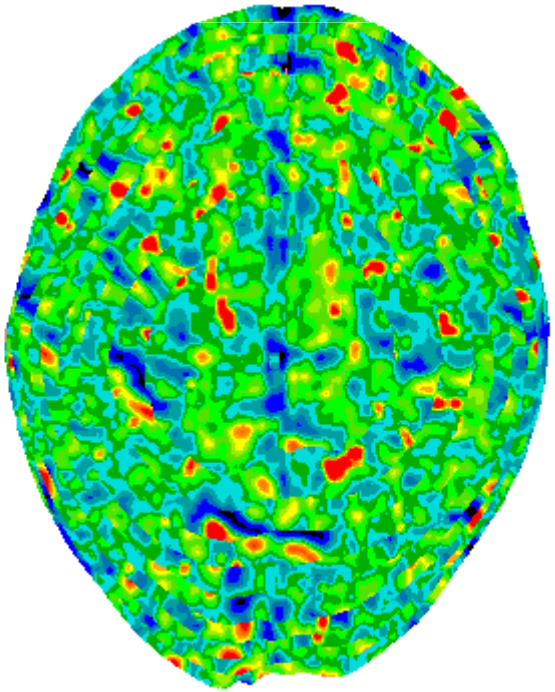
Healthy Volunteer
(77-y.o. Woman)

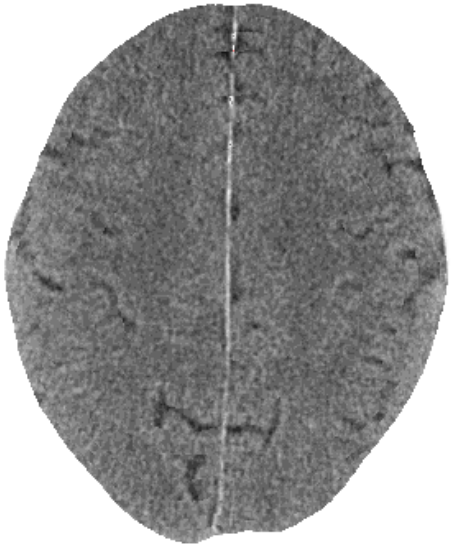
Blood Flow

Lambda

5th Layer





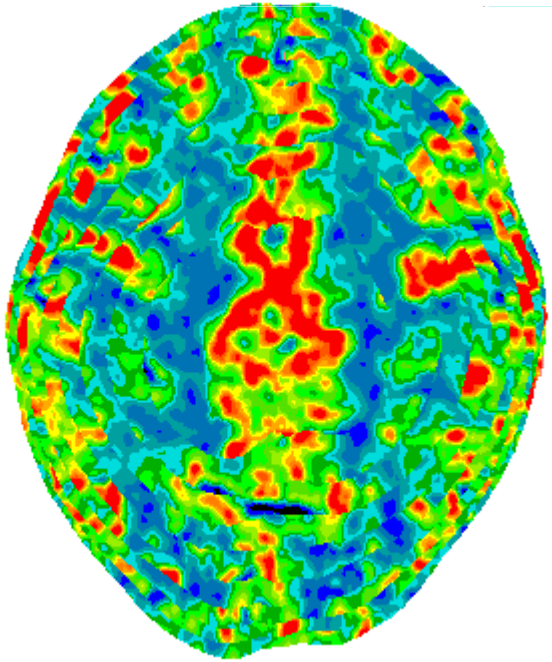


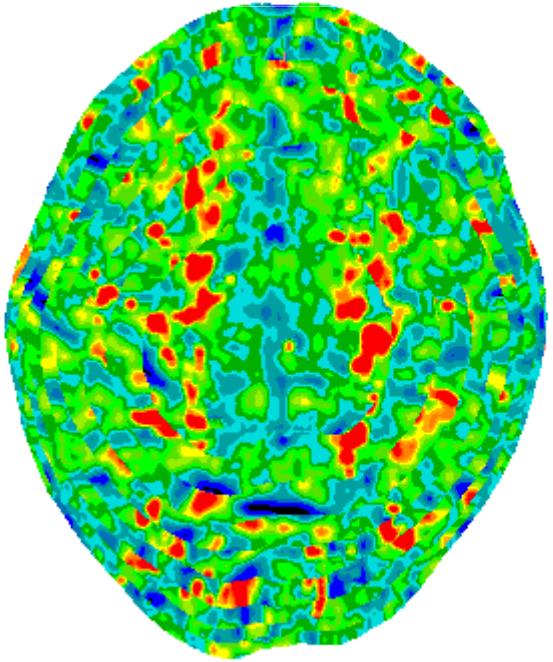
Healthy Volunteer
(77-y.o. Woman)

Blood Flow

Lambda

6th Layer



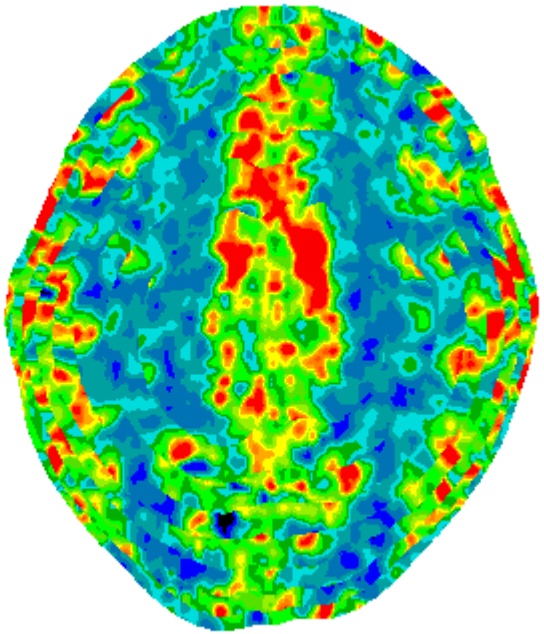


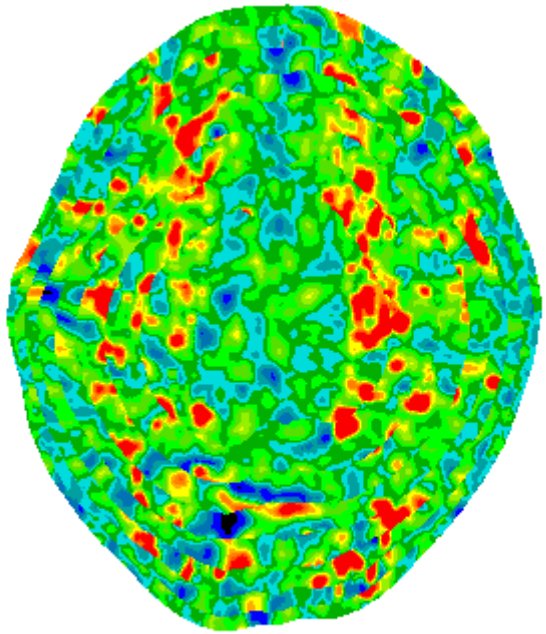
Healthy Volunteer
(77-y.o. Woman)

Blood Flow

Lambda

7th Layer



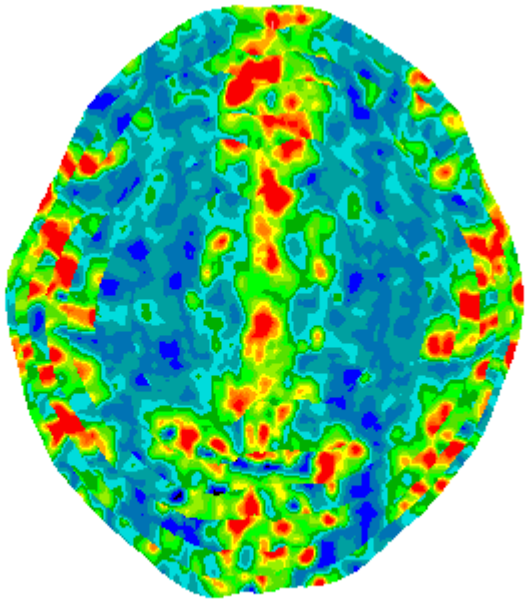


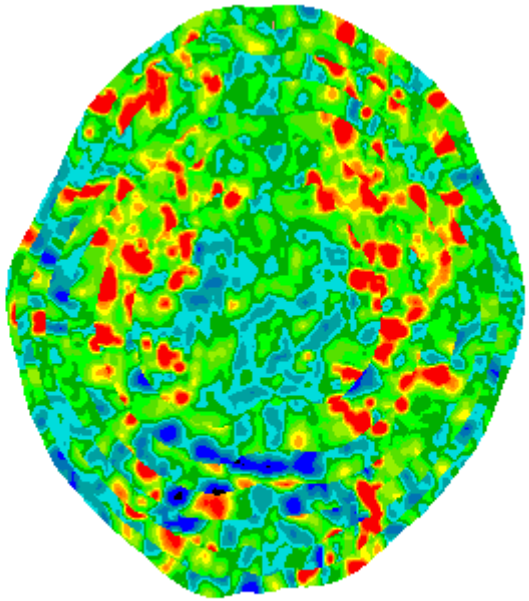
Healthy Volunteer
(77-y.o. Woman)

Blood Flow

Lambda

8th Layer



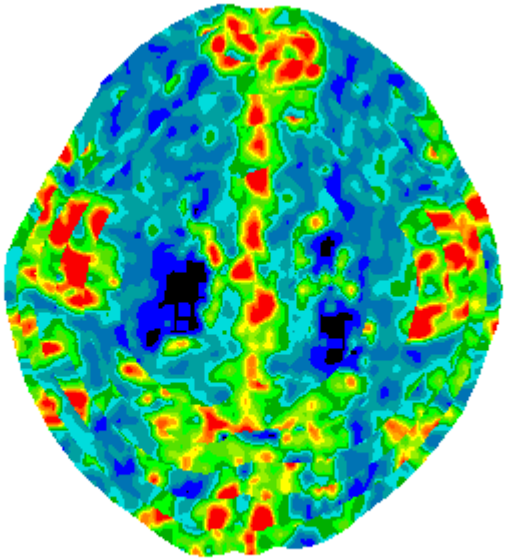


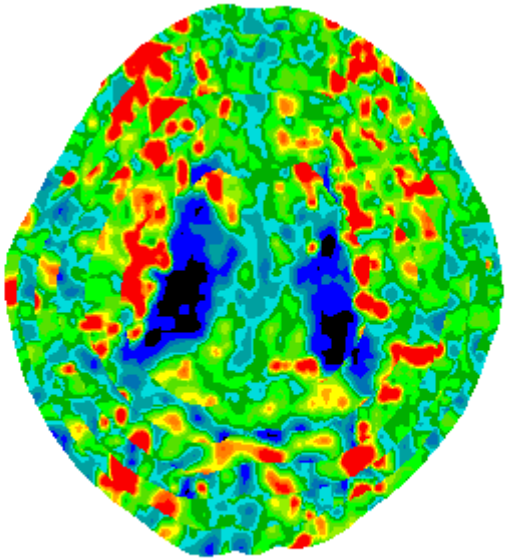
Healthy Volunteer
(77-y.o. Woman)

Blood Flow

Lambda

9th Layer



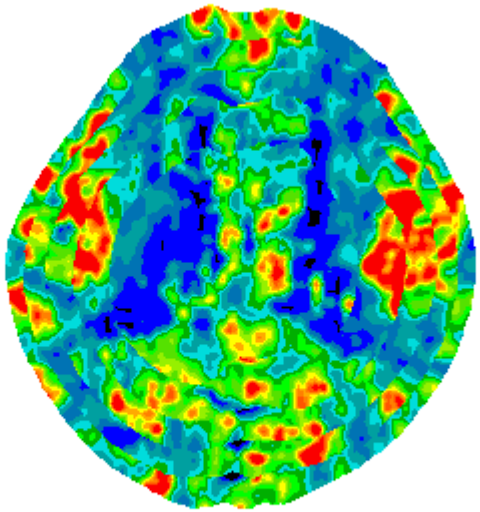


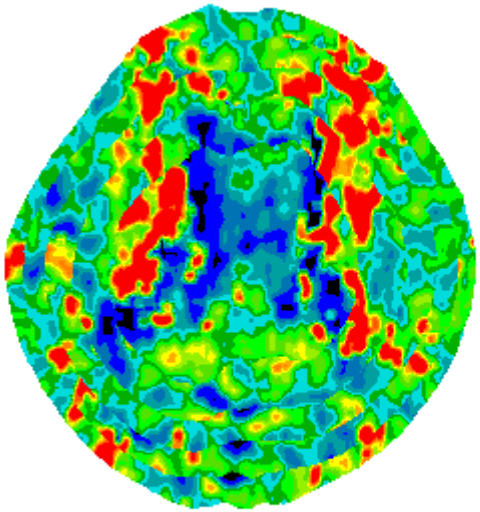
Healthy Volunteer
(77-y.o. Woman)

Blood Flow

Lambda

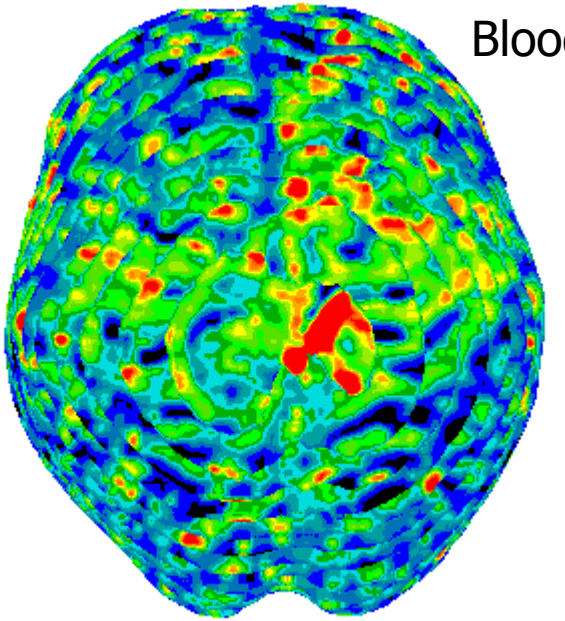
10th Layer



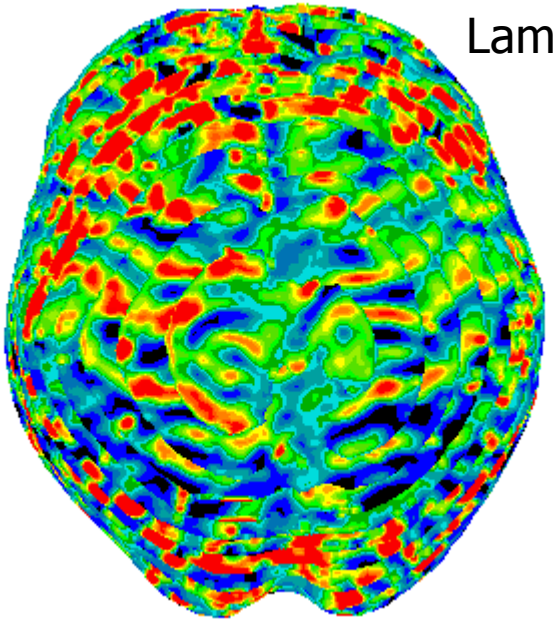


AD Patient
(83-y.o. Woman)

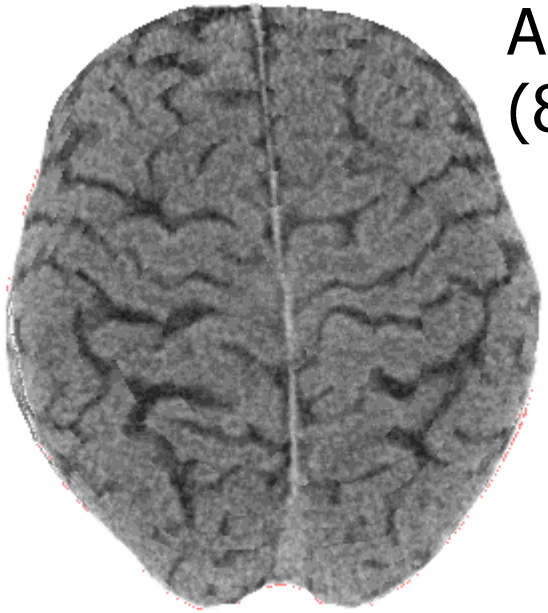
1st Layer



Blood Flow

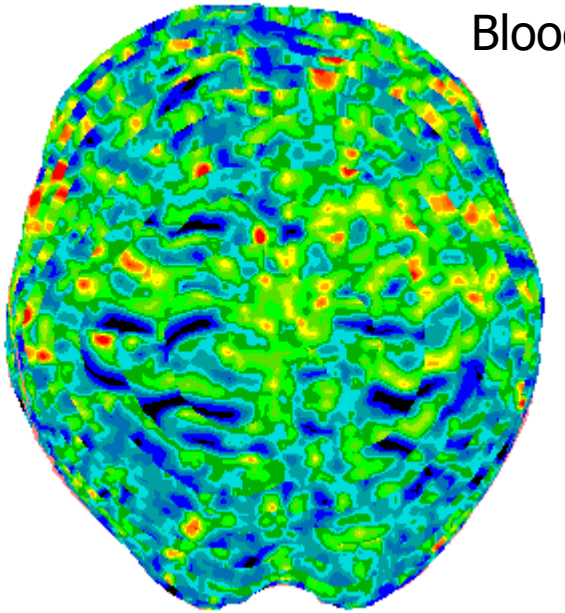


Lambda

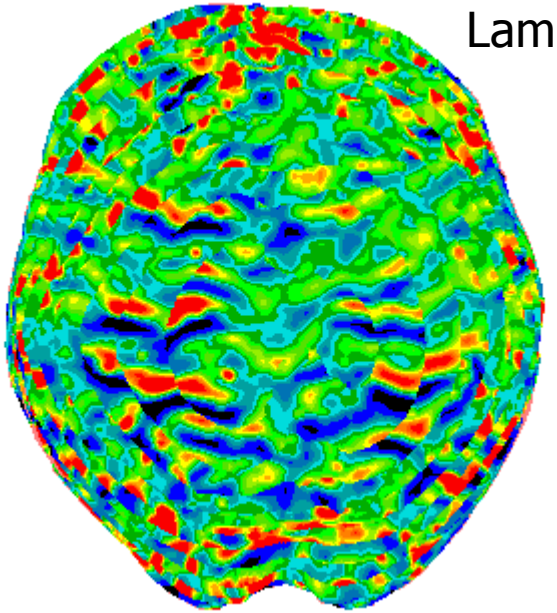


AD Patient
(83-y.o. Woman)

2nd Layer

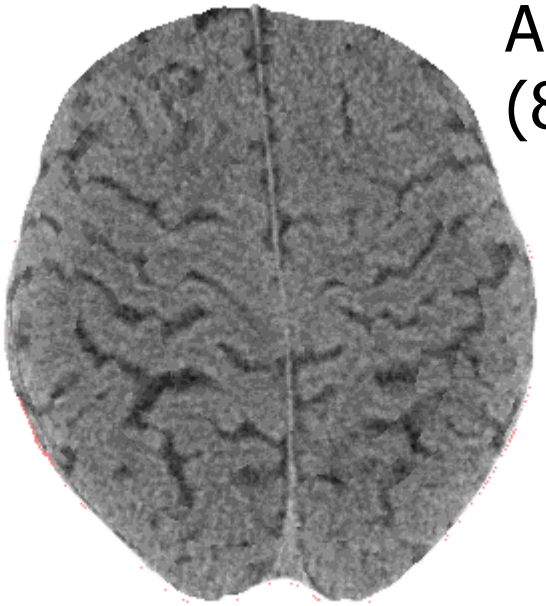


Blood Flow



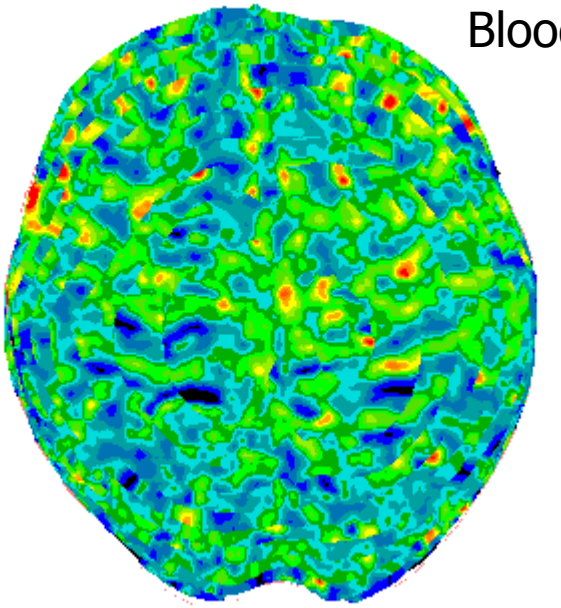
Lambda

AD Patient
(83-y.o. Woman)

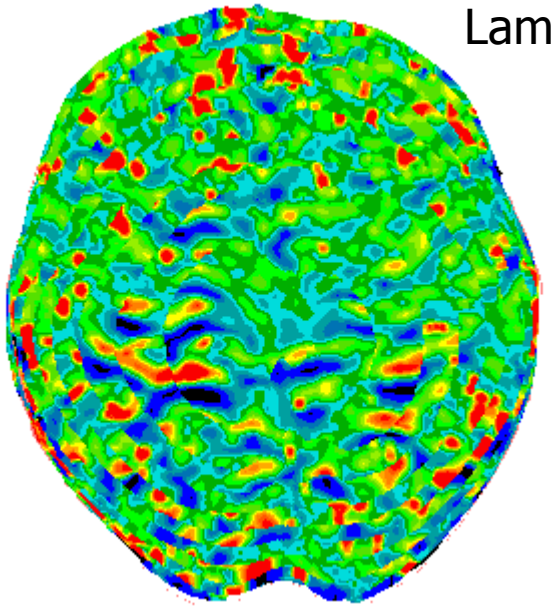


3rd Layer

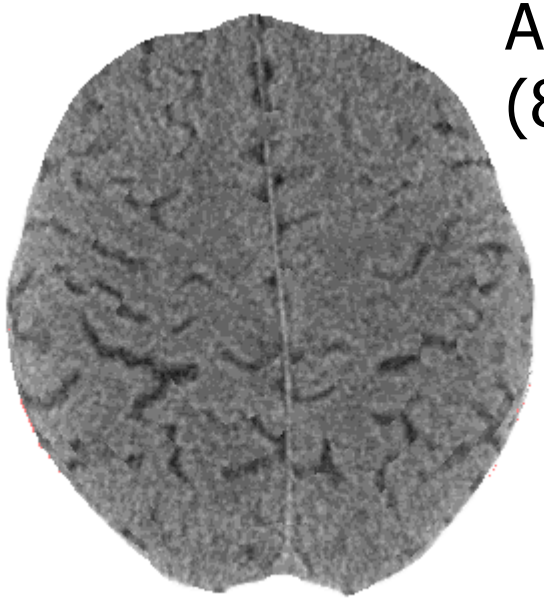
Blood Flow



Lambda

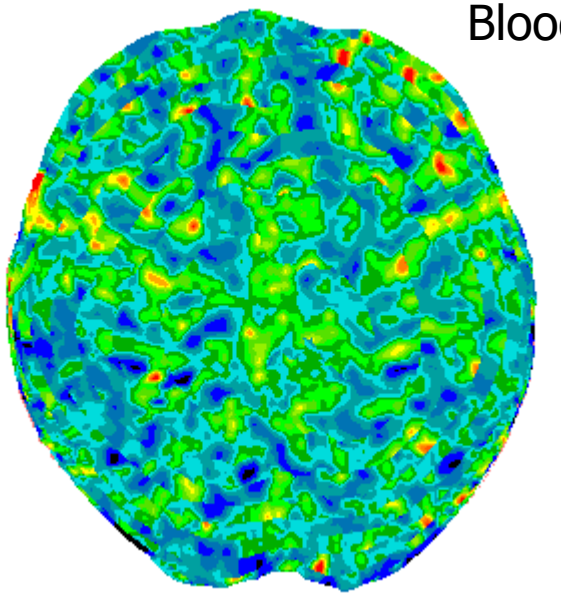


AD Patient
(83-y.o. Woman)

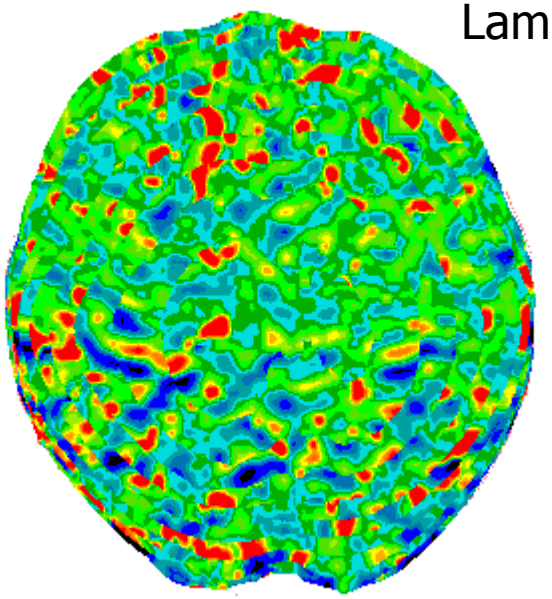


4th Layer

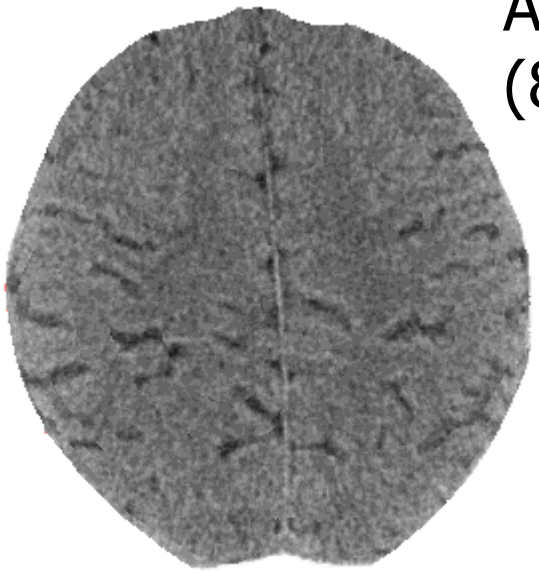
Blood Flow



Lambda

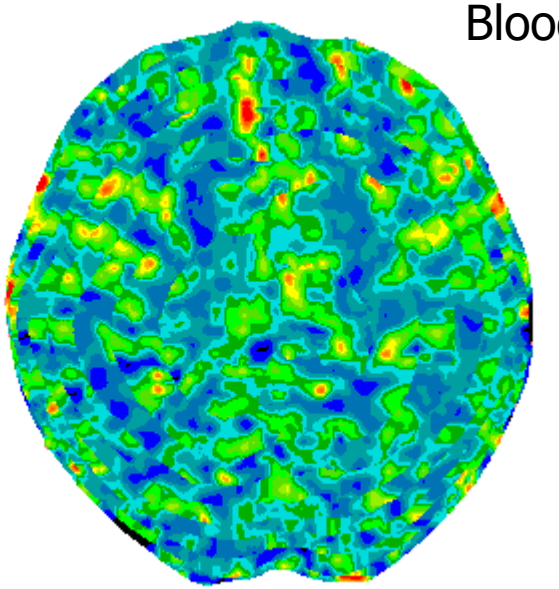


AD Patient
(83-y.o. Woman)

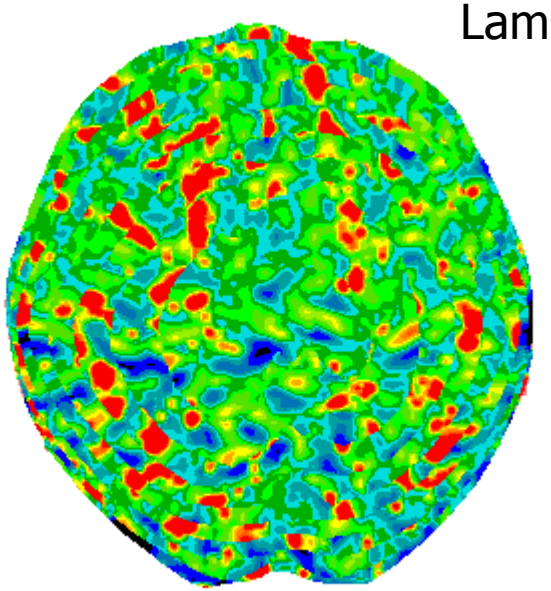


5th Layer

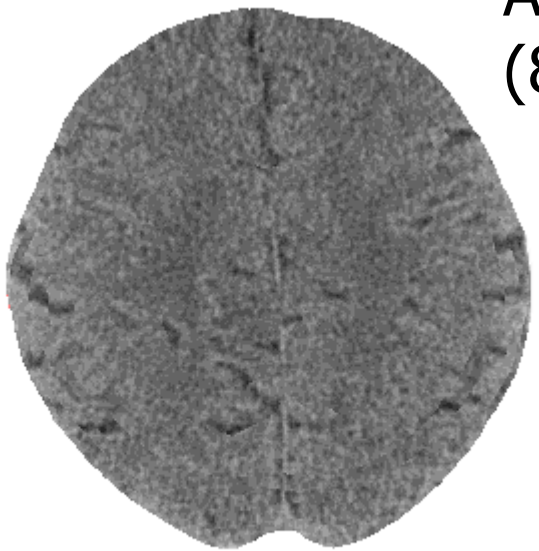
Blood Flow



Lambda

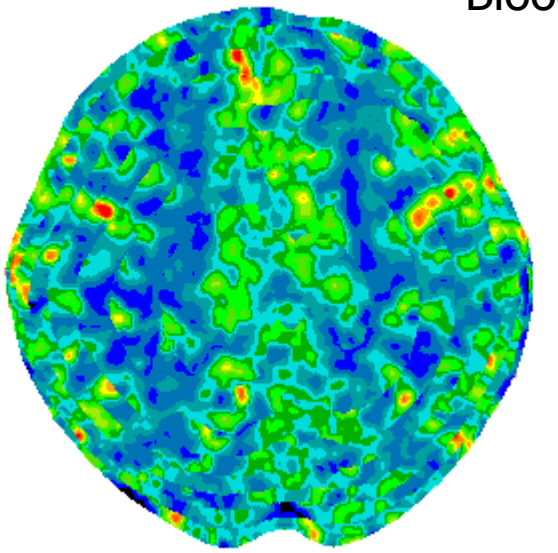


AD Patient
(83-y.o. Woman)

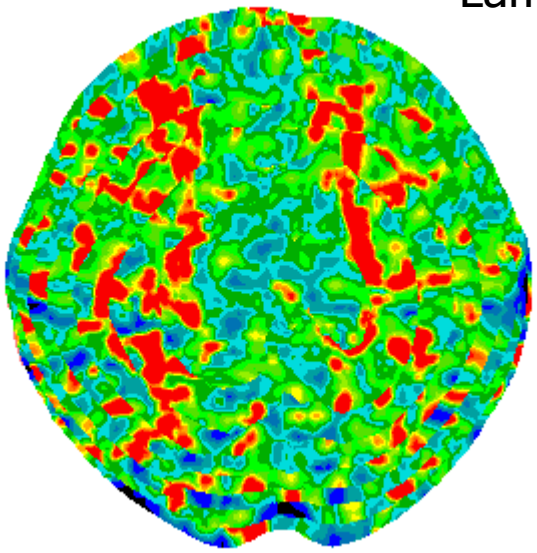


6th Layer

Blood Flow



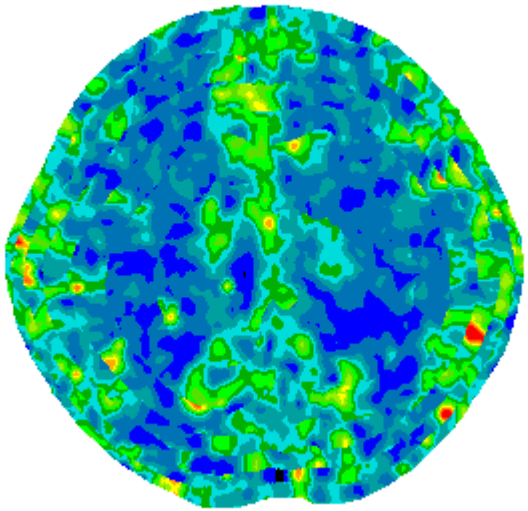
Lambda



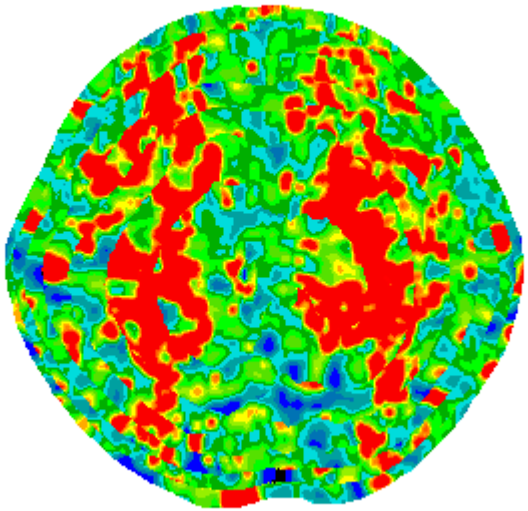
AD Patient
(83-y.o. Woman)

7th Layer

Blood Flow



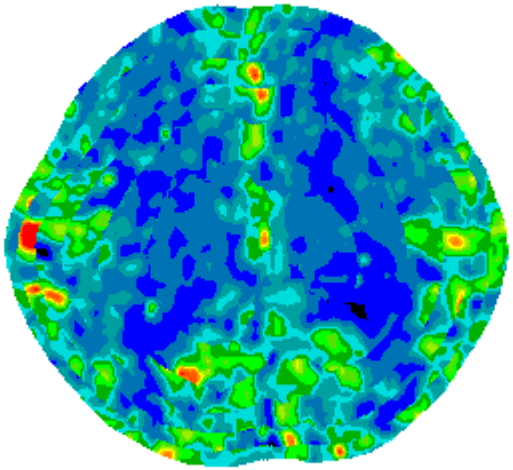
Lambda



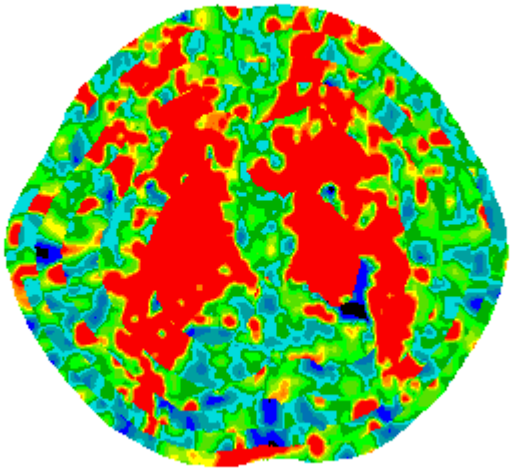
AD Patient
(83-y.o. Woman)

8th Layer

Blood Flow



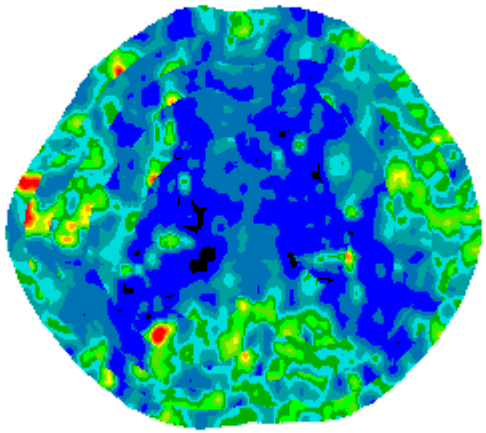
Lambda



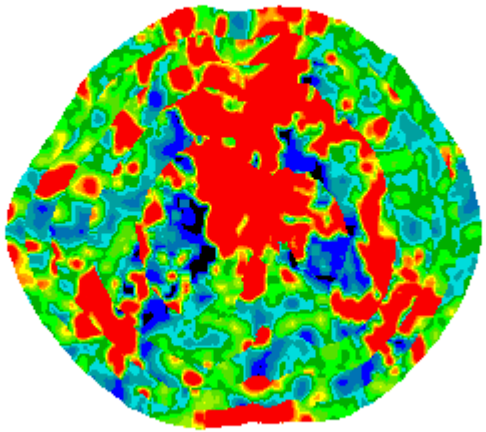
AD Patient
(83-y.o. Woman)

9th Layer

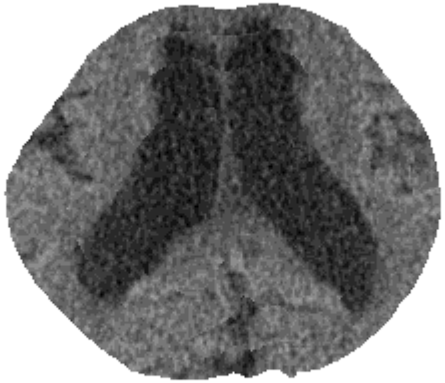
Blood Flow



Lambda

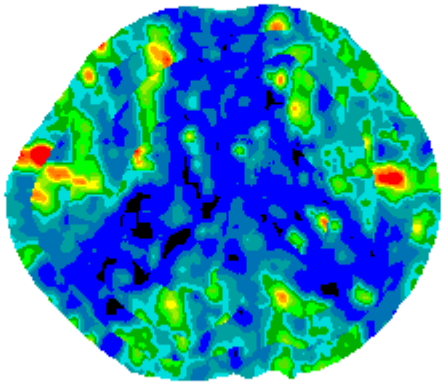


AD Patient
(83-y.o. Woman)

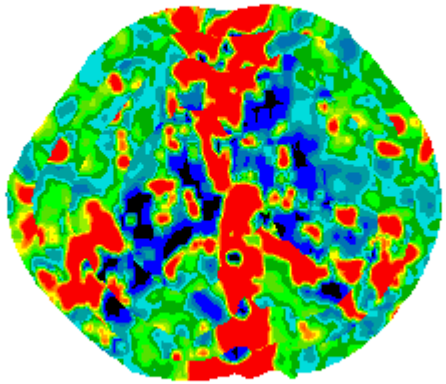


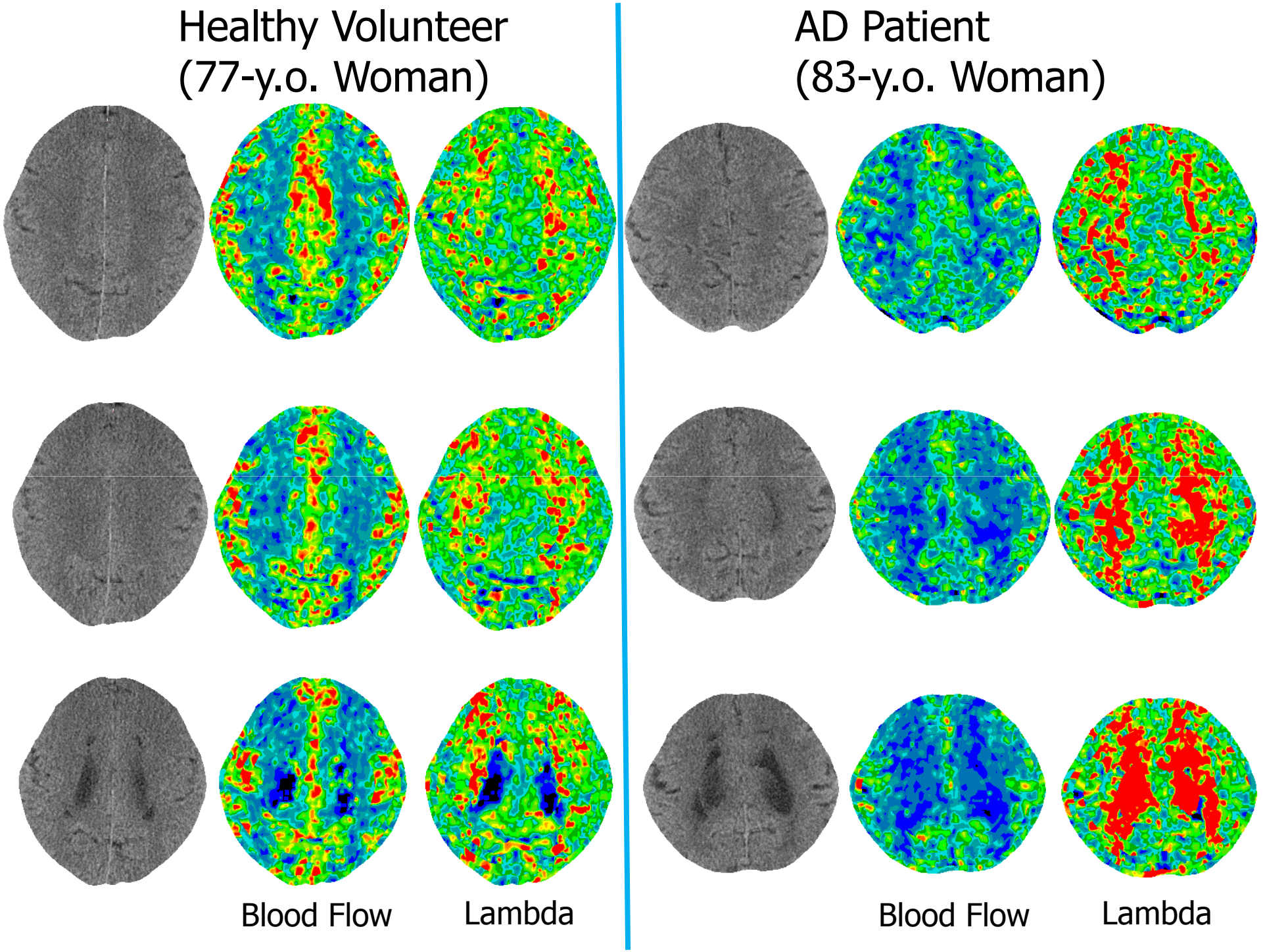
10th Layer

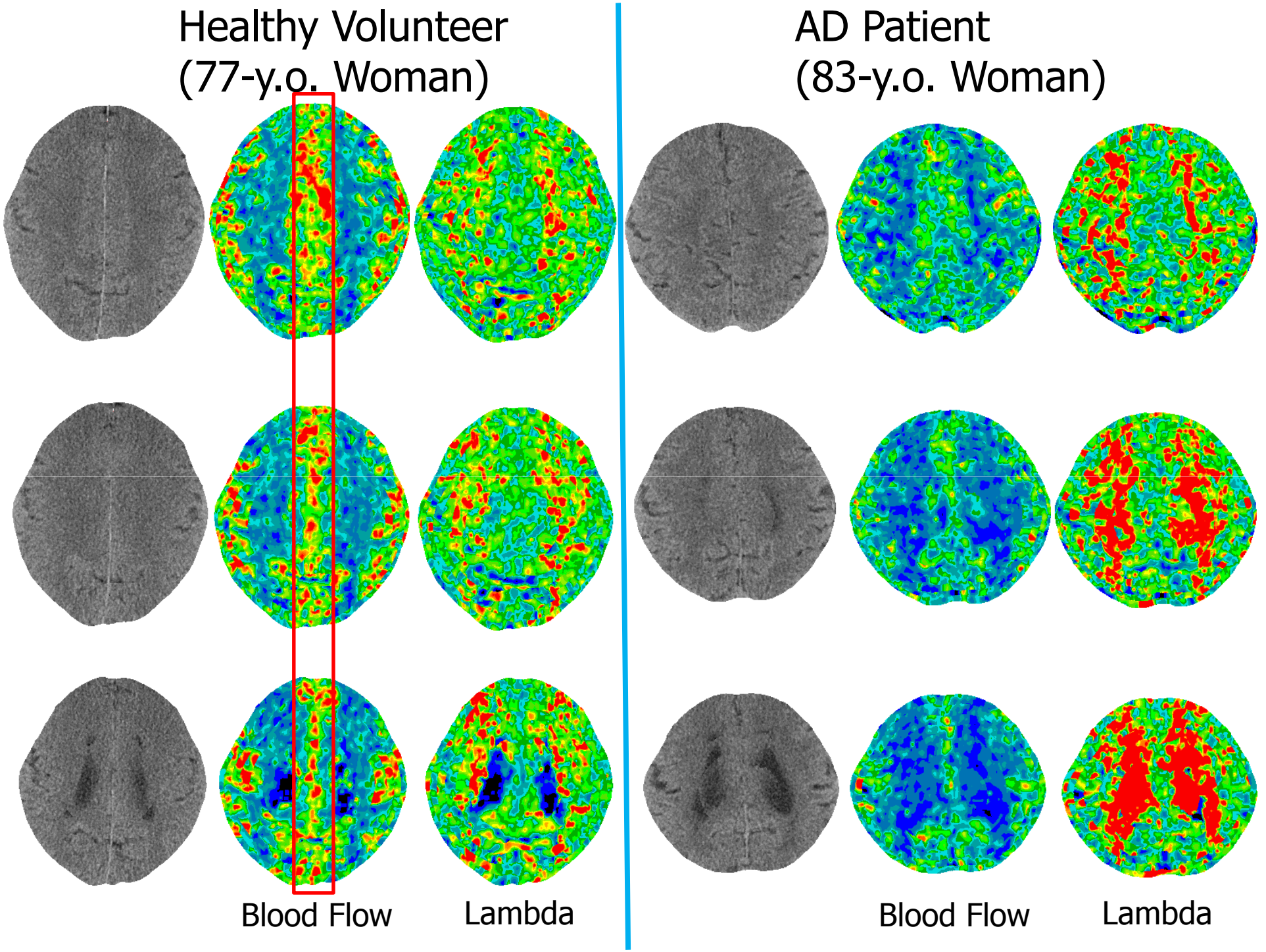
Blood Flow

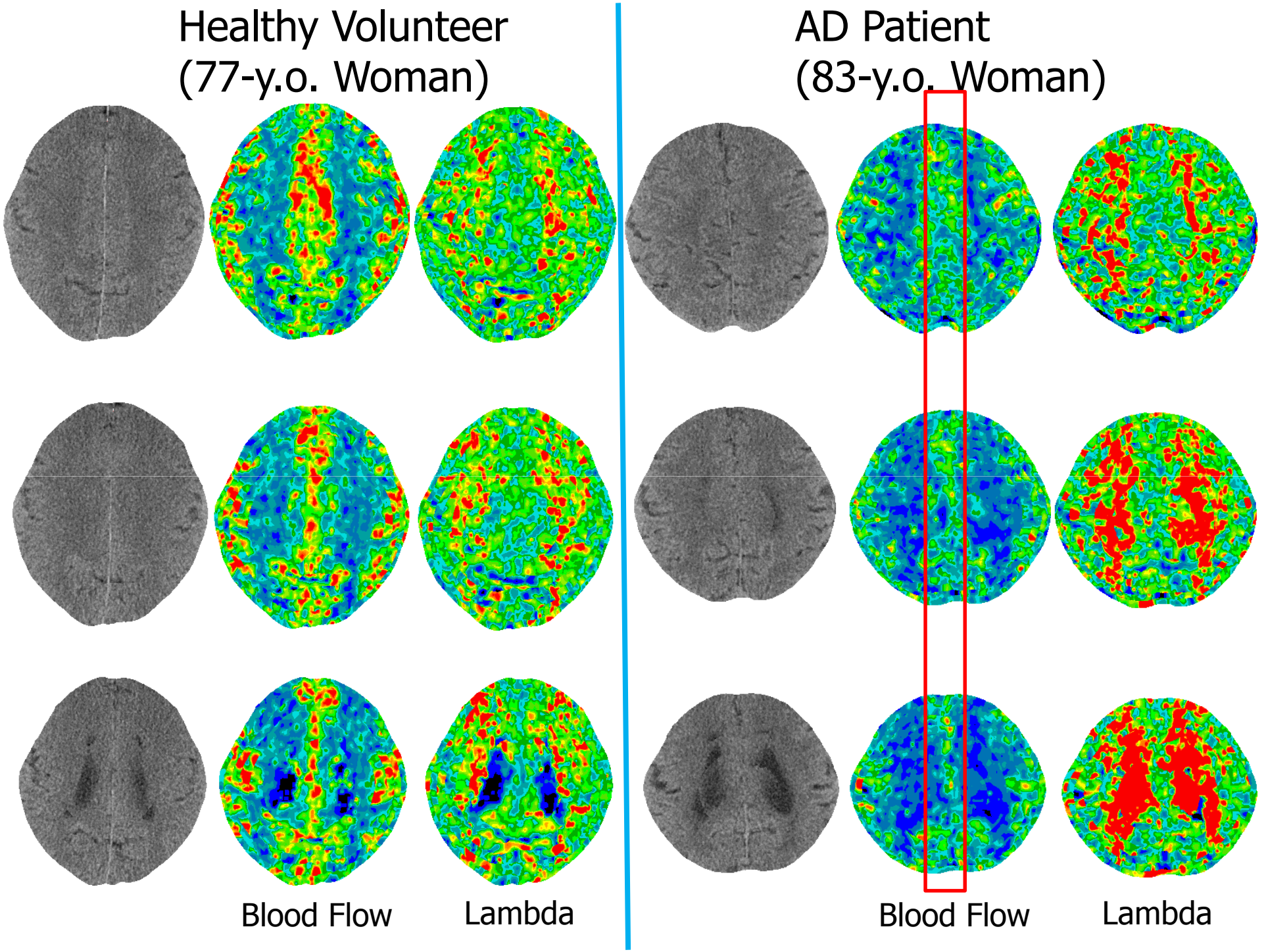


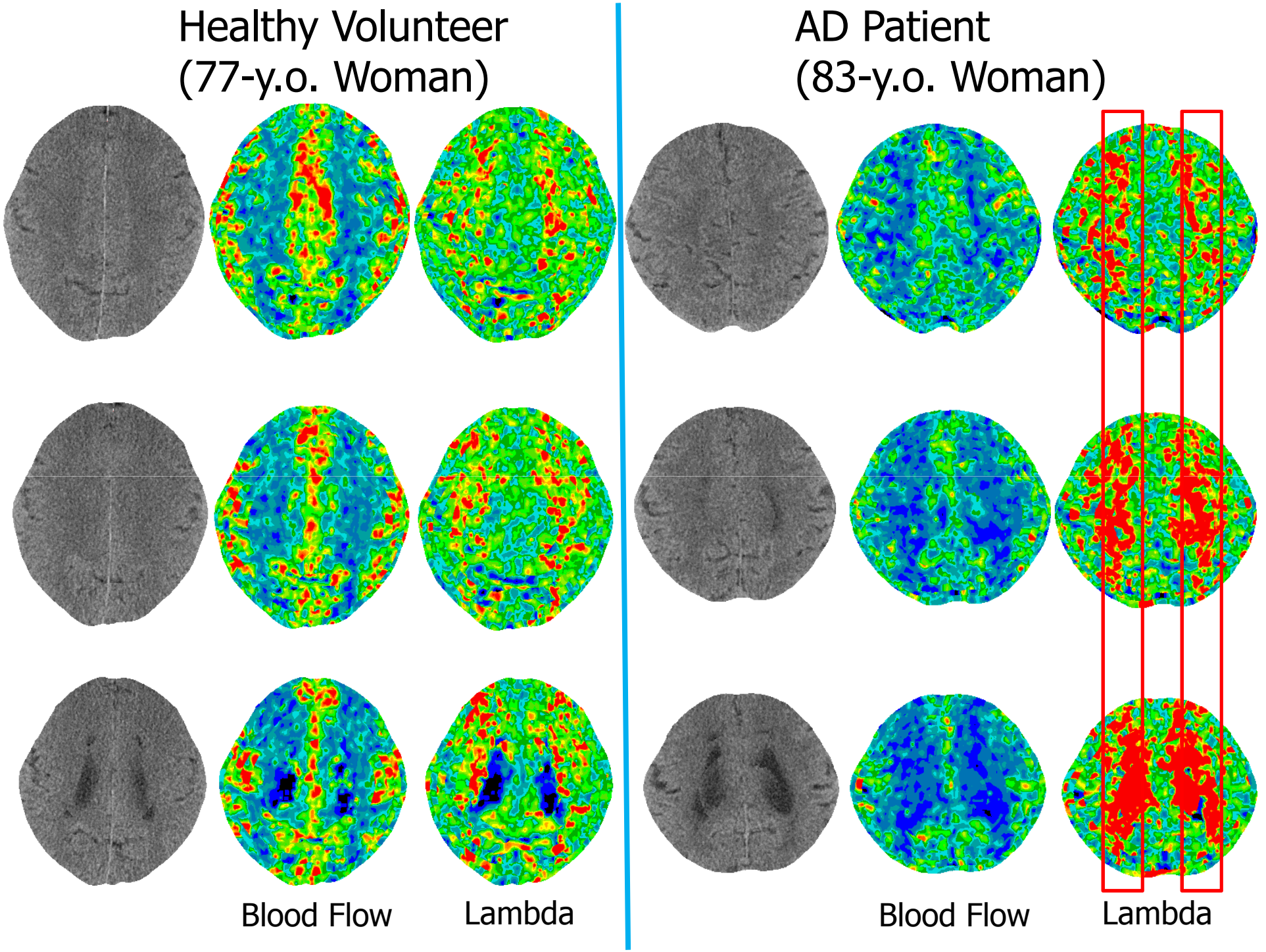
Lambda

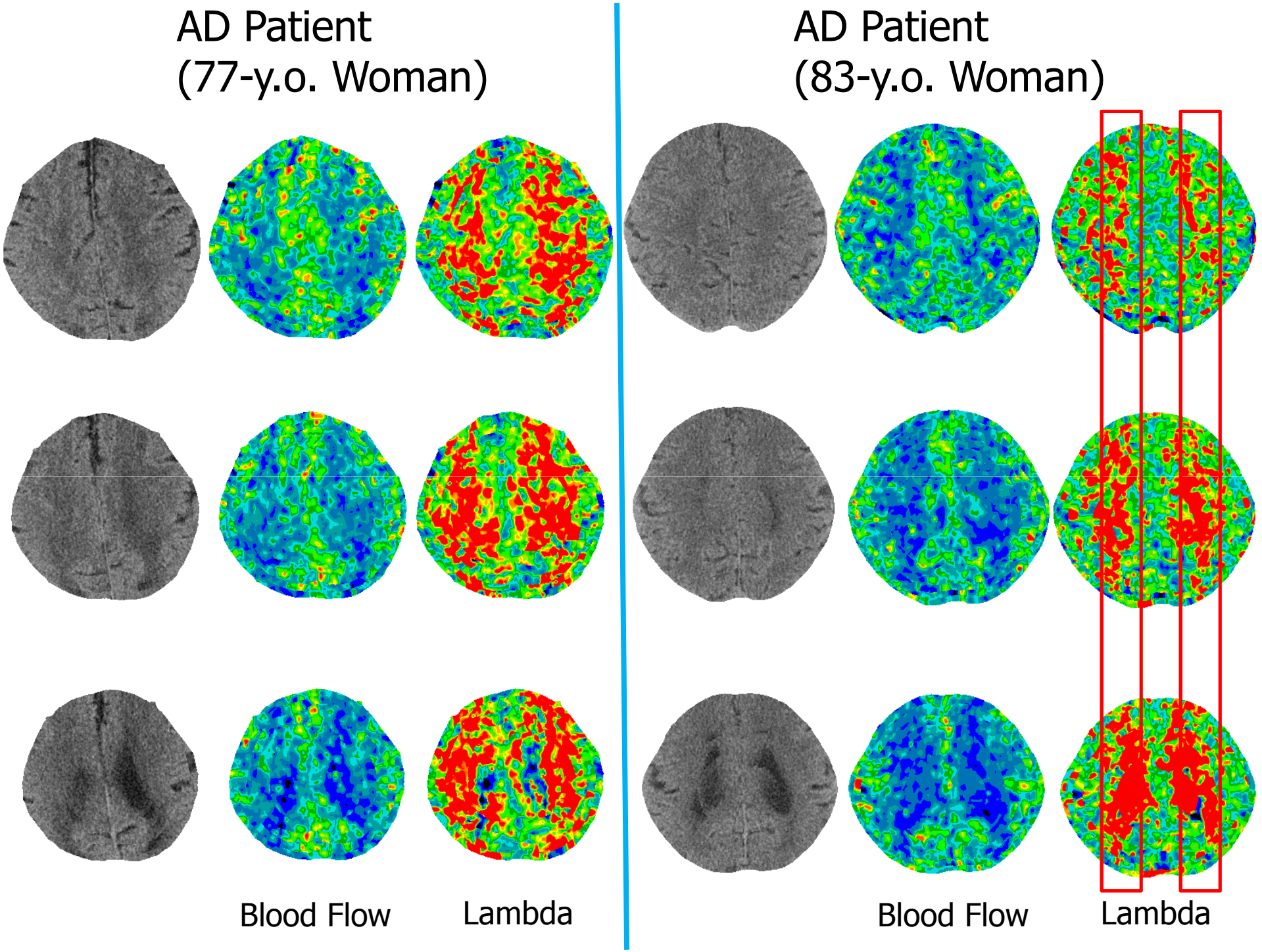



Healthy Volunteer
(77-y.o. Woman)
AD Patient
(83-y.o. Woman)
Blood Flow
Lambda
Blood Flow
Lambda


Healthy Volunteer
(77-y.o. Woman)
AD Patient
(83-y.o. Woman)
Blood Flow
Lambda
Blood Flow
Lambda


Healthy Volunteer
(77-y.o. Woman)
AD Patient
(83-y.o. Woman)
Blood Flow
Lambda
Blood Flow
Lambda


Healthy Volunteer
(77-y.o. Woman)
AD Patient
(83-y.o. Woman)
Blood Flow
Lambda
Blood Flow
Lambda


AD Patient
(77-y.o. Woman)
AD Patient
(83-y.o. Woman)
Blood Flow
Lambda
Blood Flow
Lambda

[Conclusions]

- Method of creating quantitative blood flow images for the brain surface was established.
- Layer-by-layer spherical analysis would provide useful information which could not be obtained from tomographic images.
- High lambda suggests accumulation of substances in which xenon is highly soluble.

[Future]

- When the function of head movement correction is much more accomplished, radiation exposure will be reduced by nearly half by decreasing the number of CT scans (from 9 to 5).
- Improvement of CT image processing by TOSHIBA could reduce mAs with little deterioration of the quality of CT images and also reduce the radiation exposure.
- Quantitative judgment of treatment effectiveness, specifying the form of dementia, and detecting the dementia in its early stage, by means of Xe-CT.

Thank you very much.