

Functional Imaging for a refined Diagnosis of Brain Tumors

Pr. Denis DUCREUX, MD, PhD, HDR

Diagnostic Neuroradiology Department, CHU Bicetre
CNRS IR4M (UMR 8081), Paris Sud University
Le Kremlin-Bicêtre, FRANCE

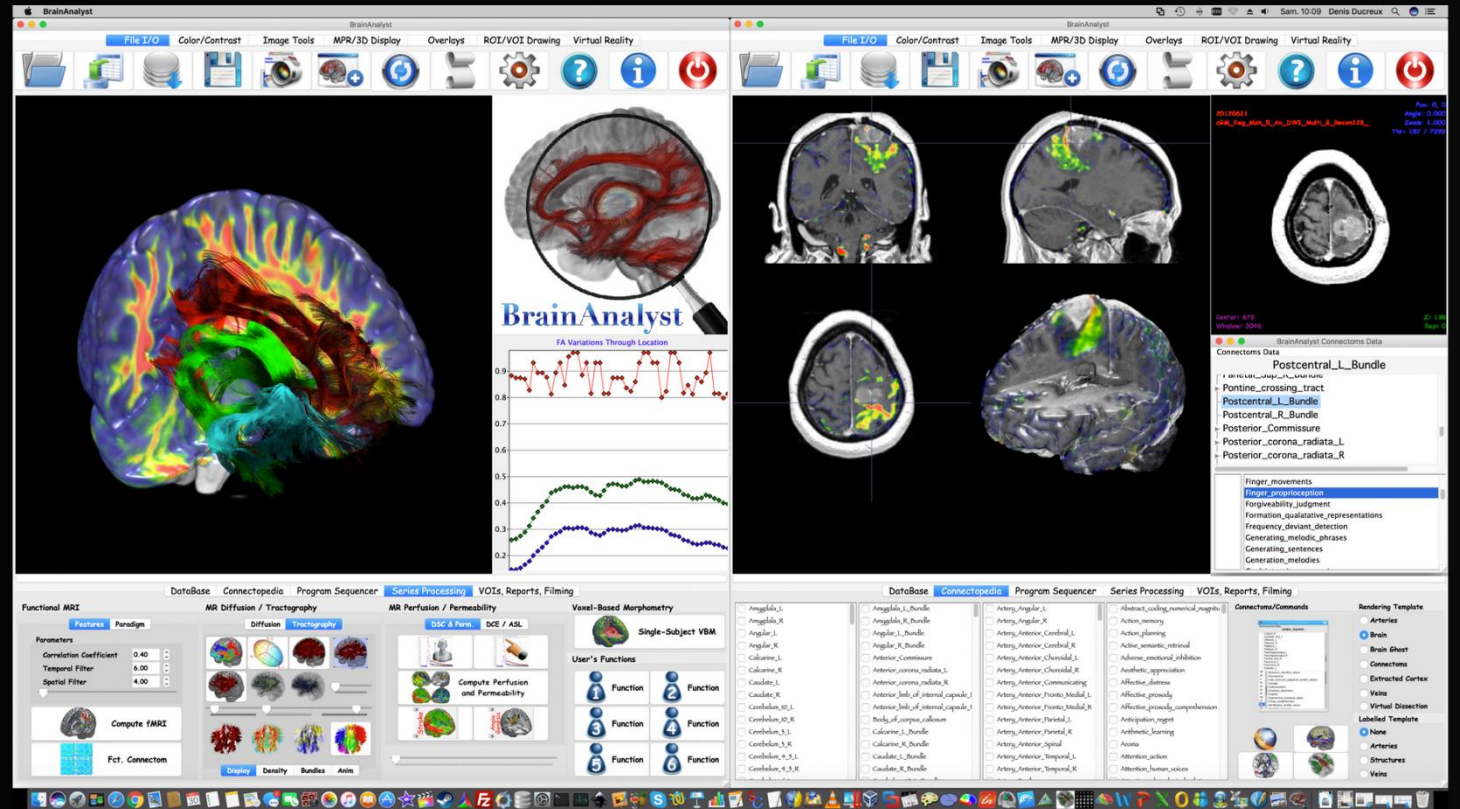
Pr Denis Ducreux,

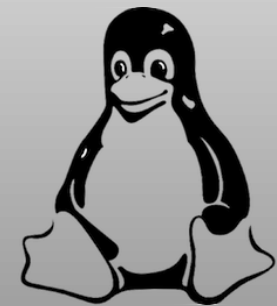
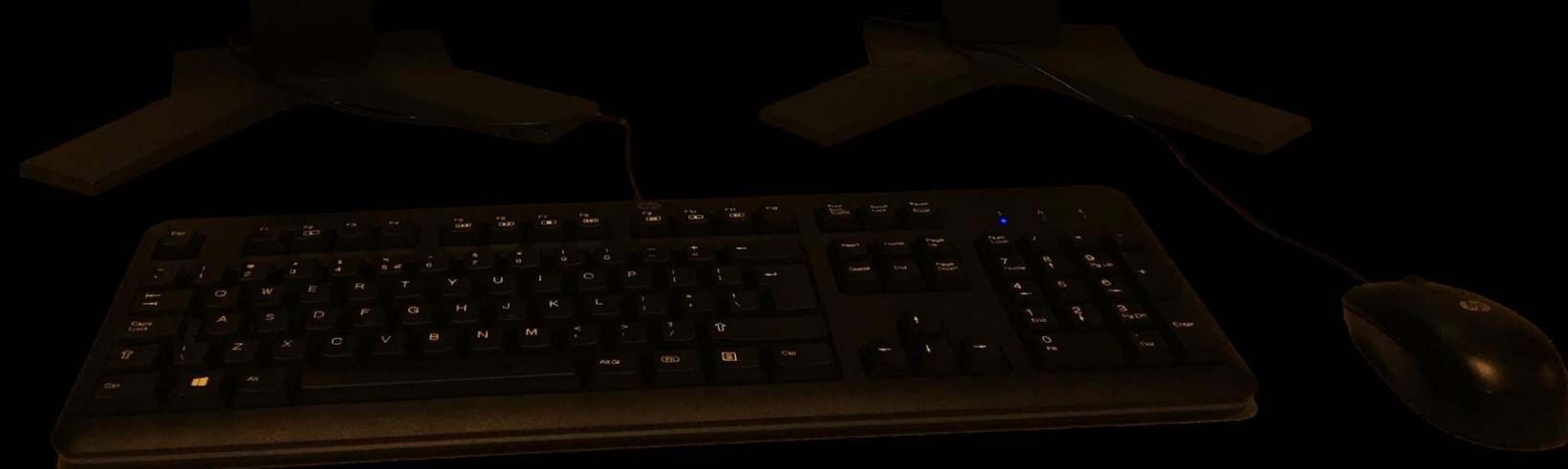
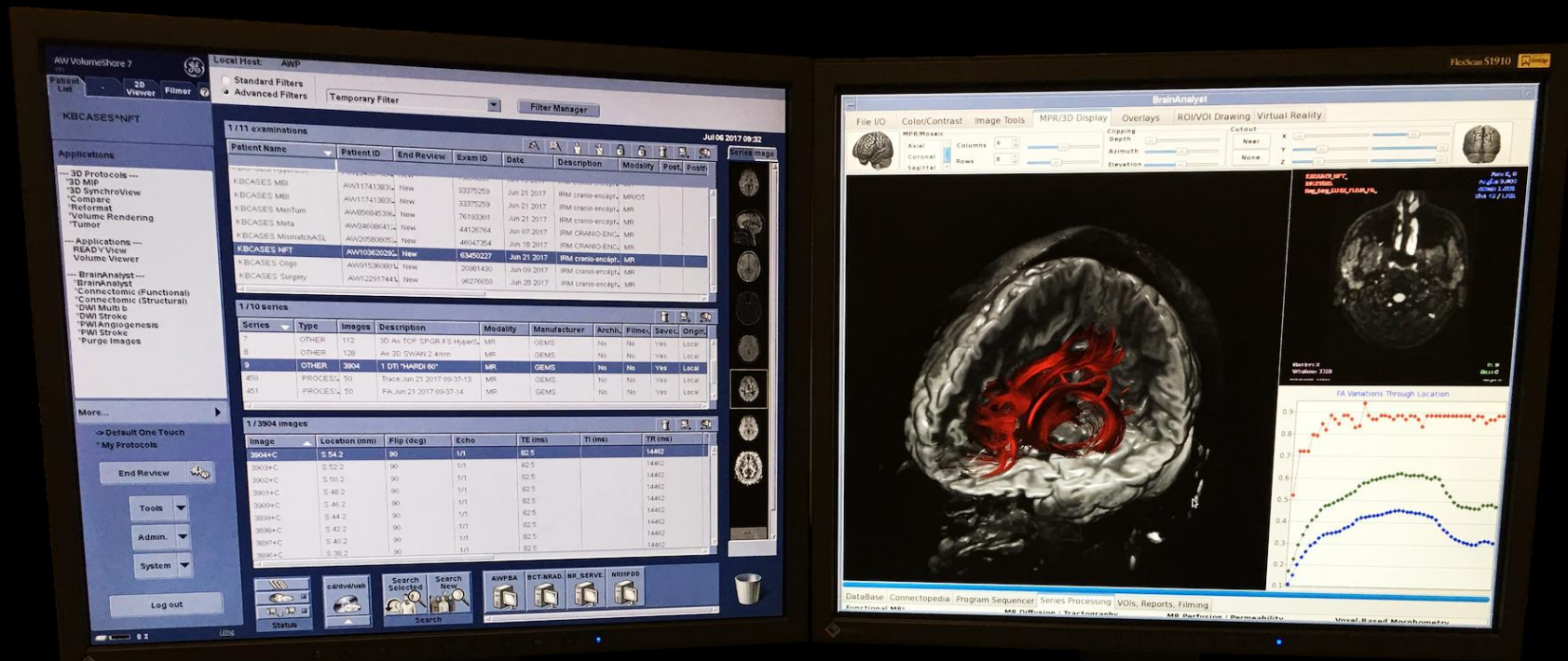
MD, PhD, HDR



- Head of Diagnostic Neuroradiology Department since 2009, C.H.U. Bicêtre, France
- Team 1, CNRS IR4M – MRI Methodology and Instrumentations
- PhD in MRI Physics, Image Processing – Brain PWI
- HDR in Physics, Image Processing – Spinal Cord Fibertracking

Software developer since 1997 (Neural Network, Image Processing : Activ2000, DPTools, Connectopedia, fMRICRoTools, *BrainAnalyst*)







Functional MRI Methods

Multi-Compartmental Diffusion

Multi-Compartmental Diffusion

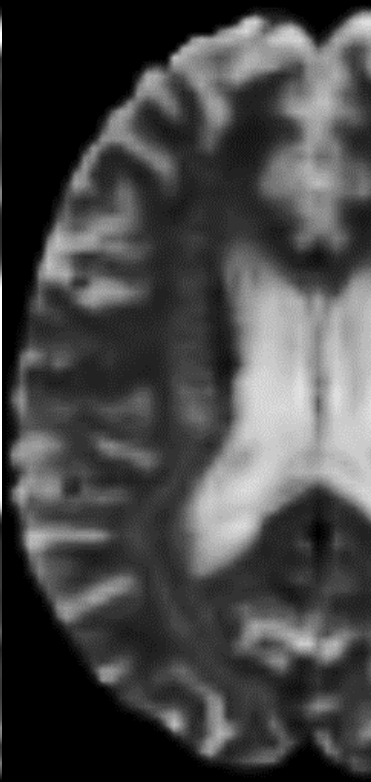
Signal Attenuation



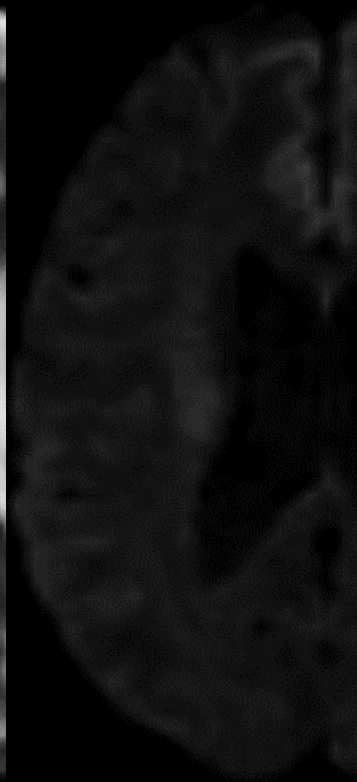
$b=0$ s/mm²



$b=100$ s/mm²



$b=500$ s/mm²



$b=1000$ s/mm²



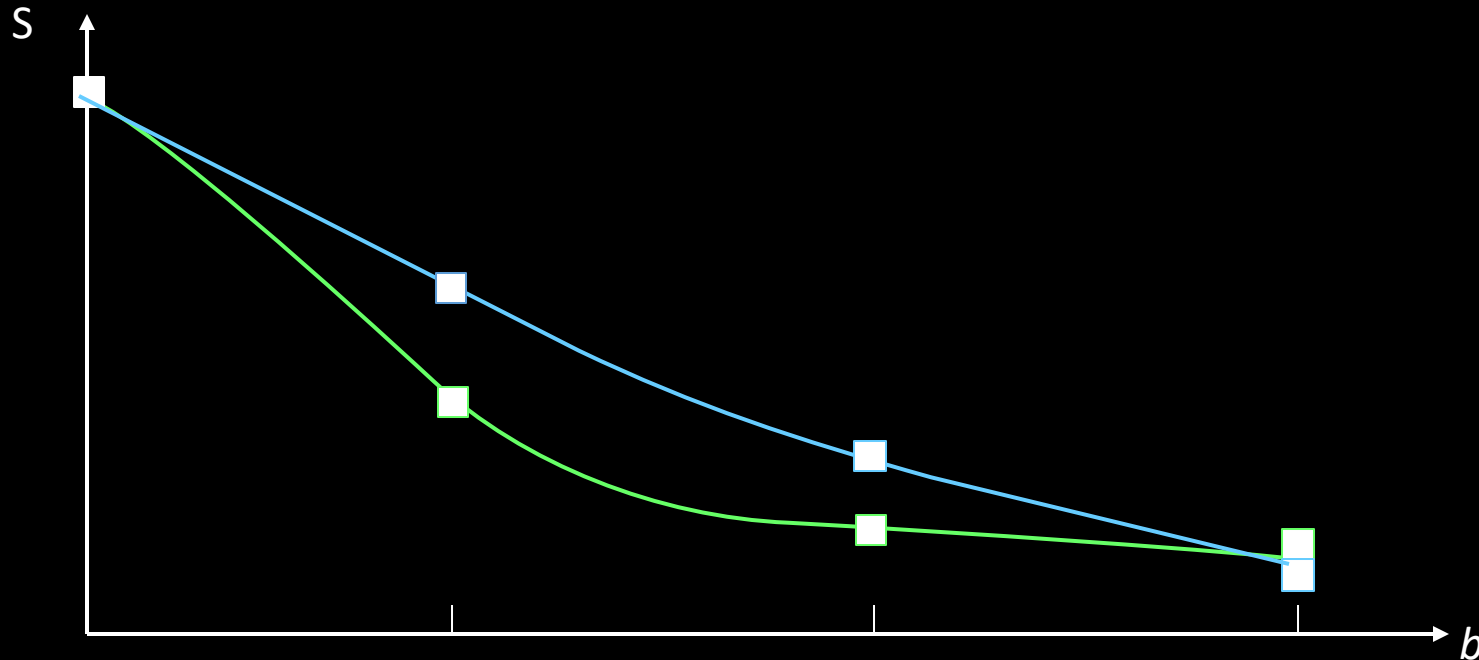
$b=2500$ s/mm²



$b=5000$ s/mm²

Multi-Compartmental Diffusion

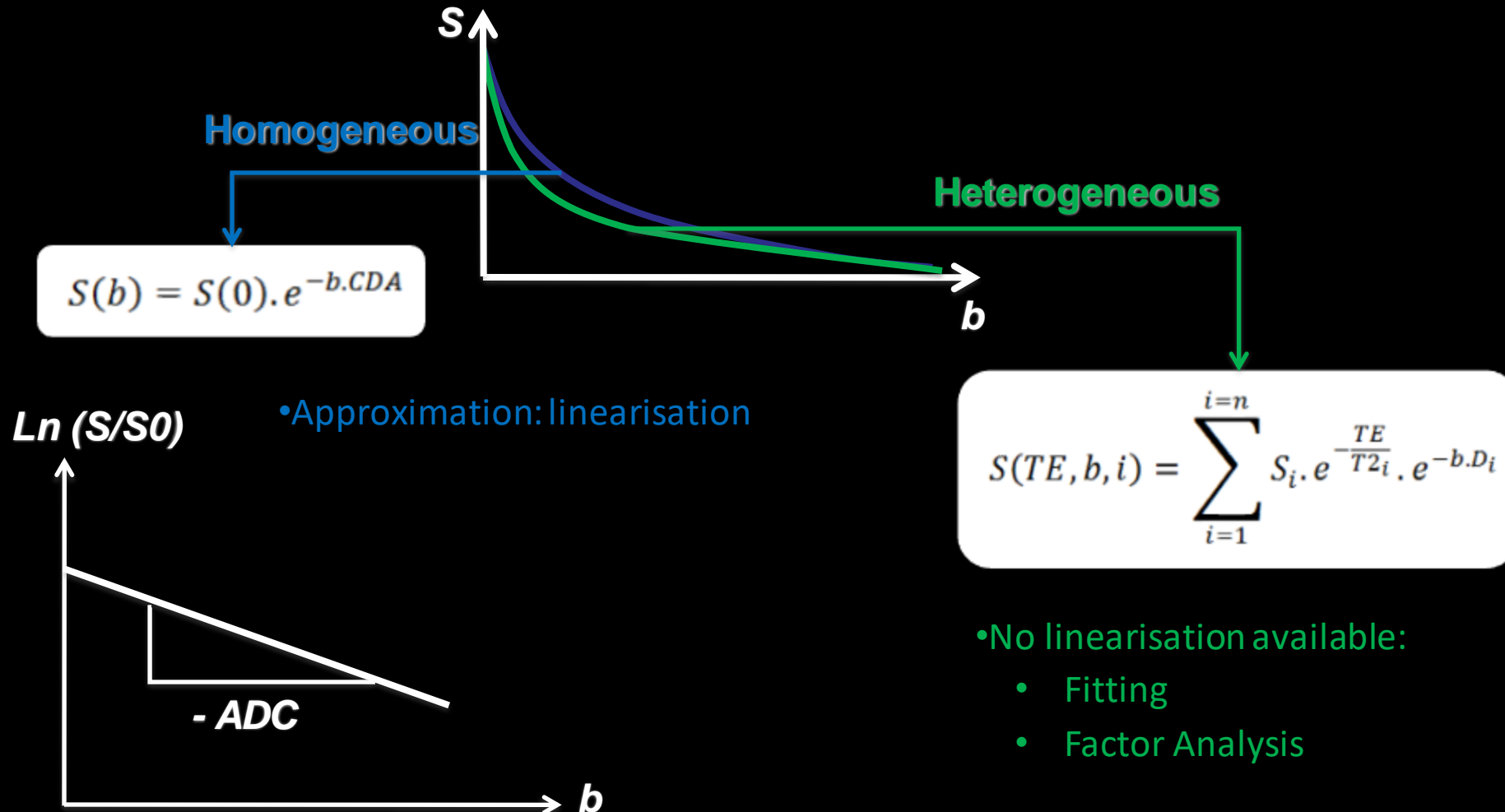
Homogeneous vs Heterogeneous Signal Attenuation



$$S_b = S_0 \cdot e^{-b \cdot D} \text{ versus } S_i(t_e, b) = [S_a \cdot e^{-t_e/T2a} \cdot e^{-b \cdot Da}] + [S_b \cdot e^{-(t_e/T2b)} \cdot e^{-b \cdot Db}]$$

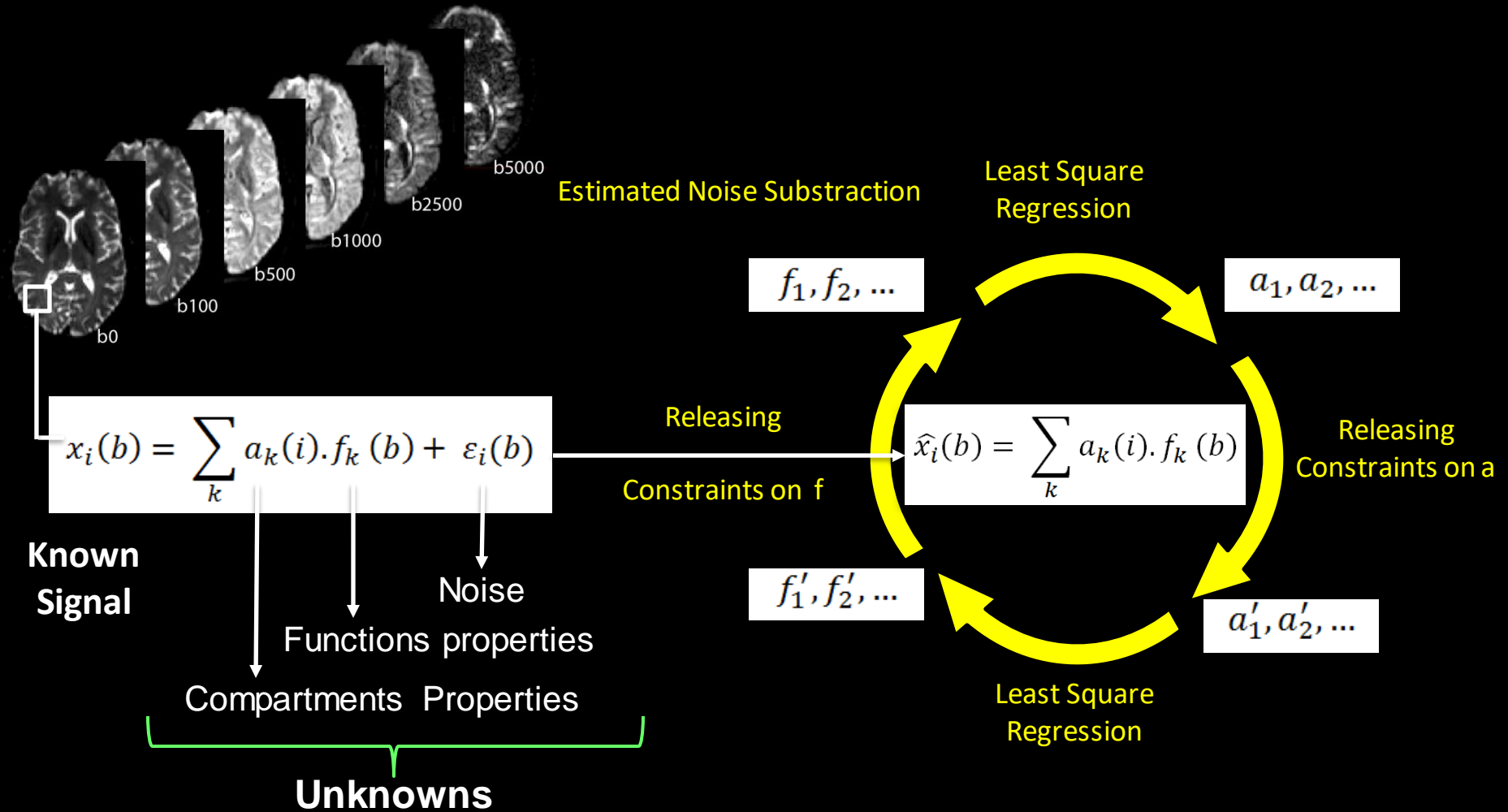
Multi-Compartmental Diffusion

Homogeneous vs Heterogeneous Signal Decay



Multi-Compartmental Diffusion

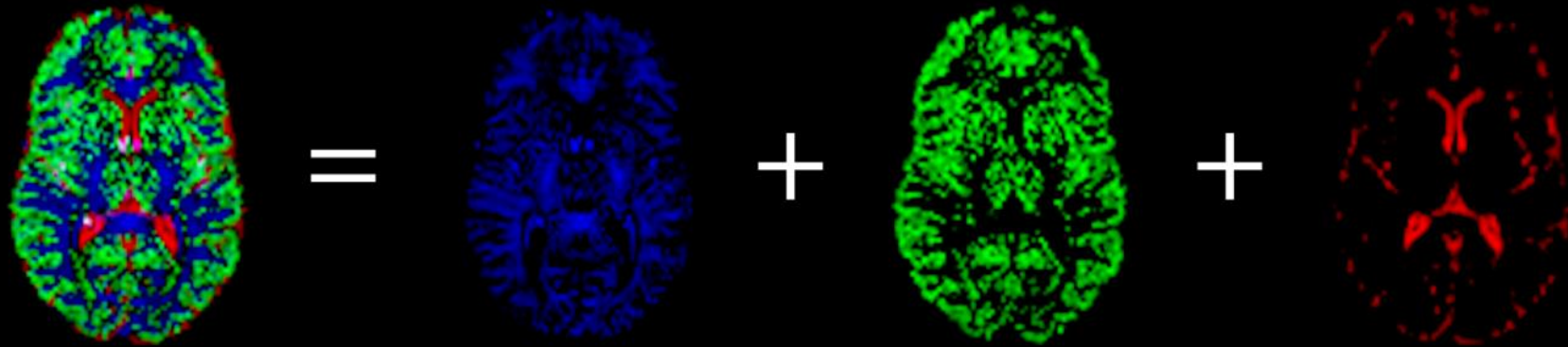
PCA and FA Analysis



Multi-Compartmental Diffusion

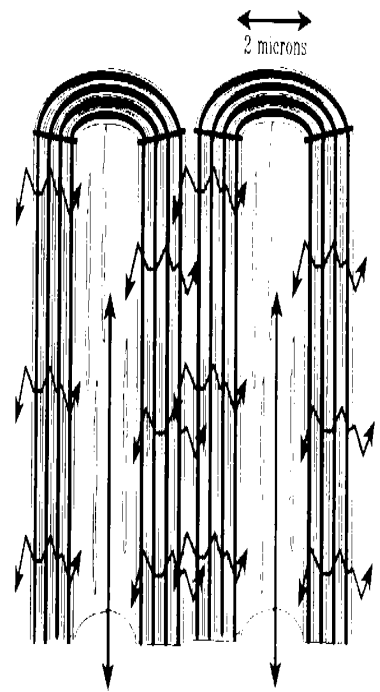
Compartments Extraction

$$x_i(b) \begin{array}{c} \uparrow \\ \text{---} \\ \downarrow \\ \text{---} \\ \rightarrow \end{array} = a_1(i) \begin{array}{c} \uparrow \\ \text{---} \\ \downarrow \\ \text{---} \\ \rightarrow \end{array} + a_2(i) \begin{array}{c} \uparrow \\ \text{---} \\ \downarrow \\ \text{---} \\ \rightarrow \end{array} + a_3(i) \begin{array}{c} \uparrow \\ \text{---} \\ \downarrow \\ \text{---} \\ \rightarrow \end{array}$$

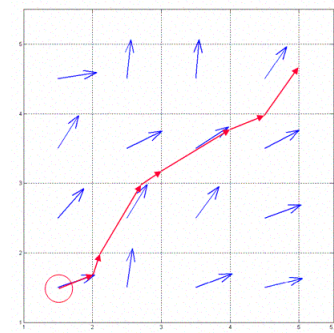
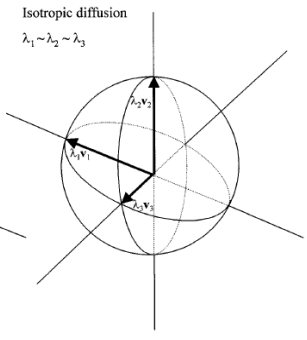
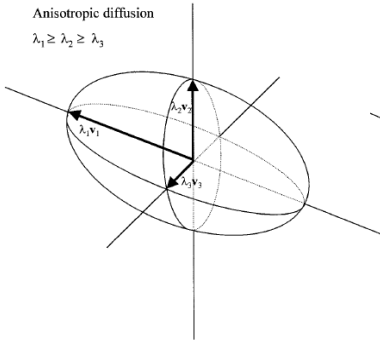
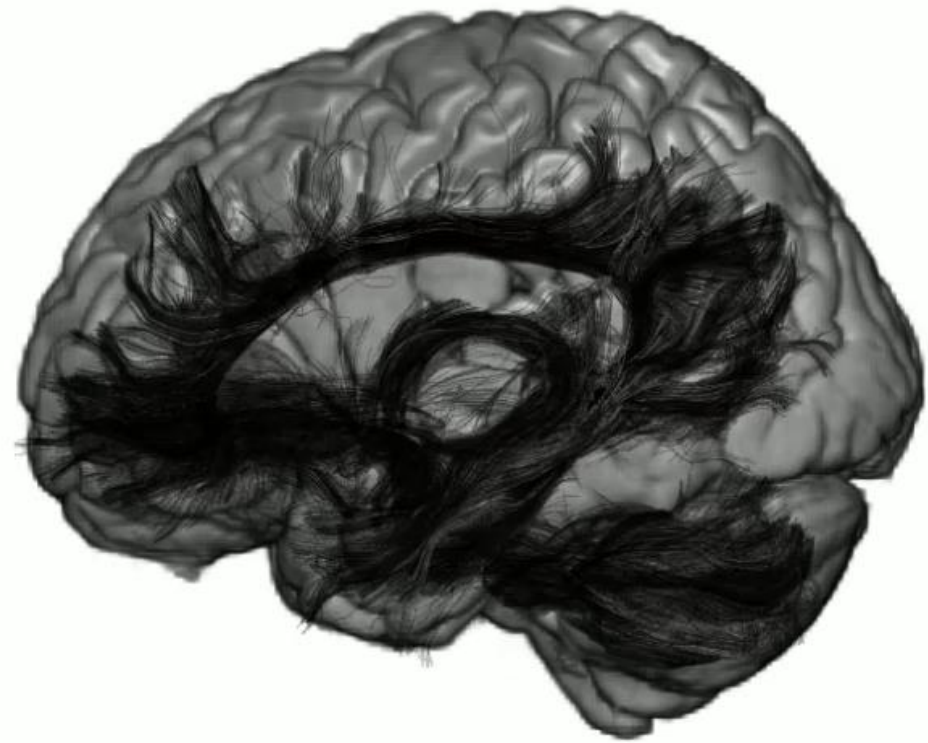
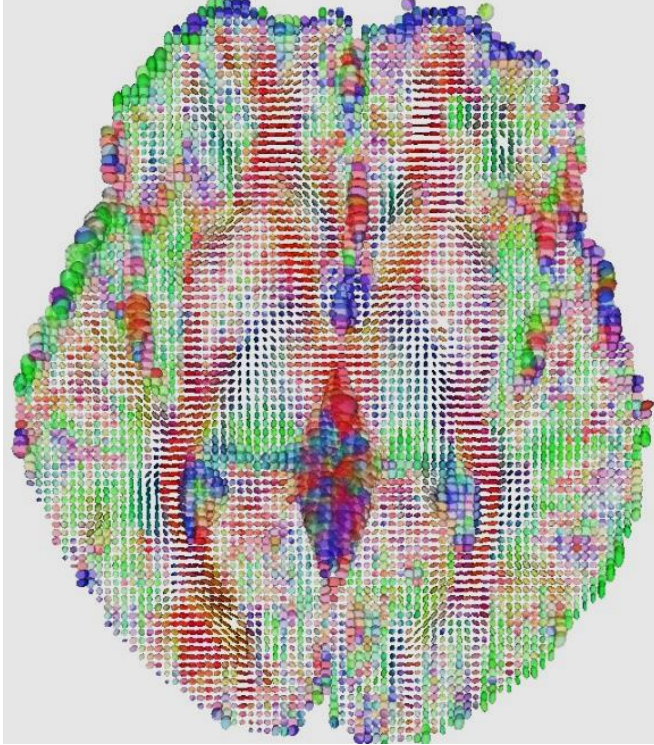


DTI & Fibertracking

DTI & Fibertracking



(d'après D. Le Bihan)

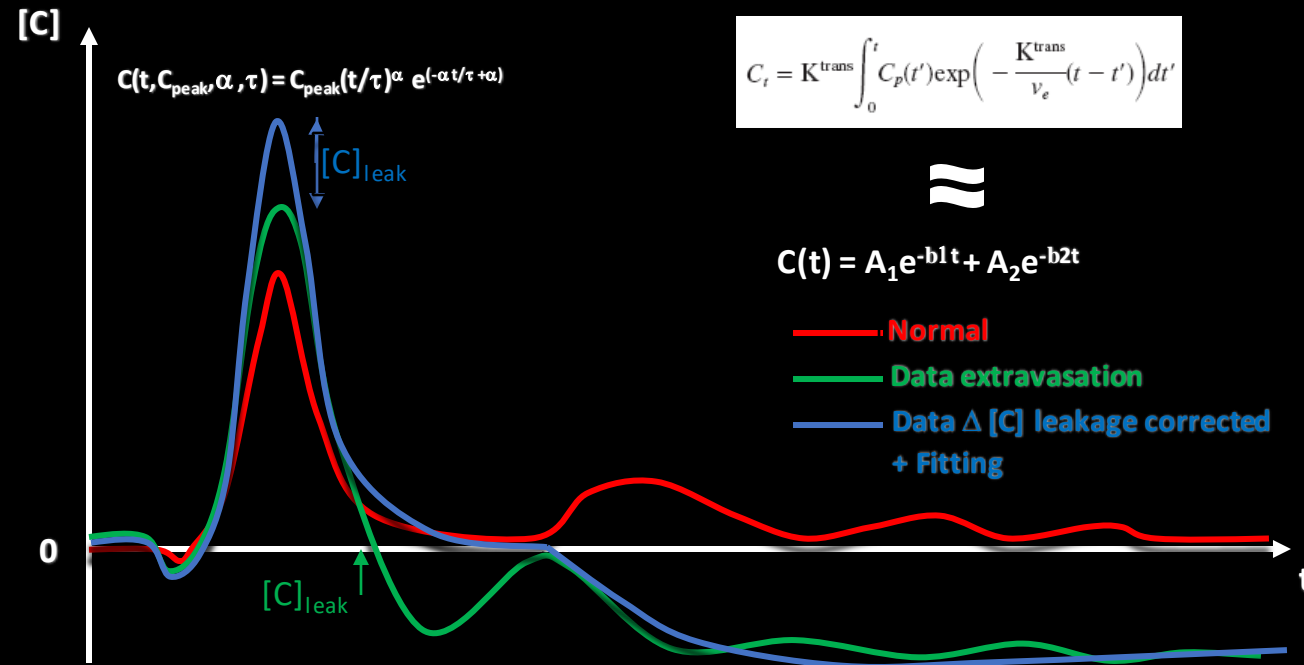


Perfusion & Permeability

Perfusion & Permeability

Combined estimation of Perfusion and Permeability in T2*

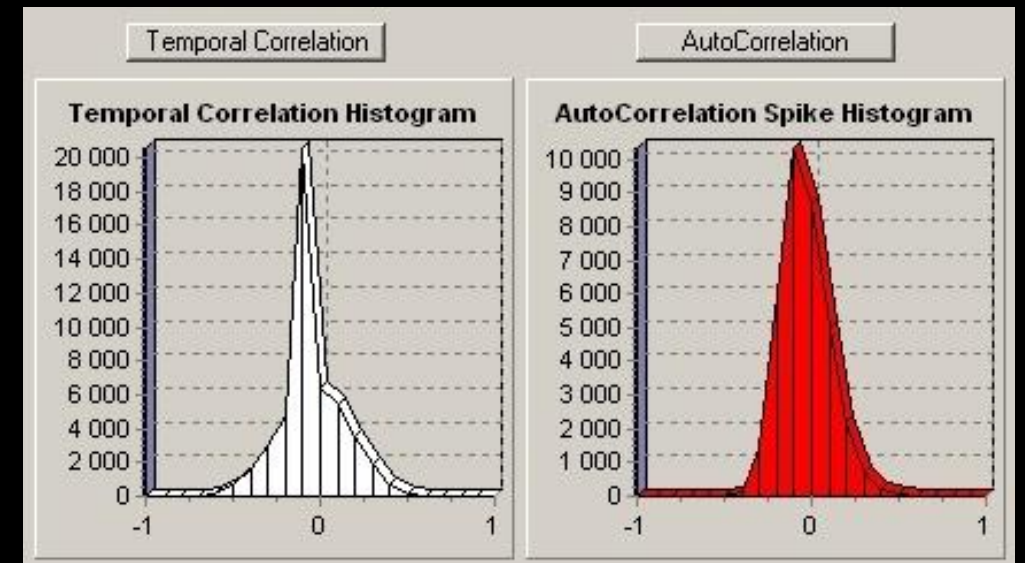
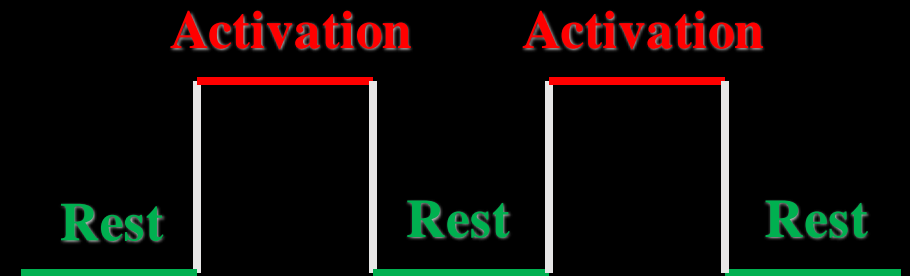
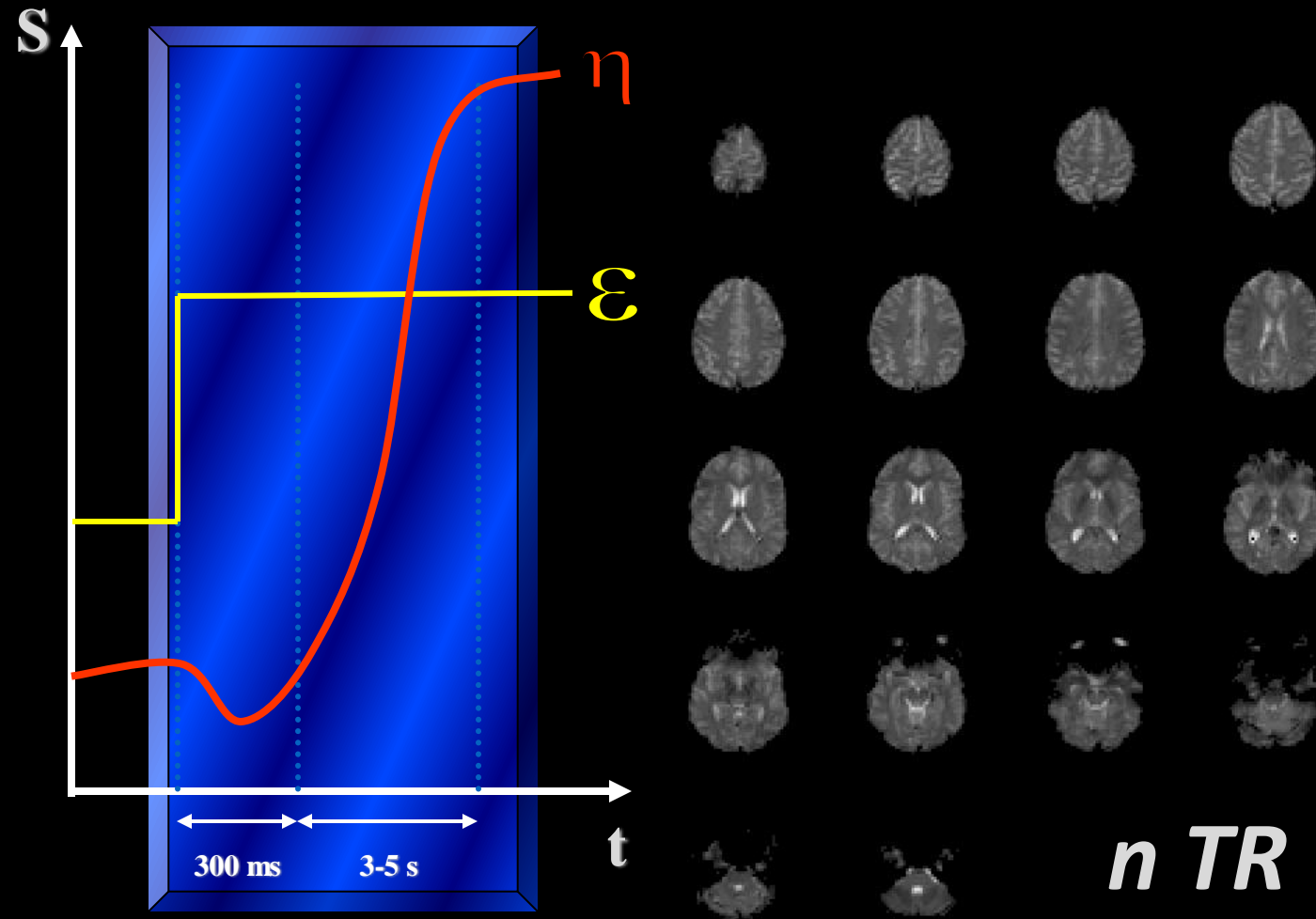
Patent WO/2008/132386



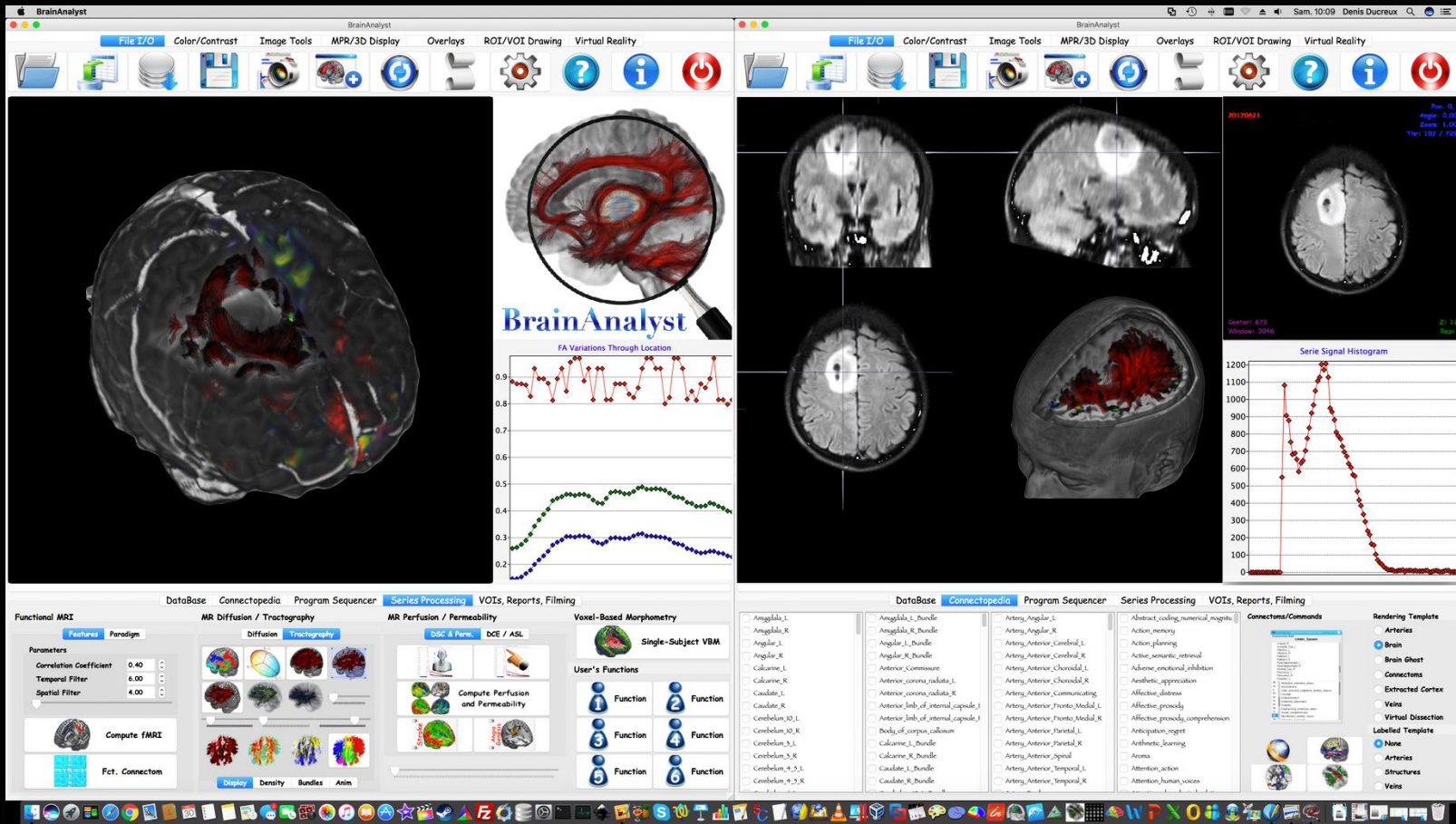
Activation

Activation - BOLD Effect

Box Car Paradigm



Clinical Cases



AW VolumeShare 7

Filter Manager

1/11 examinations

Patient Name	Patient ID	Exam ID	Date	Description	Modality	Inst.	Phys.
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) AXC	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	
KBCASES MB	AW117412024	New	2007029	Jun 21 2017	MR (non-contrast) MR	MR	

1/130 series

Series	Type	Images	Description	Modality	Manufacturer	APAC	FIMES	Series	Origin
OTHER	110	10	3D-Ax T1W T1 3D T1 1.5mm	MR	GEANT	MR	MR	1462	
OTHER	128	14	3D-SWAN 1.5mm	MR	GEANT	MR	MR	1462	
OTHER	304	1	3D-SWAN 40"	MR	GEANT	MR	MR	1462	
PROCESSED	56	1	Track Jun 21 2017 09:37:10	MR	GEANT	MR	MR	1462	
PROCESSED	56	1	Track Jun 21 2017 09:37:14	MR	GEANT	MR	MR	1462	

1/2904 images

Image	Location (mm)	FPS (deg)	Slice	TE (ms)	T1 (ms)	T2 (ms)
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462
304C	5.94.2	90	1A	82.0		1462

Applications

- 3D Protocols
- 3D SynchronView
- Compare
- Relaxmat
- Volume Rendering
- Tumor
- Applications
- READY View
- Volume Steerer
- Brain Analyst
- Connectome (Functional)
- Connectome (Structural)
- DWI Multi b
- DWI Stroke
- SWI Angiogenesis
- PMI Stroke
- Purple Images

More...

Default One Touch

My Protocols

End Review

Tools

Admin

System

Logout

Electron S1910

1/11 examinations

1/130 series

1/2904 images

0 Axial M30CubeT2In... KBCASES GBM
S: 18.48 (mm)
DFOV 23.0 x 24.5 cm
38 %
Ex: Jun 14 2017

0 Axial M30CubeT2In... KBCASES GBM
S: 18.48 (mm)
DFOV 23.0 x 24.5 cm
38 %
Ex: Jun 14 2017

0 Axial M30CubeT2In... KBCASES GBM
S: 18.48 (mm)
DFOV 23.0 x 24.5 cm
38 %
Ex: Jun 14 2017

0 Axial M30FSPGR: Ax 30... KBCASES GBM
S: 15.87 (mm)
DFOV 34.8 x 25.6 cm
38 %
Ex: Jun 14 2017

0 Axial M30FSPGR: Ax 30... KBCASES GBM
S: 15.87 (mm)
DFOV 34.8 x 25.6 cm
38 %
Ex: Jun 14 2017

0 Axial M30FSPGR: Ax 30... KBCASES GBM
S: 15.87 (mm)
DFOV 34.8 x 25.6 cm
38 %
Ex: Jun 14 2017



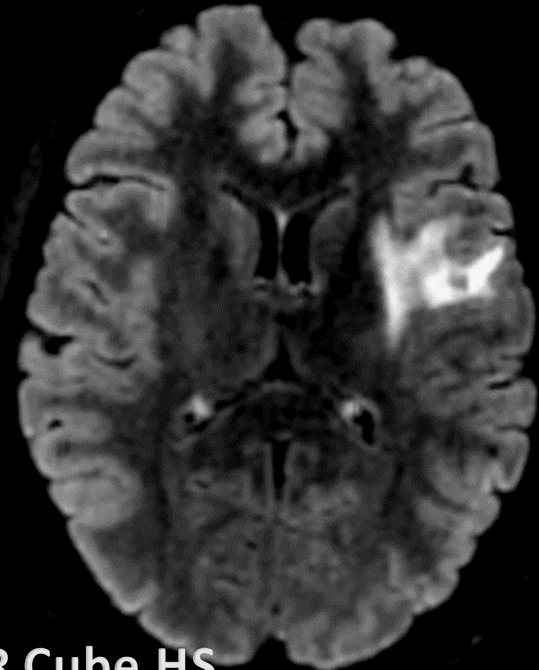
Case 1

Metastasis DWI

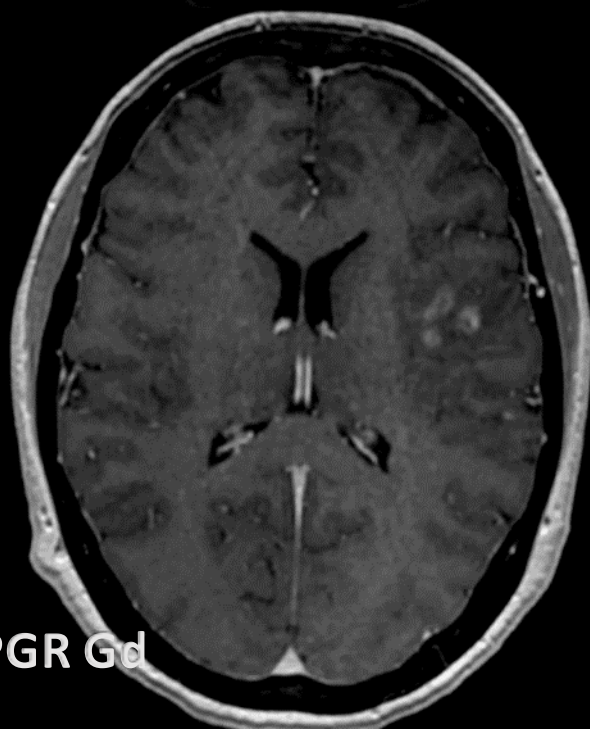
Automated Processing

Q: Aggressivity of Tumoral Cells?

A: Highly Active Tumoral Cells in Edema

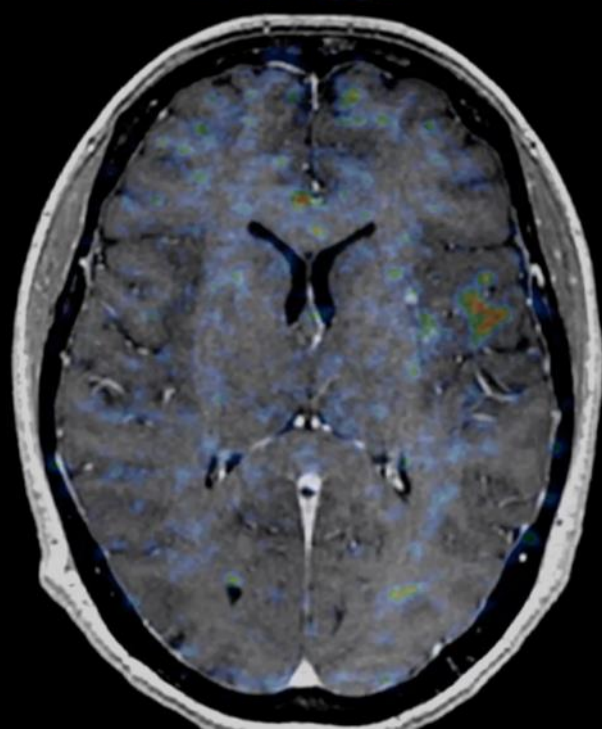
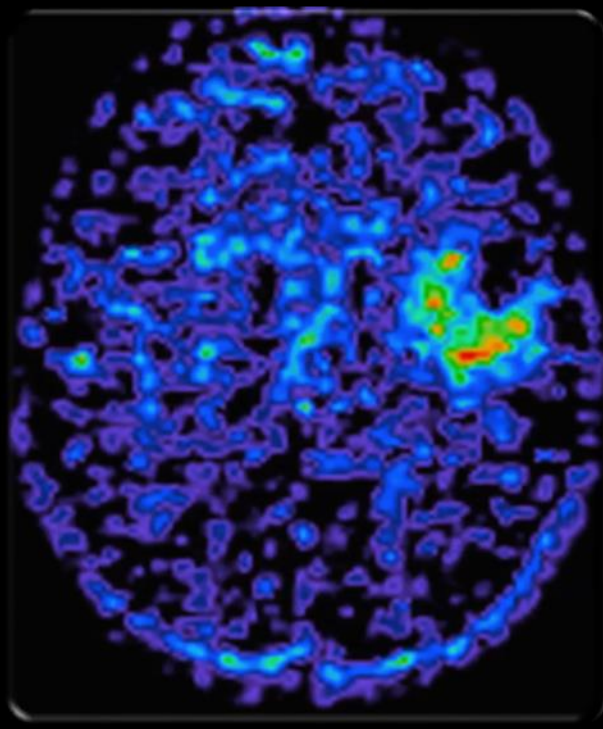
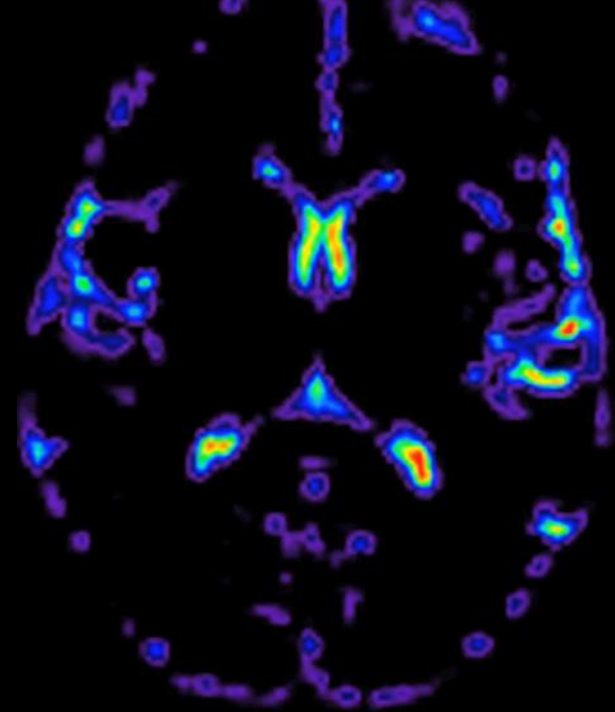
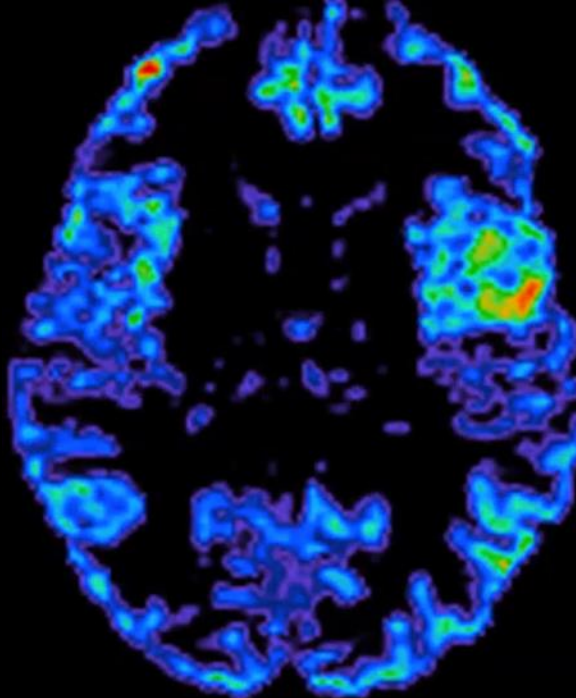


T2Prep FLAIR Cube HS



3D T1 FSPGR Gd

Multib DWI Maps



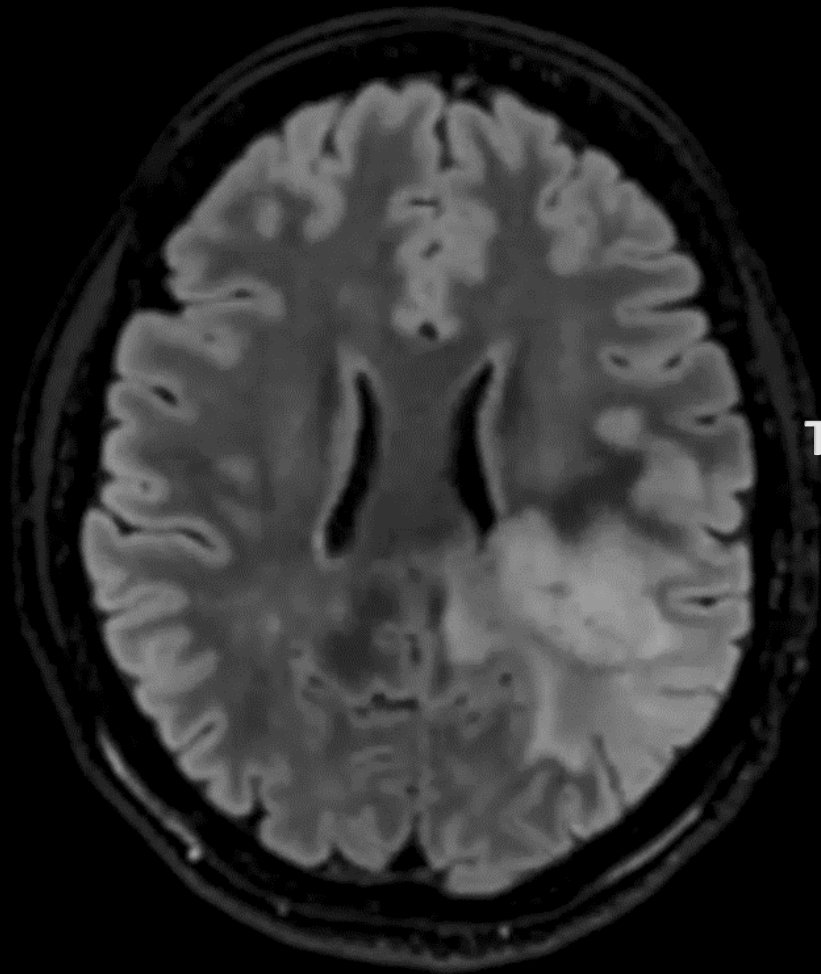
Case 2

Oligodendroglioma DWI / PWI

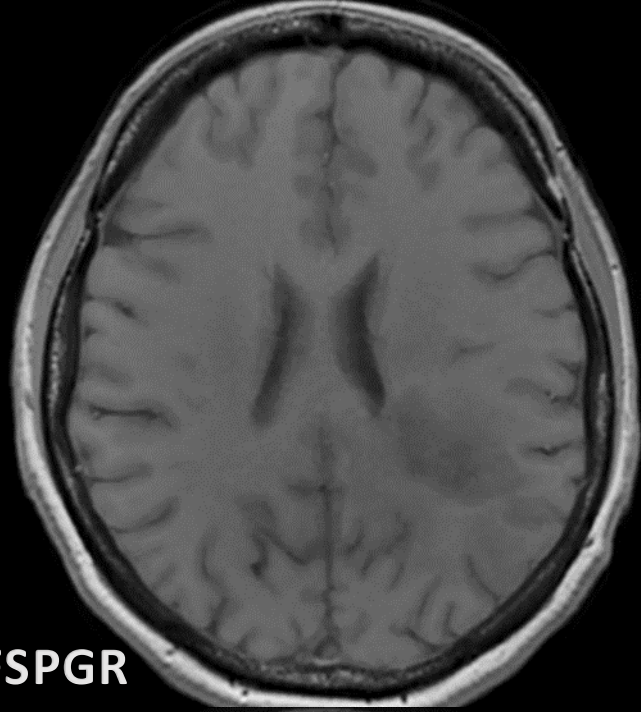
Automated Processing

Q: Extension ?

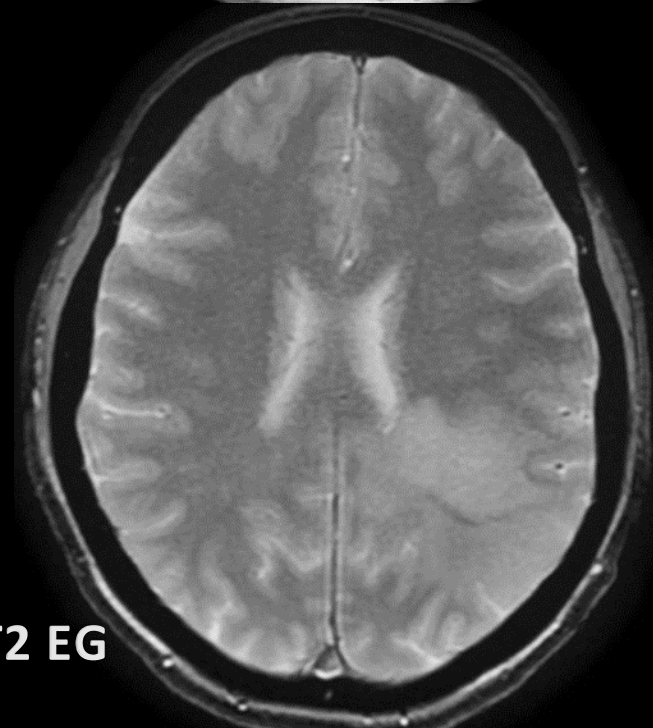
A: Left Parietal Area = Tumoral Cells Involvement and
NOT Edema !



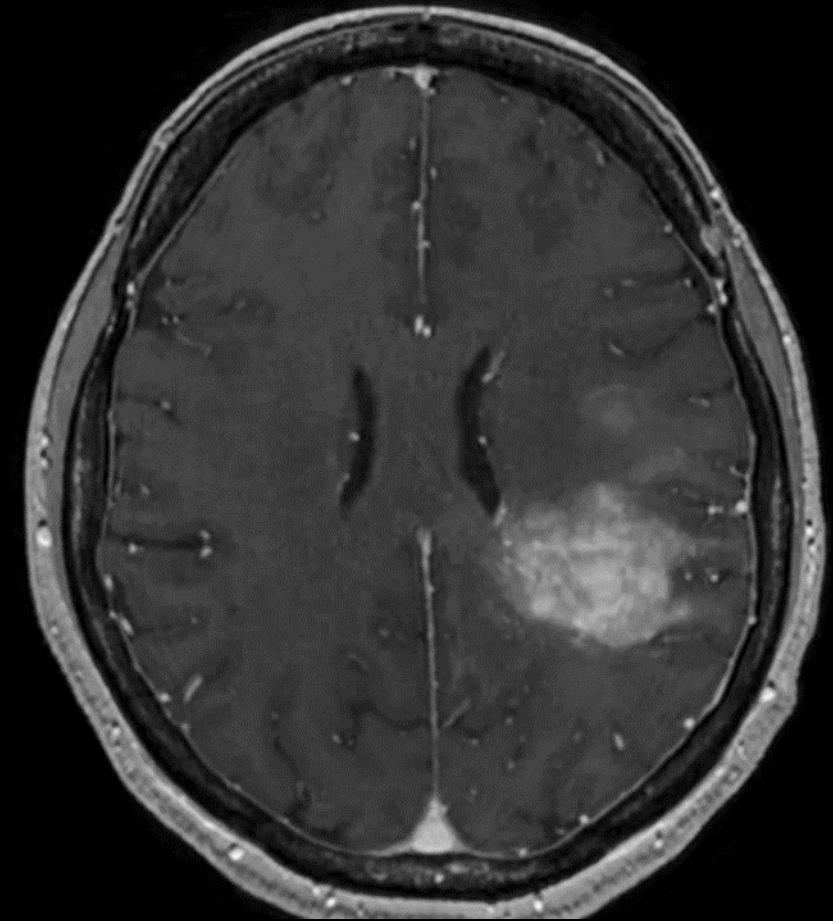
T2Prep FLAIR Cube HS



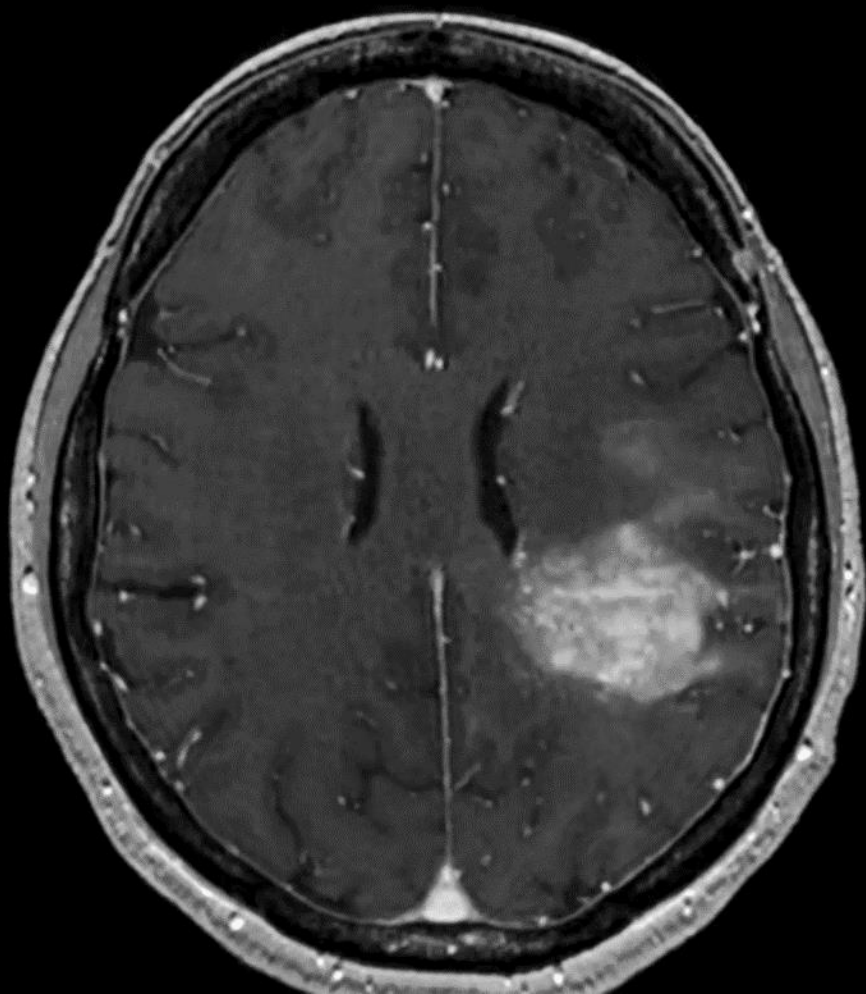
T1 FSPGR



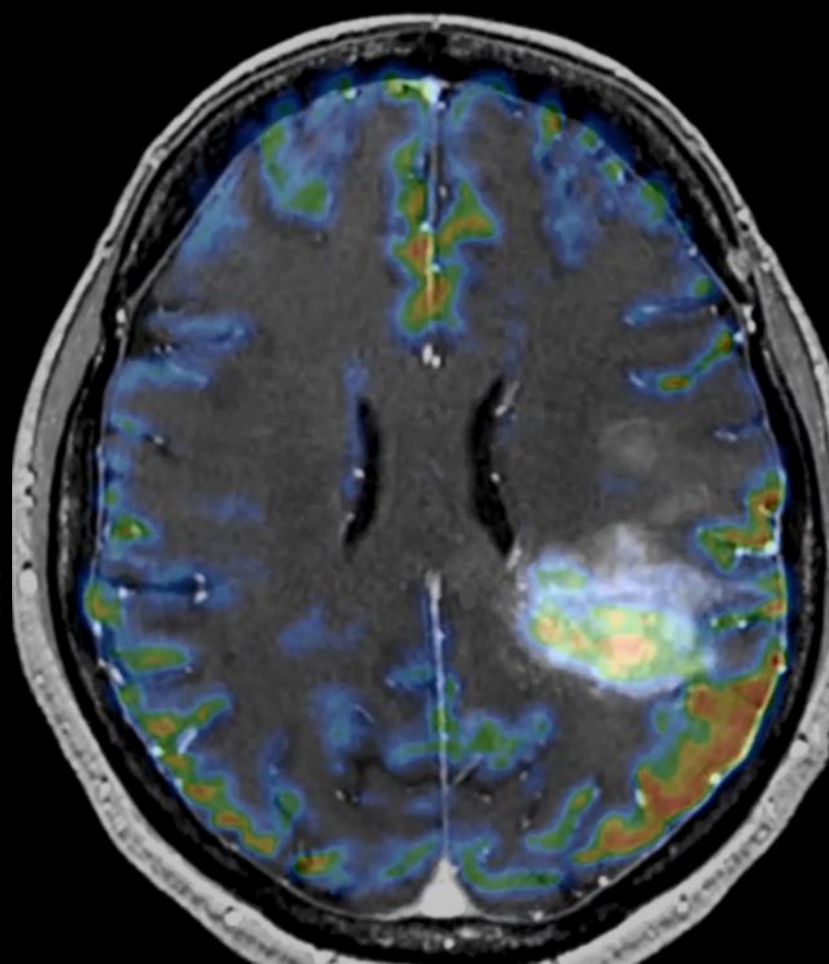
T2 EG



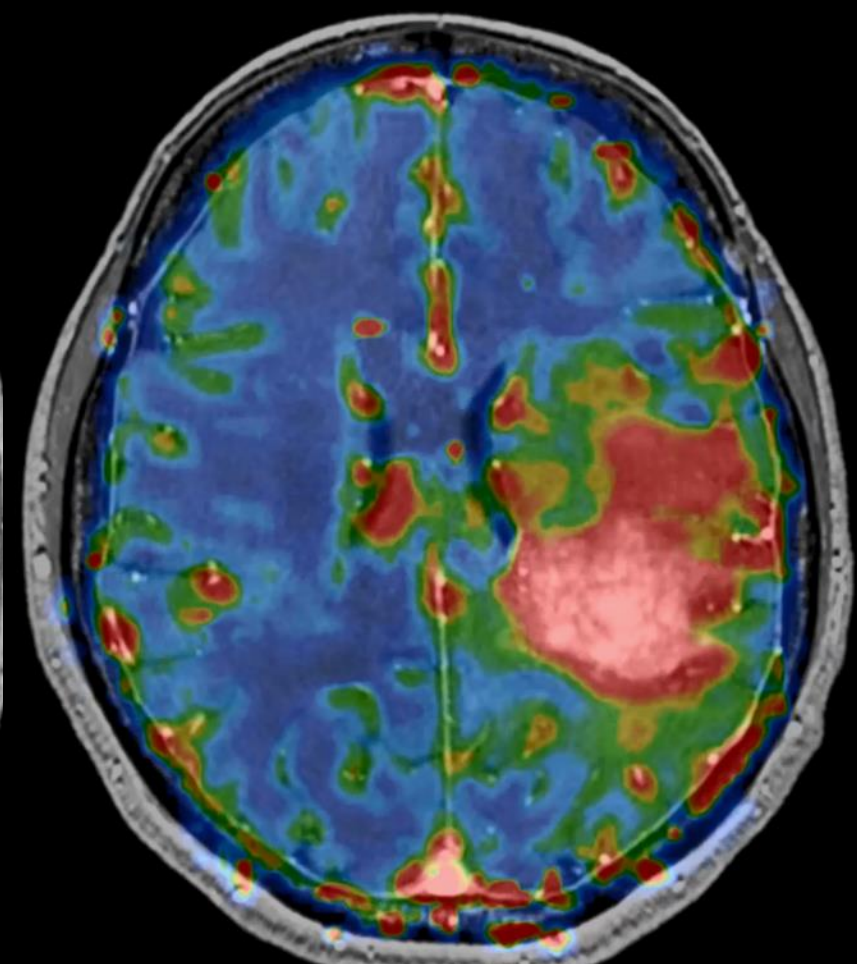
3D T1 FSPGR Gado



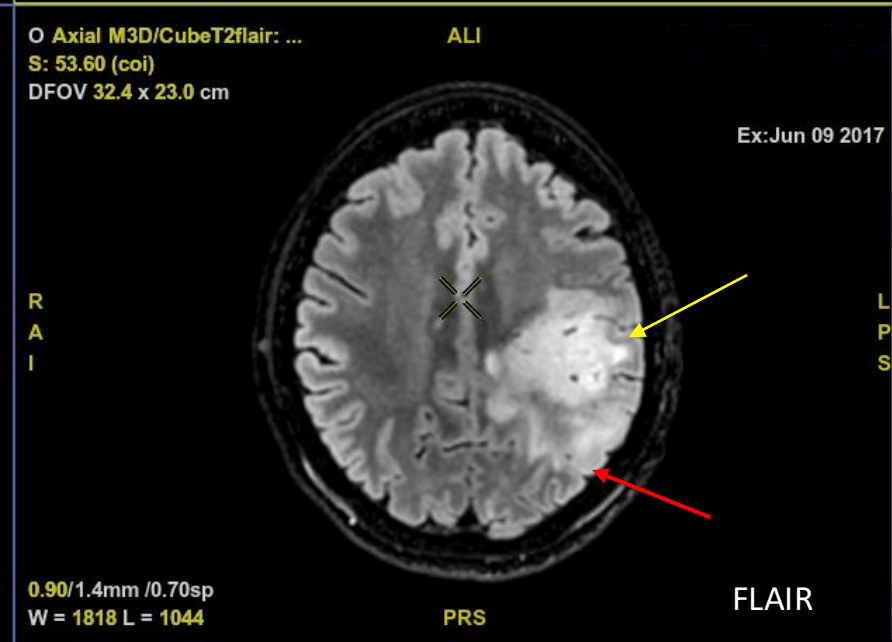
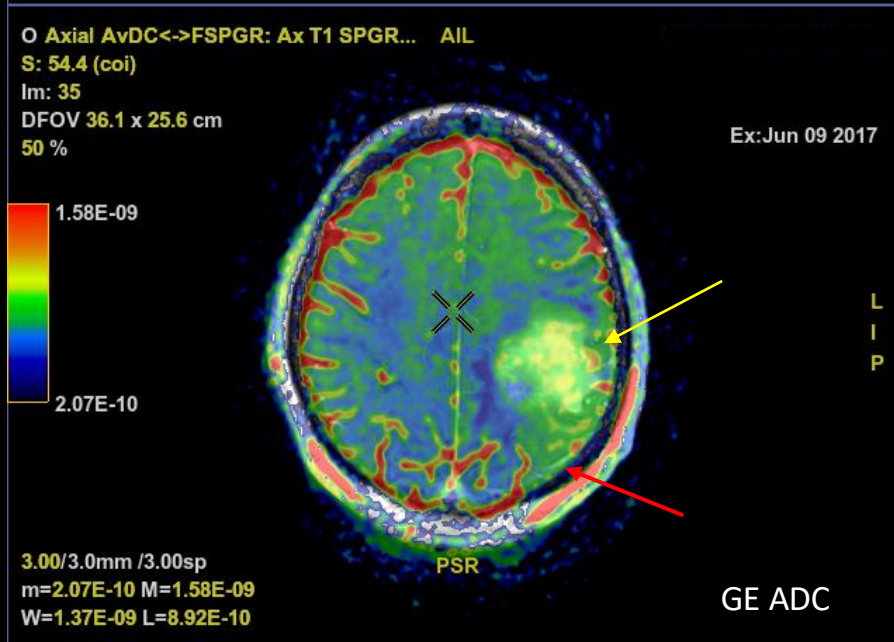
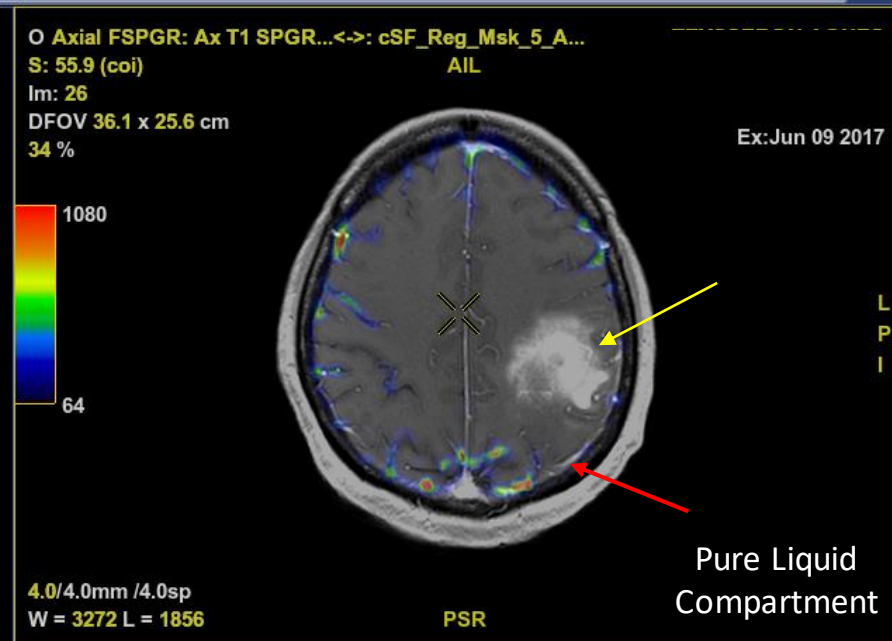
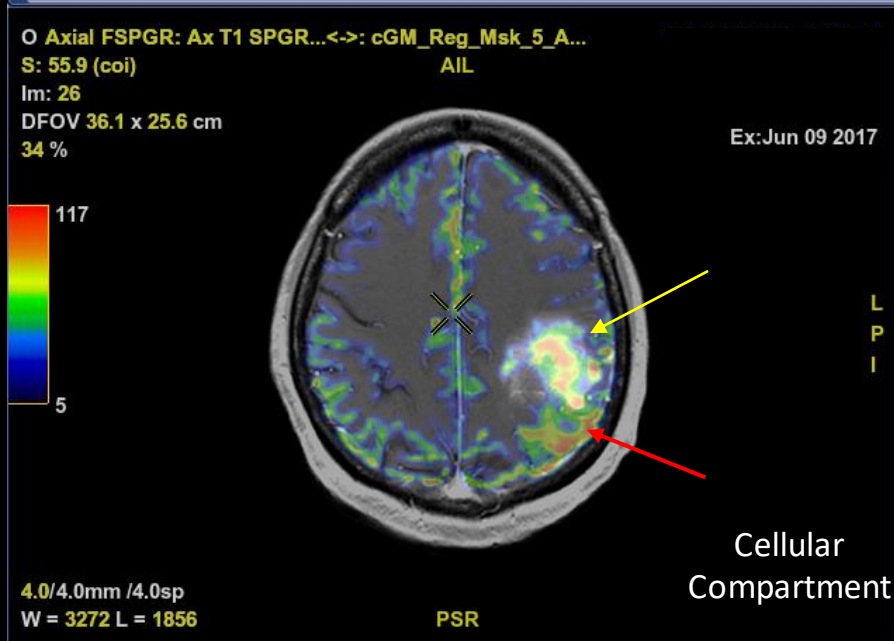
3D T1 FSPGR Gd



cGM on 3D T1 FSPGR Gd



CBV on 3D T1 FSPGR Gd



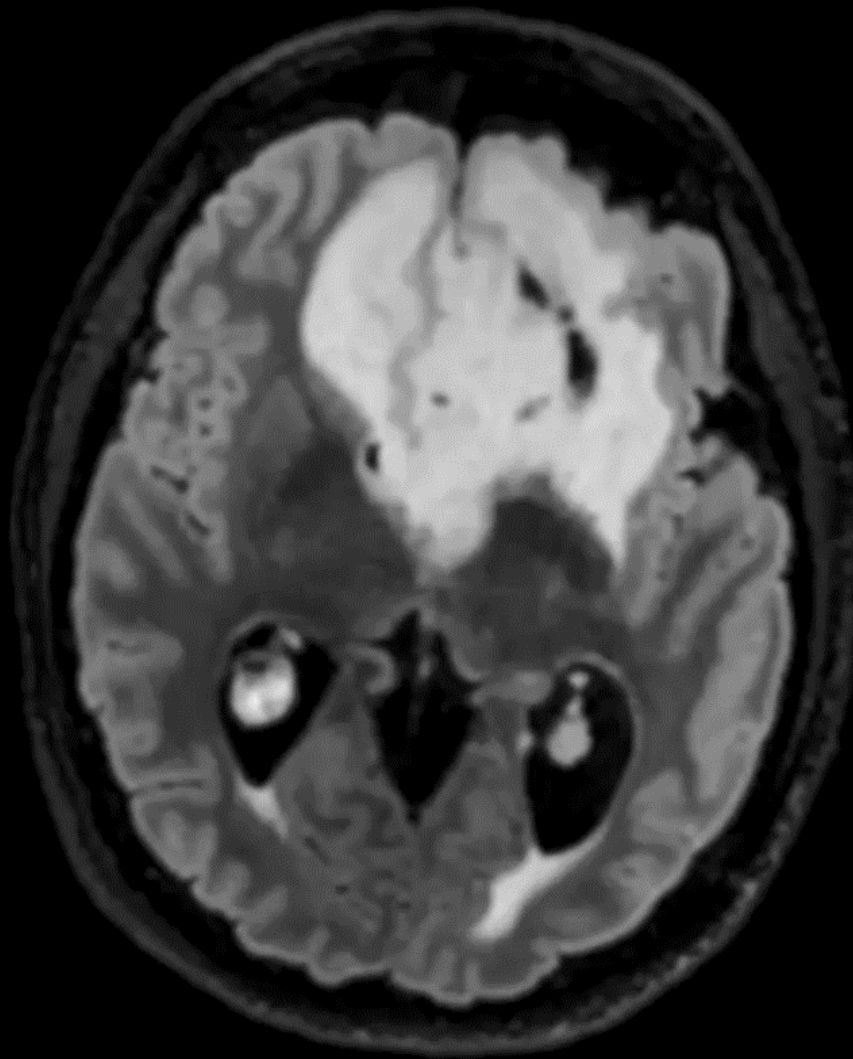
Case 3

Glioblastoma DWI / PWI

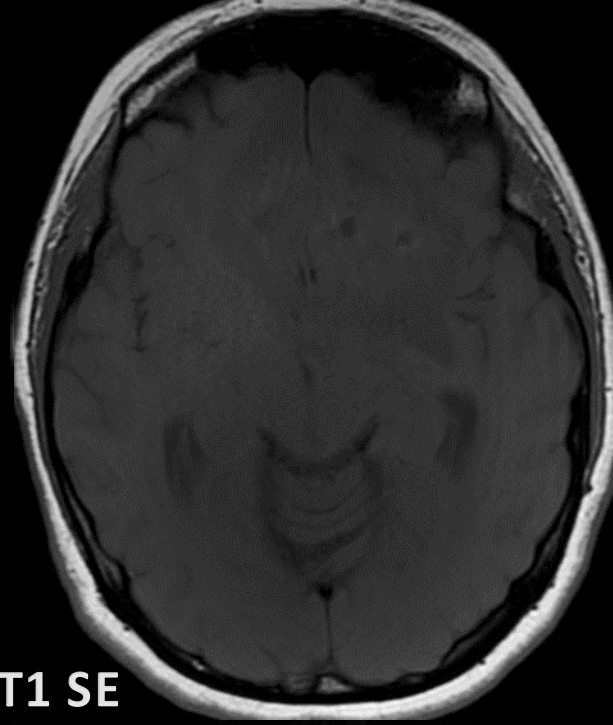
Automated Processing

Q: Tumoral Cells & Angiogenesis ?

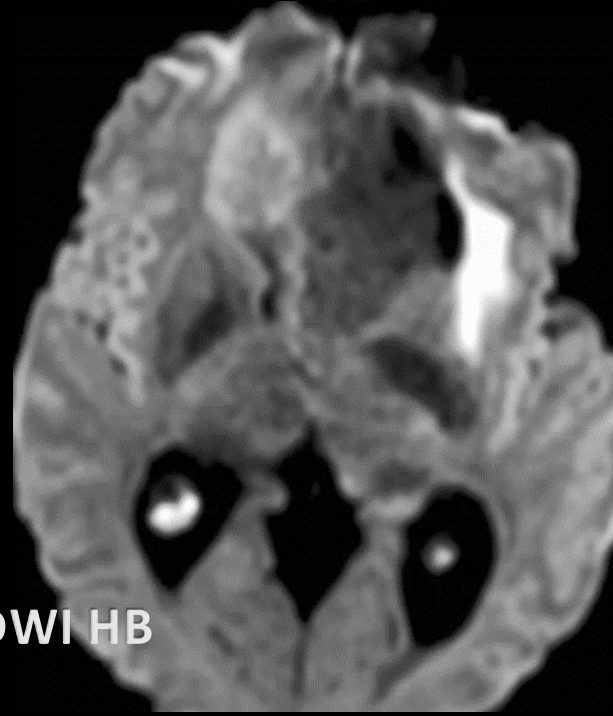
A: Tumoral Cells Infiltration seen in Edema, Surrounding
Neoangiogenesis



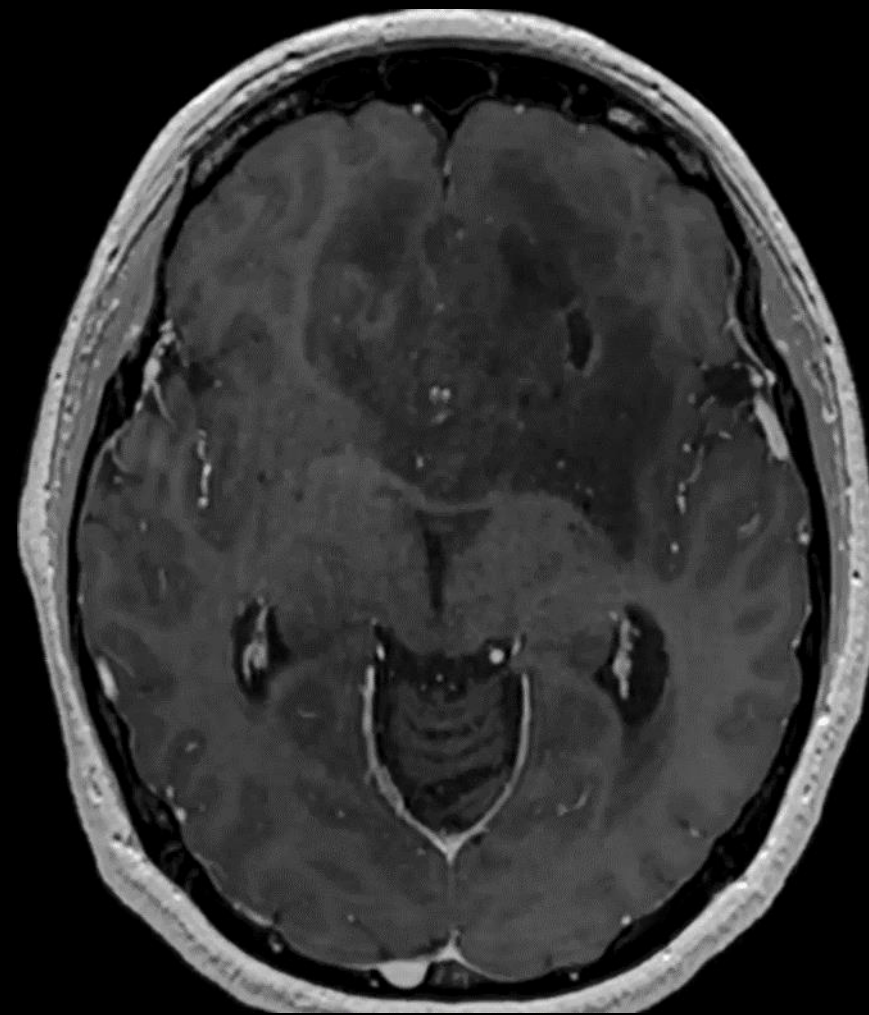
T2Prep FLAIR Cube HS



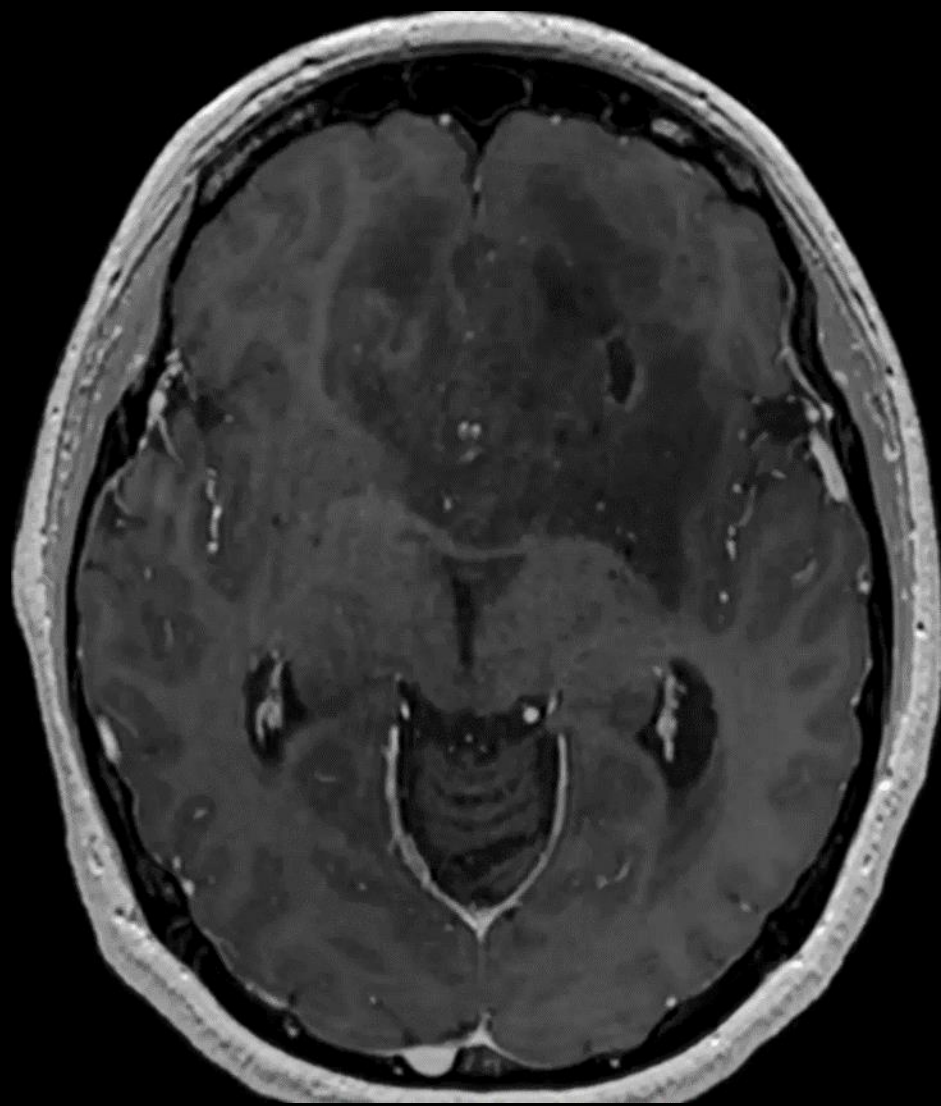
T1 SE



DWI HB



3D T1 FSPGR Gd



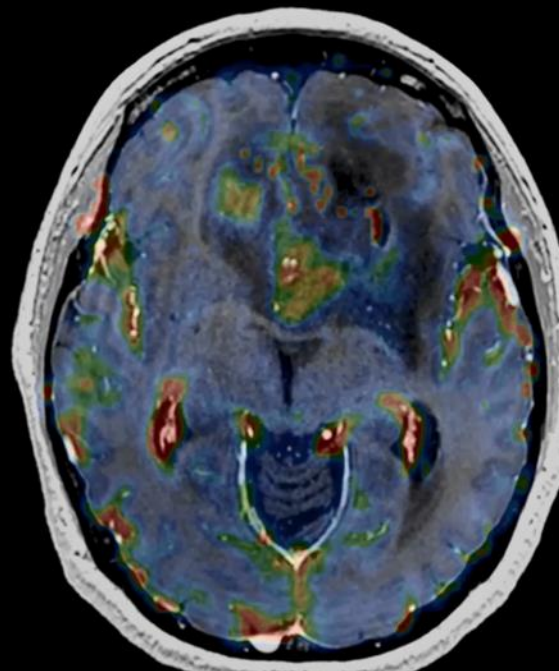
3D T1 FSPGR Gd

..<->: CBV_Reg_MoC_Msk...

ASL

D ...<->: fBV_Reg_MoC_Msk...

ASL



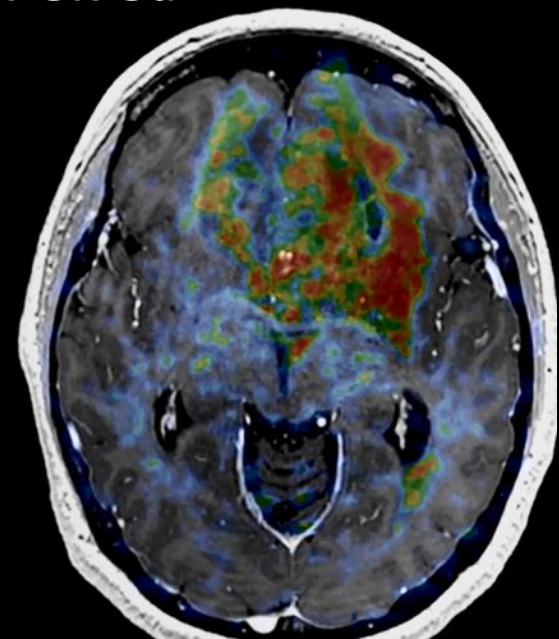
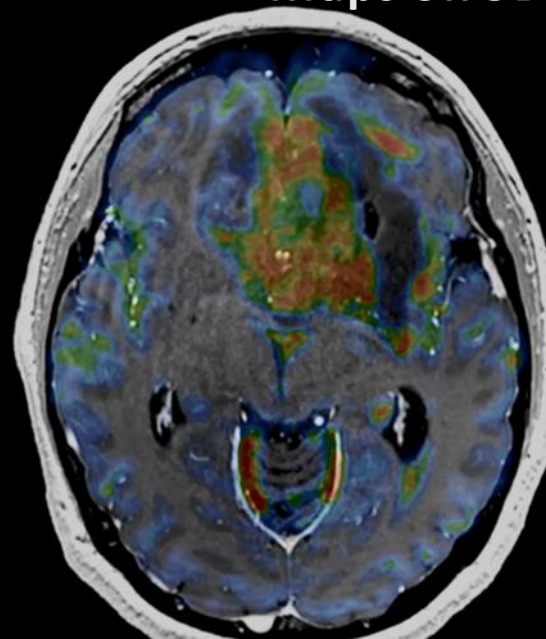
! ...<->: cGM_Reg_Msk_5_A...

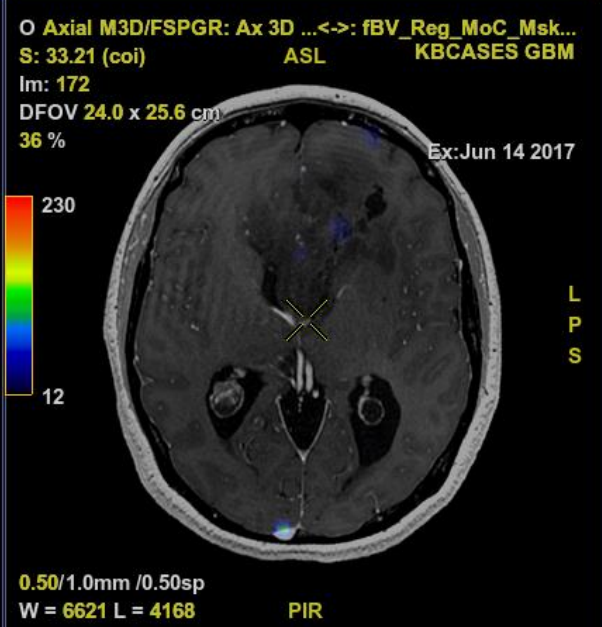
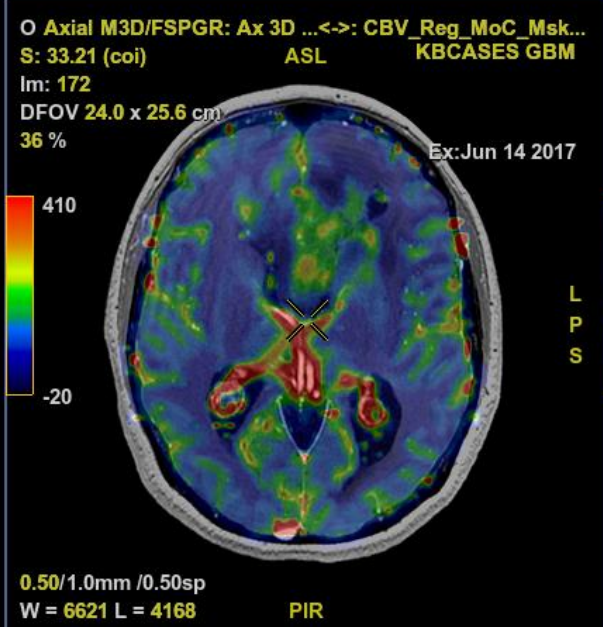
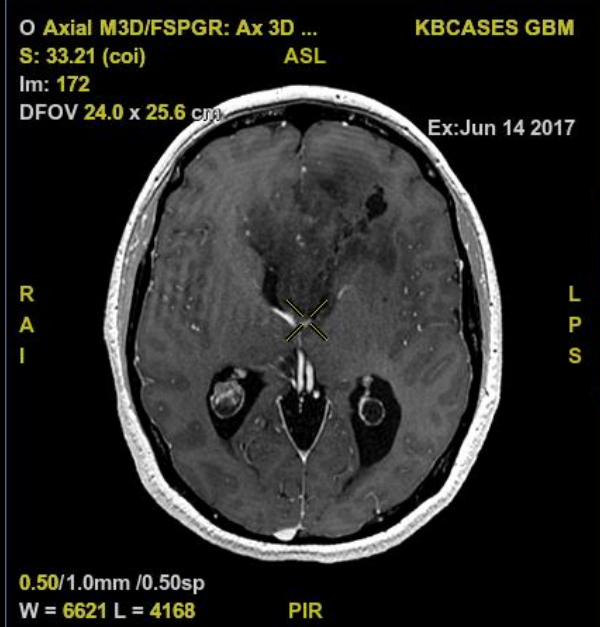
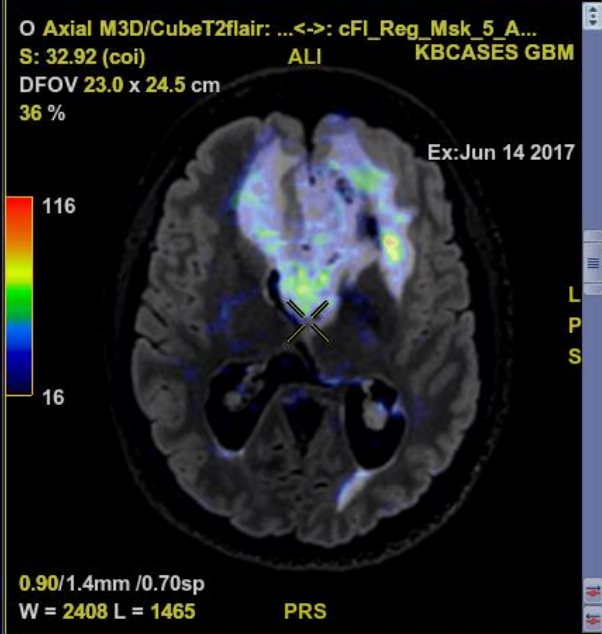
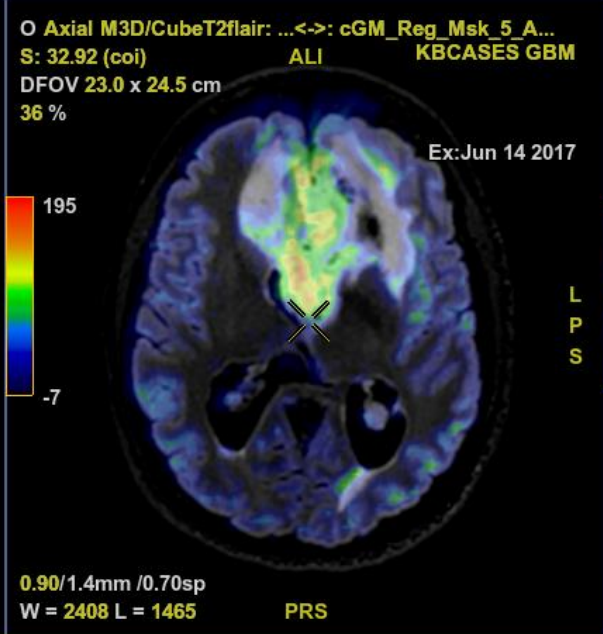
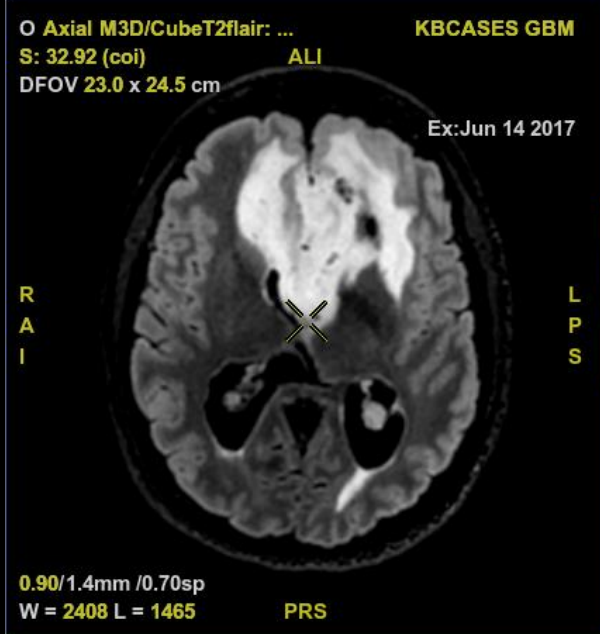
ASL

κ 3D ...<->: cFl_Reg_Msk_5_A...

ASL

Maps on 3D T1 FSPGR Gd

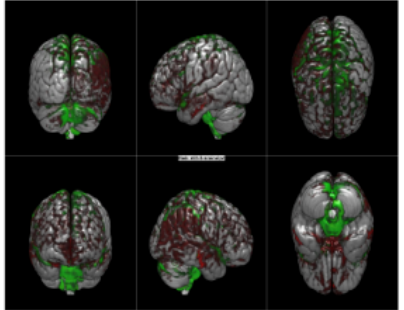




BRAINANALYZE
BRAINANALYST
 Ex: 23276064
 Se: 23131
 Im: 1

NEURORADIO_CHU_BICETRE
 Cells Infiltration Analysis
 Patient: KBCASES_GBM / Date: 20170614

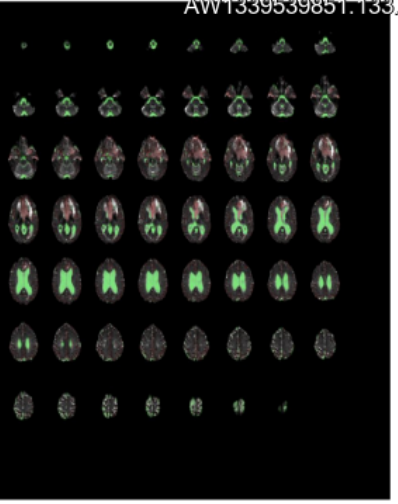
AW1339539851.133.1499161329
 Jun 14 2017
 10:17:43 AM
 Mag = 1.00
 FL:
 ROT:



BRAINANALYZE
BRAINANALYST
 Ex: 23276064
 Se: 23131
 Im: 3

NEURORADIO_CHU_BICETRE
 Compartments

AW1339539851.133.1499161329
 Jun 14 2017
 10:17:45 AM
 Mag = 1.00
 FL:
 ROT:



Navigator

KBCASES GBM

- Jun 14 2017 - IRM cranio-encéphali...
- 704. CBV_Reg_MoC_Msk_7_Ax_Perfu...
- 705. CBF_Reg_MoC_Msk_7_Ax_Perfu...
- 706. MTT_Reg_MoC_Msk_7_Ax_Perfu...
- 805. fBV_Reg_MoC_Msk_7_Ax_Perfus...
- 3111. cSF_Reg_Msk_5_Ax_DWI_Multi...
- 3112. cWM_Reg_Msk_5_Ax_DWI_Mult...
- 3113. cGM_Reg_Msk_5_Ax_DWI_Multi...
- 3114. cFI_Reg_Msk_5_Ax_DWI_Multi...
- 23131. Cells_Reg_Msk_5_Ax_DWI_M...

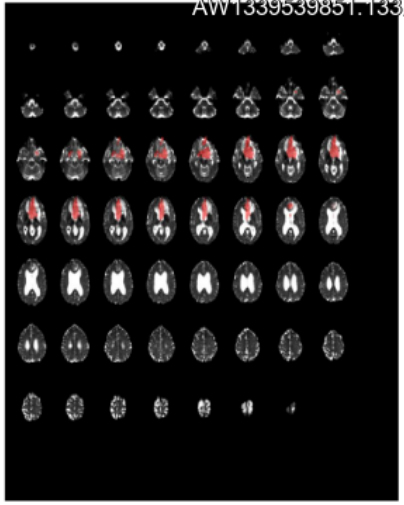
23131.
 Cells_Reg_Msk_5_Ax_DWI_Multi_...
 (OTHER) - 8 image(s)
 320009.

Add patient

BRAINANALYZE
BRAINANALYST
 Ex: 23276064
 Se: 23131
 Im: 4

NEURORADIO_CHU_BICETRE
 Cells Infiltration

AW1339539851.133.1499161329
 Jun 14 2017
 10:17:45 AM
 Mag = 1.00
 FL:
 ROT:



BRAINANALYZE
BRAINANALYST
 Ex: 23276064
 Se: 23131
 Im: 6

NEURORADIO_CHU_BICETRE
 Involved Structures

AW1339539851.133.1499161329
 Jun 14 2017
 10:17:47 AM
 Mag = 1.00
 FL:
 ROT:

Involved Cells Volume: 66.320 cm3
 Involved Cells Signal (min/max/mean/std): 0.0000 / 646.2373 / 3.2584 / 15.0295

Cingulum_Callosum:
 Volume: 5.320 cm3
 Signal (min/max/mean/std): 0.0000 / 213.7966 / 103.3553 / 37.6777

Limbic_System:
 Volume: 3.262 cm3
 Signal (min/max/mean/std): 0.0000 / 170.1319 / 106.7372 / 37.7645

Retrolenticular_part_of_internal_capsule_L:
 Volume: 3.112 cm3
 Signal (min/max/mean/std): 0.0000 / 177.7462 / 92.5666 / 35.6758

Cingulum_Ant_L:
 Volume: 3.016 cm3
 Signal (min/max/mean/std): 0.0000 / 183.5417 / 99.2298 / 38.7057

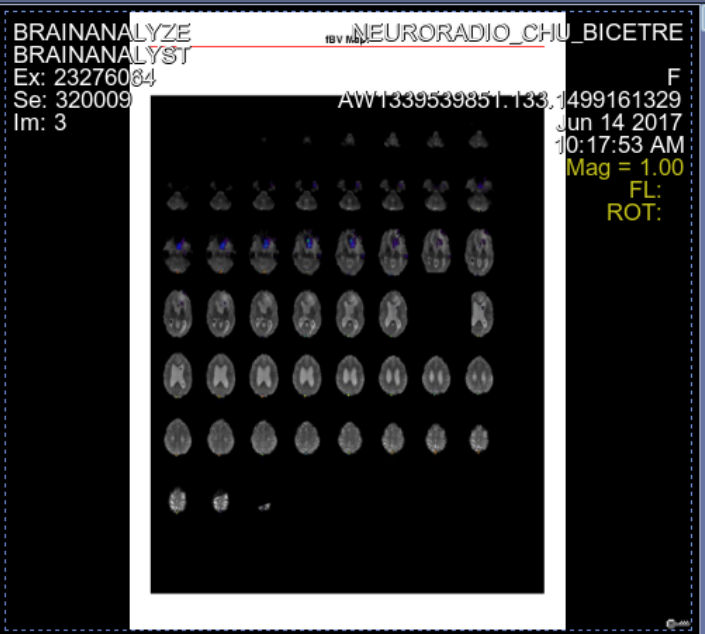
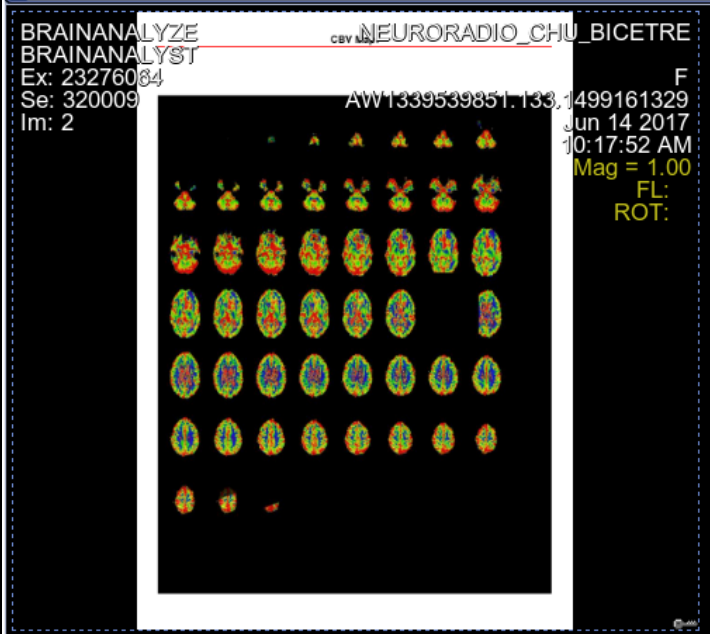
Frontal_Mid_Orb_L:
 Volume: 2.364 cm3
 Signal (min/max/mean/std): 0.0000 / 261.5951 / 65.7230 / 36.9979

Frontal_Mid_Orb_R:
 Volume: 2.364 cm3
 Signal (min/max/mean/std): 25.6252 / 156.0642 / 61.2322 / 23.6634

Caudate_L:
 Volume: 1.816 cm3
 Signal (min/max/mean/std): 0.0000 / 177.3069 / 90.2590 / 31.1101

Cingulum_Ant_R:
 Volume: 1.776 cm3
 Signal (min/max/mean/std): 20.6436 / 162.4927 / 90.0592 / 31.5145

Olfactory_L:
 Volume: 1.632 cm3
 Signal (min/max/mean/std): 21.2353 / 181.4325 / 86.0666 / 34.0937



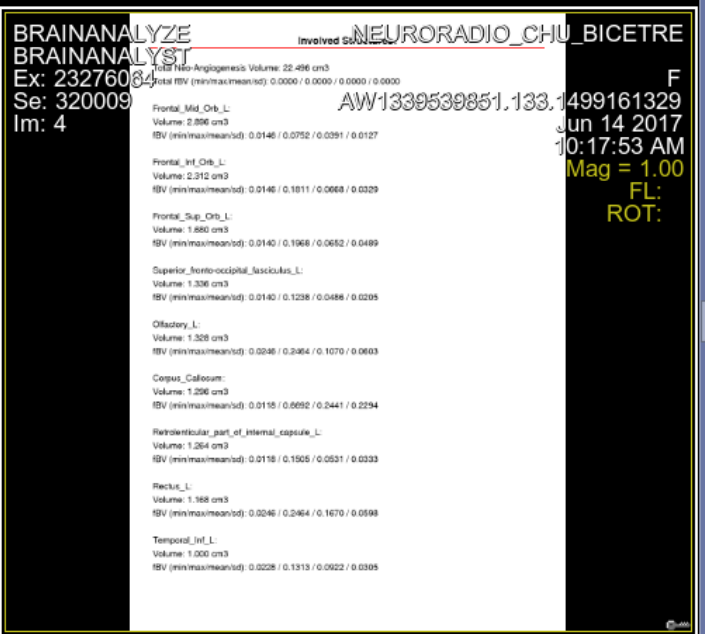
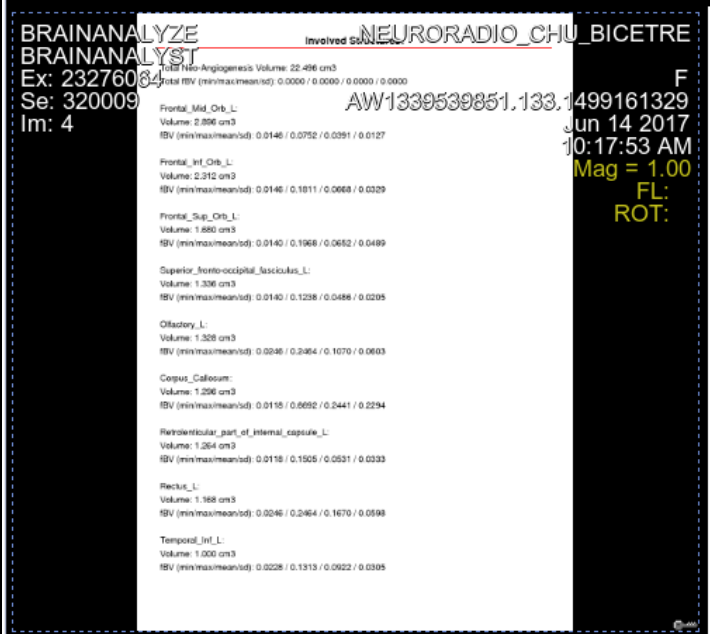
Navigator

KBCASES GBM

- Jun 14 2017 - IRM cranio-encéphali...
- 704. CBV_Reg_MoC_Msk_7_Ax_Perfu...
- 705. CBF_Reg_MoC_Msk_7_Ax_Perfu...
- 706. MTT_Reg_MoC_Msk_7_Ax_Perfu...
- 805. fBV_Reg_MoC_Msk_7_Ax_Perfus...
- 3111. cSF_Reg_Msk_5_Ax_DWI_Multi...
- 3112. cWM_Reg_Msk_5_Ax_DWI_Multi...
- 3113. cGM_Reg_Msk_5_Ax_DWI_Multi...
- 3114. cFI_Reg_Msk_5_Ax_DWI_Multi...
- 23131. Cells_Reg_Msk_5_Ax_DWI_M...
- 23131. Cells_Reg_Msk_5_Ax_DWI_M...

320009.
 Reg_MoC_Msk_7_Ax_Perfusion_E...
 (OTHER) - 5 image(s)

Add patient



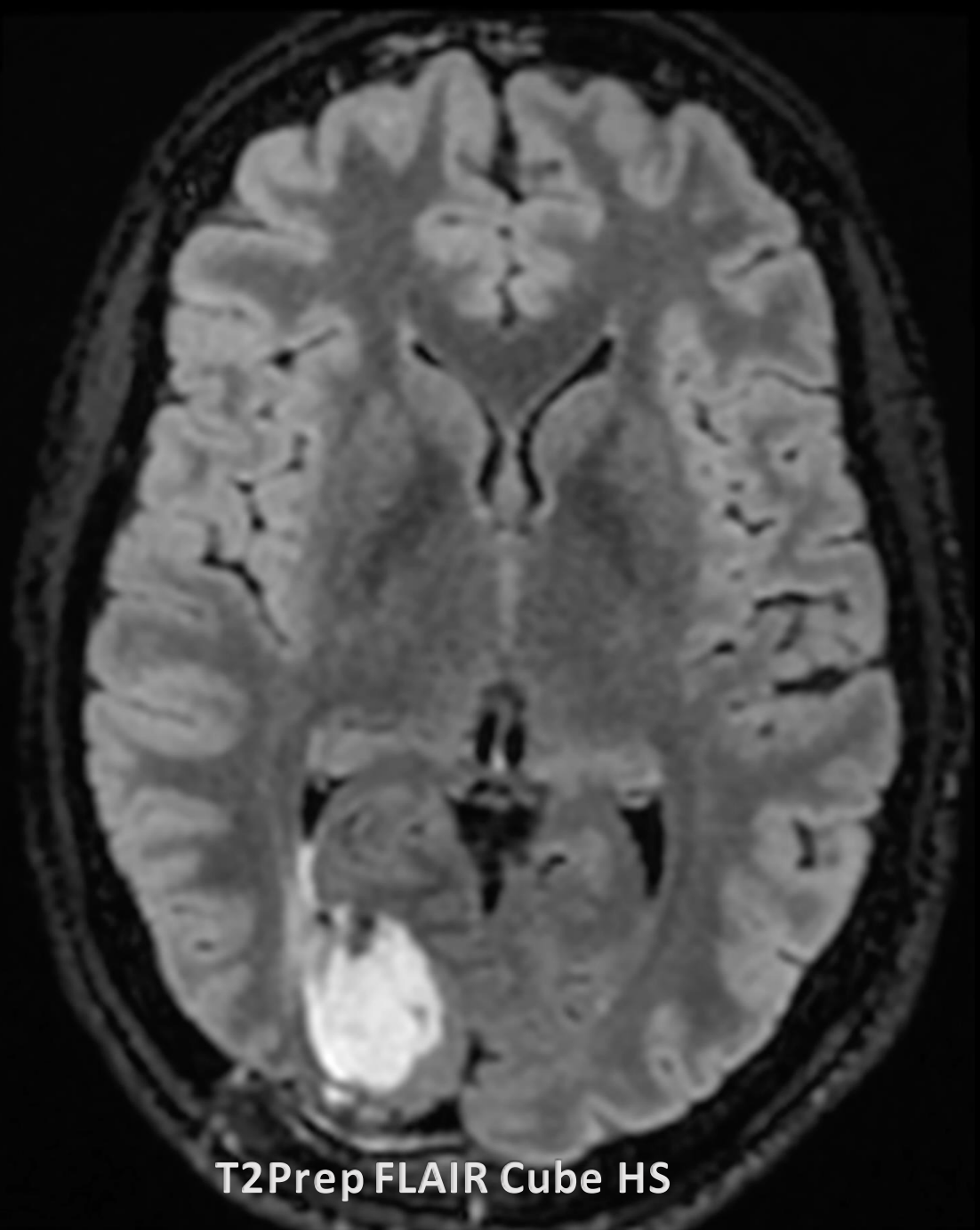
Case 4

Glioma DWI / PWI

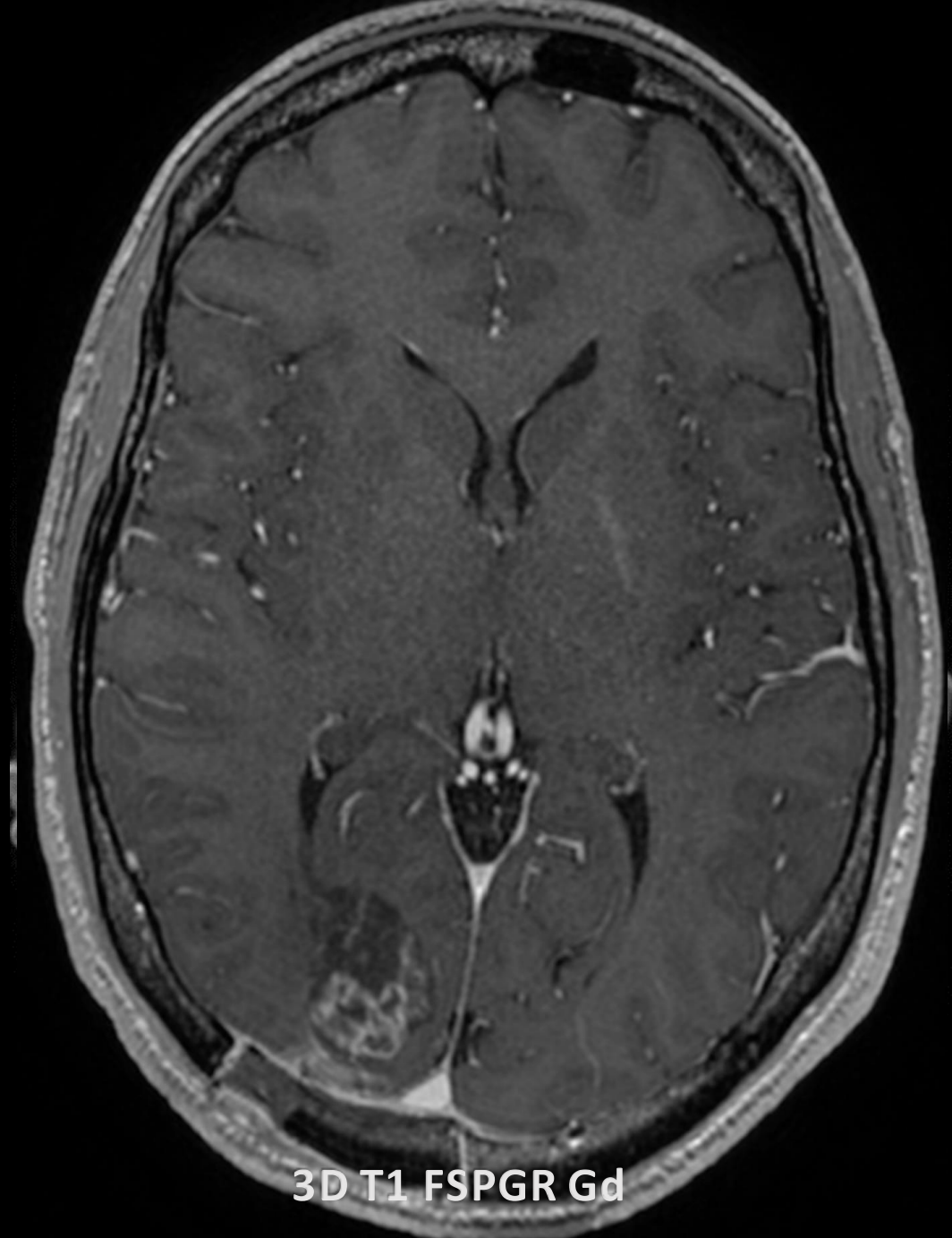
Automated Processing

Q: Recurrence vs Post-Surgery vs Infection ?

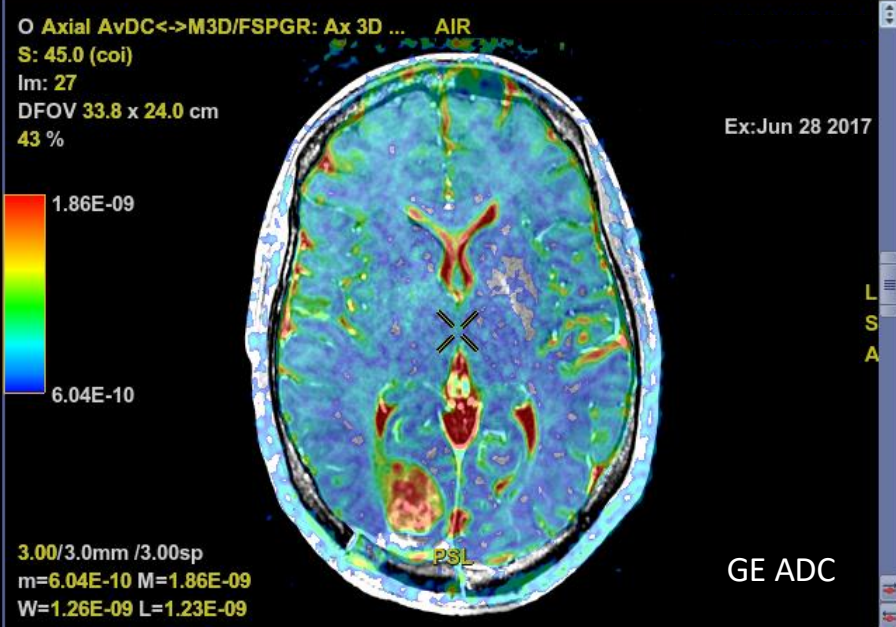
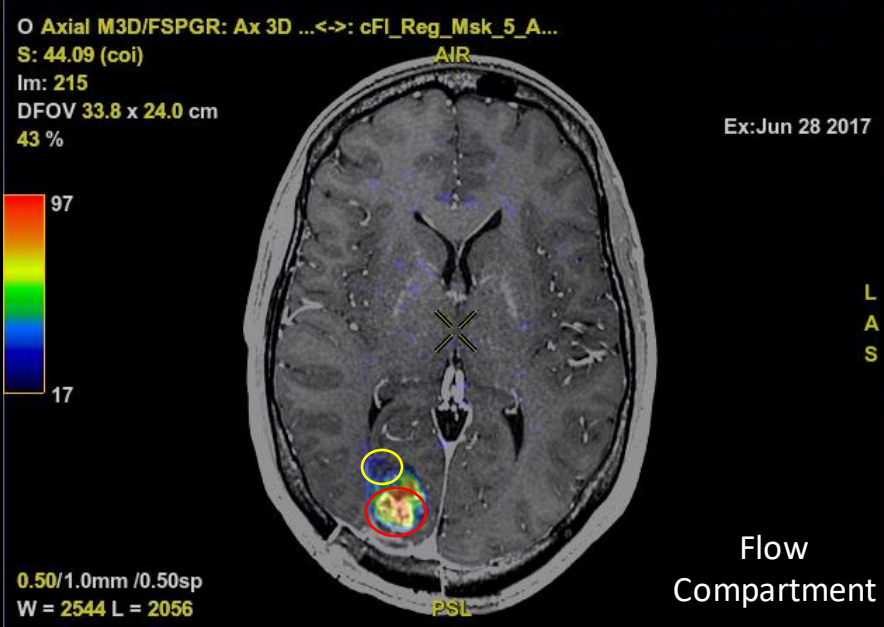
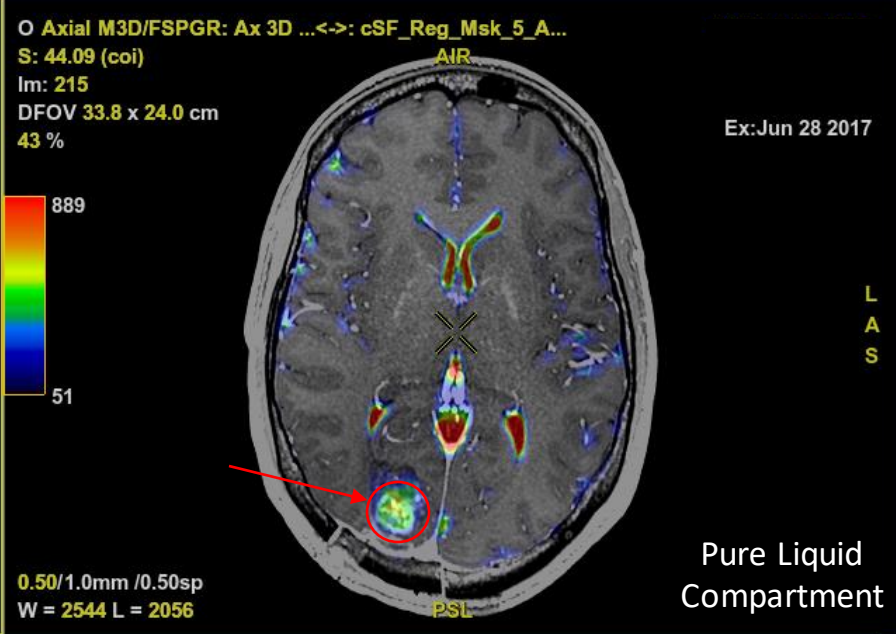
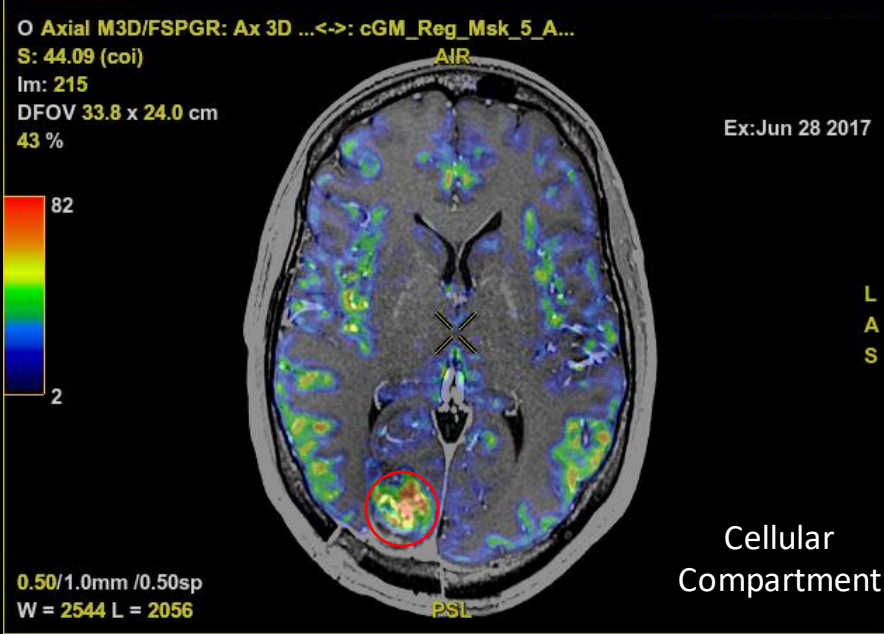
A: using CBV, fBV & Diff. Compartments = Post-Surgery AND
Recurrence

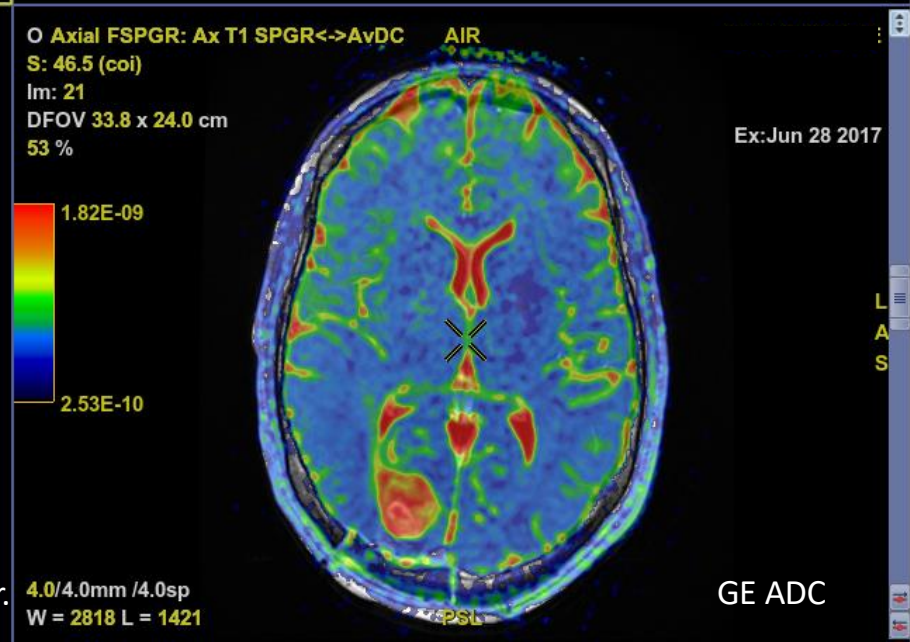
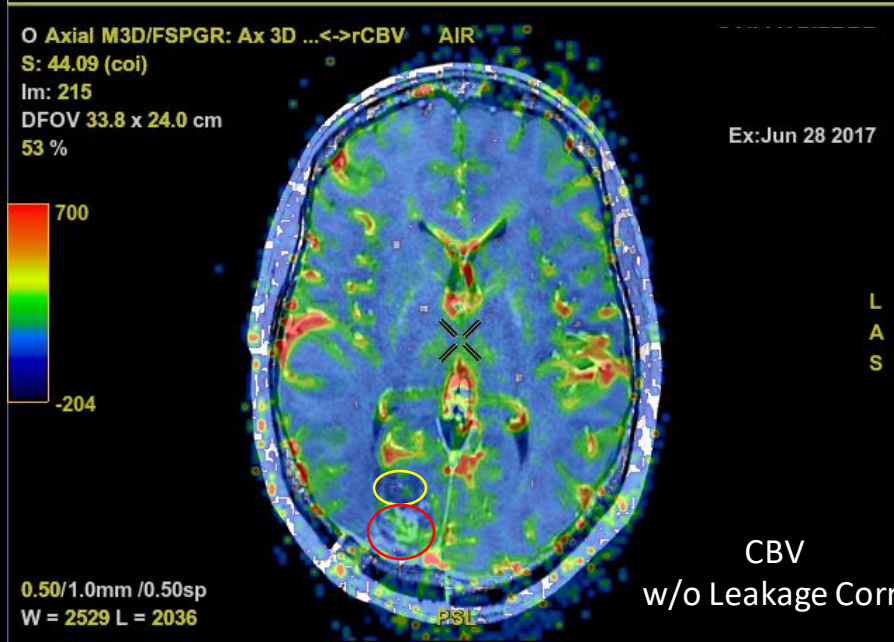
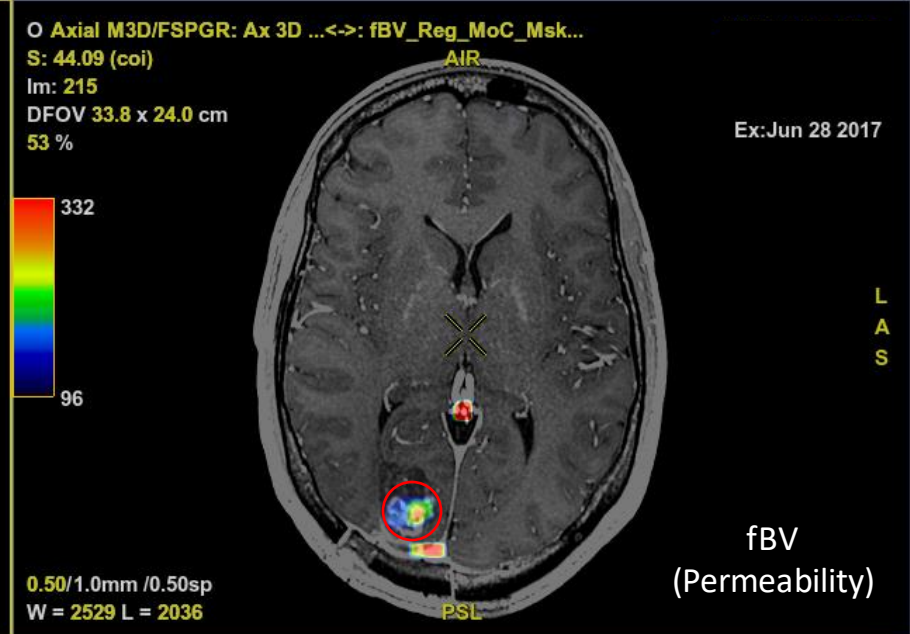
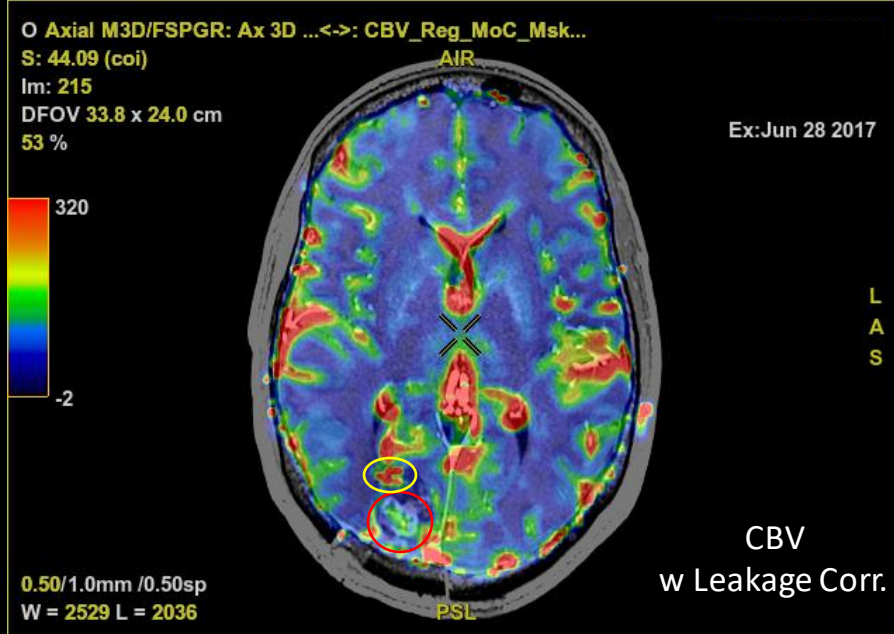


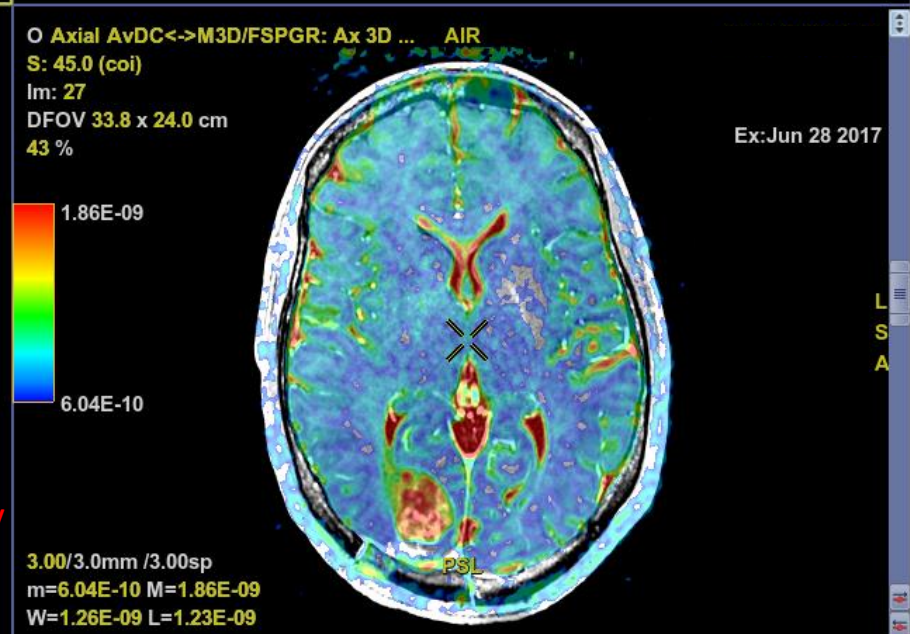
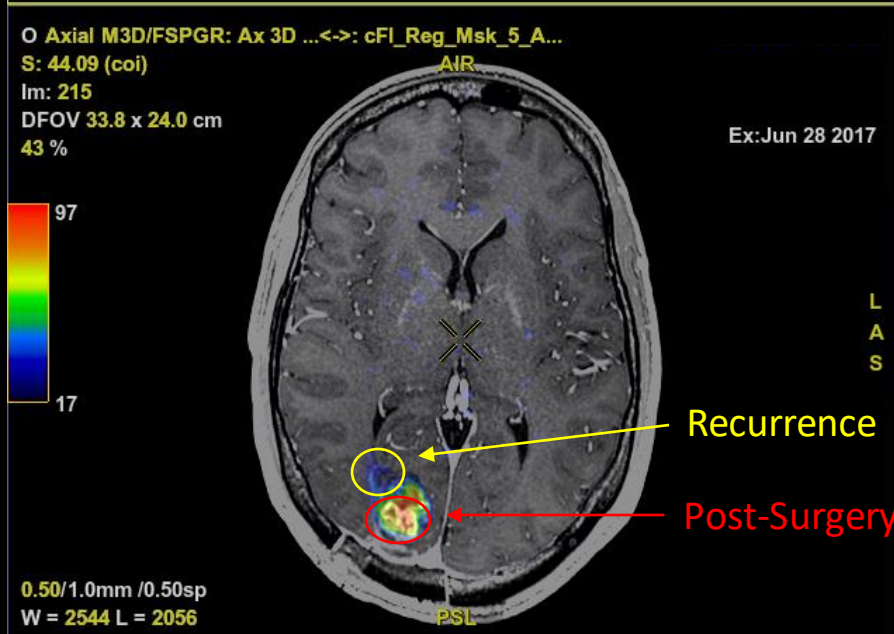
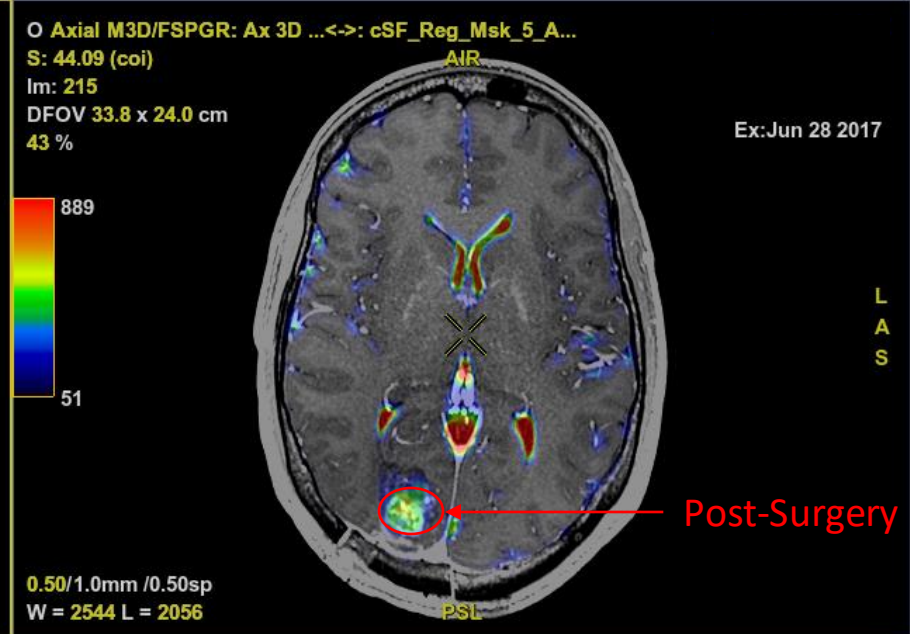
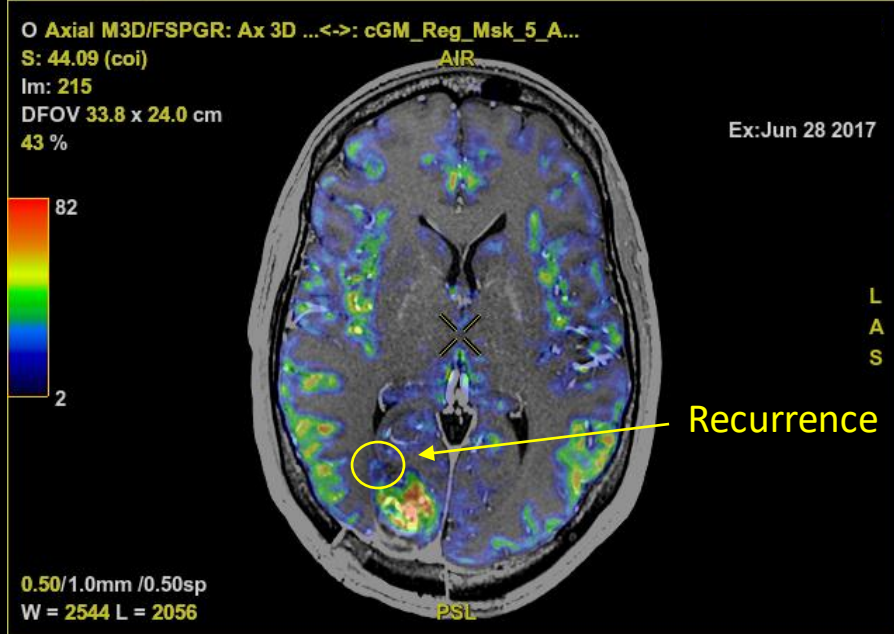
T2Prep FLAIR Cube HS



3D T1 FSPGR Gd



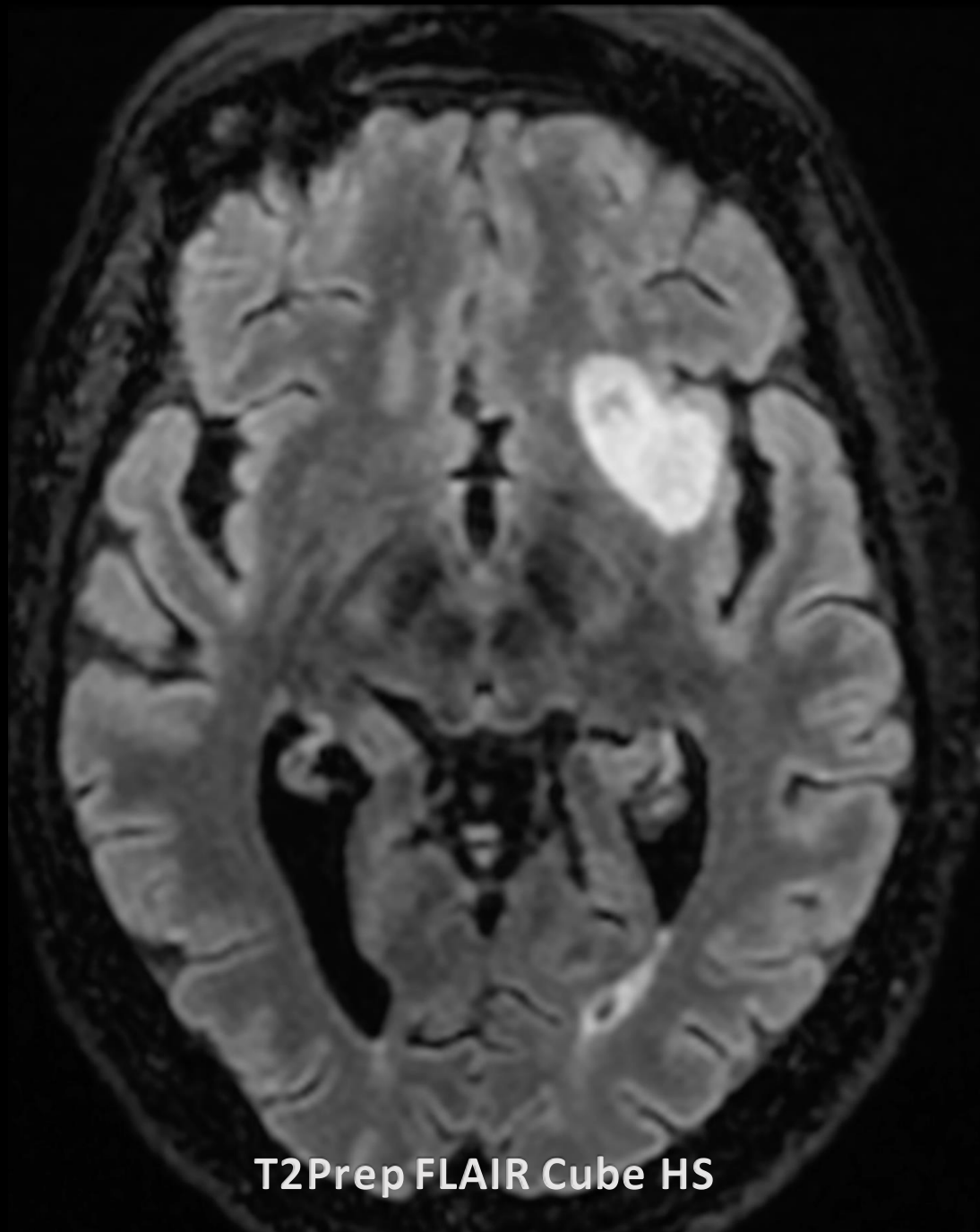




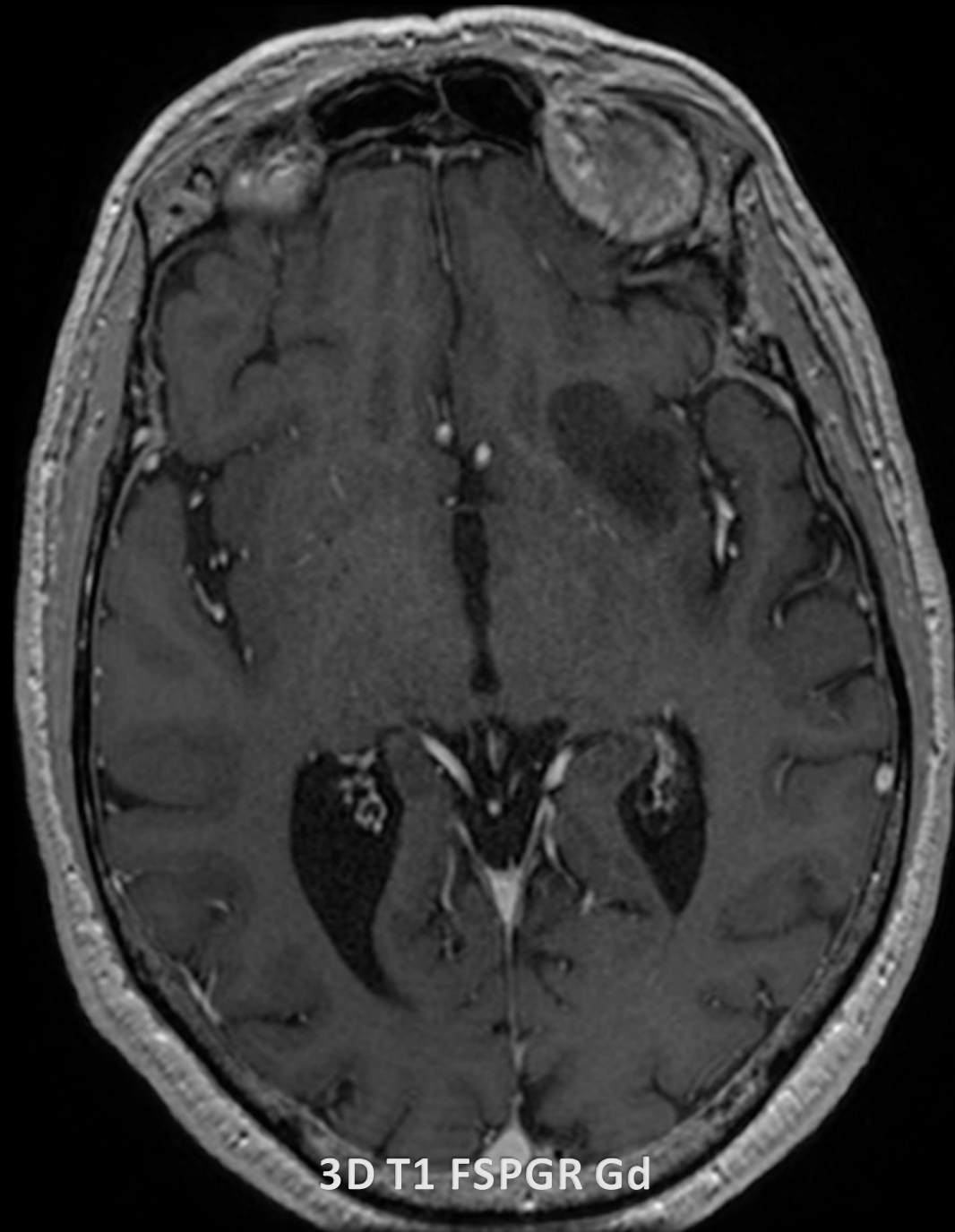
Case 5
Unknown Lesion
DWI / PWI / fMRI / Fibertracking
Automated Processing

Q: Type of Lesion and functional pre-surgical Planning ?

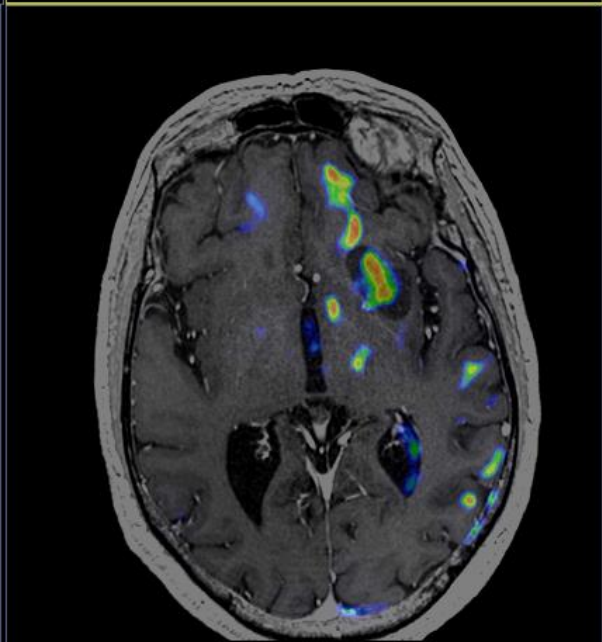
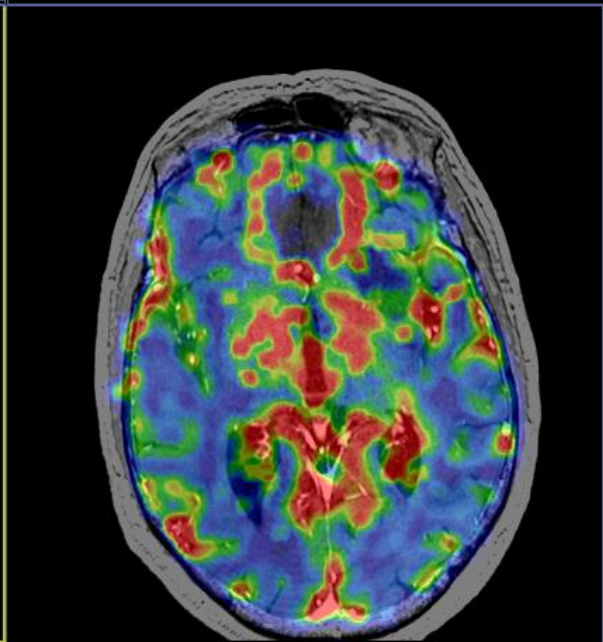
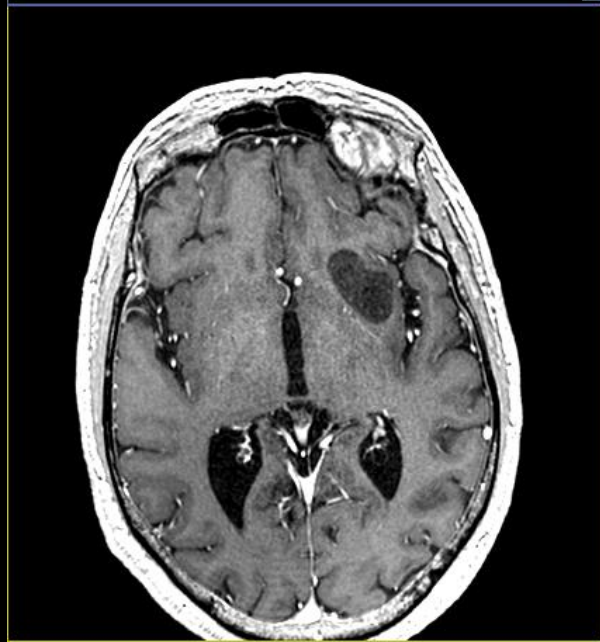
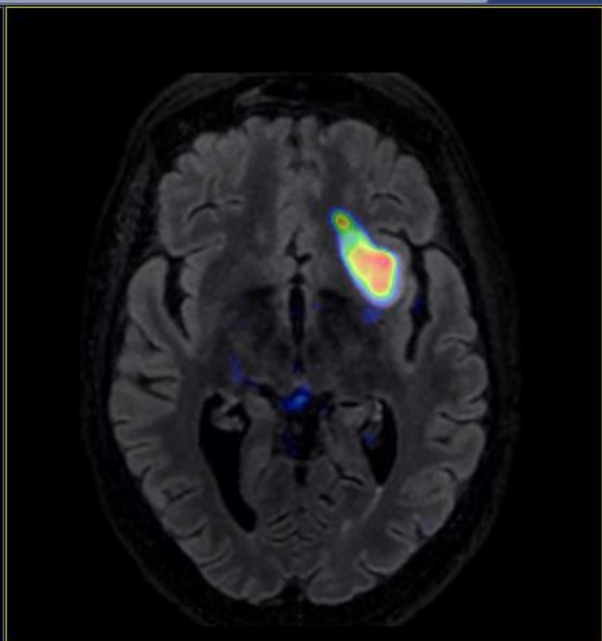
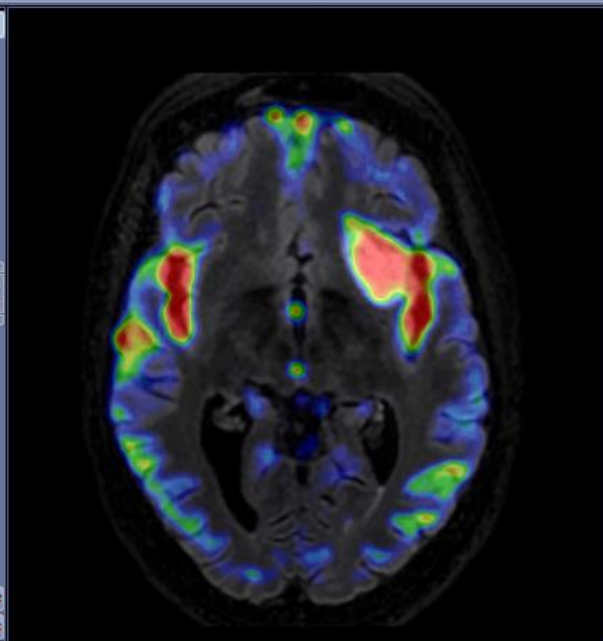
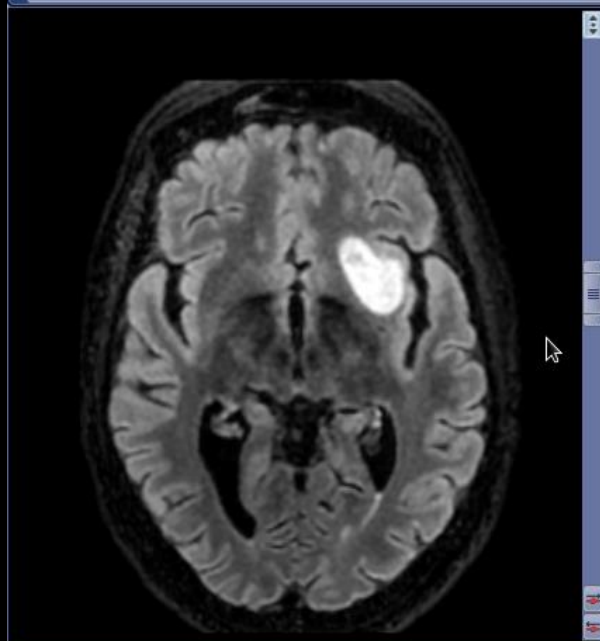
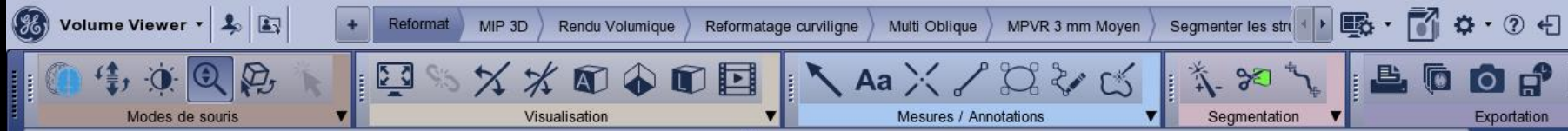
A: Low Grade Glioma, Language Colateralization



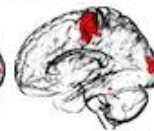
T2Prep FLAIR Cube HS

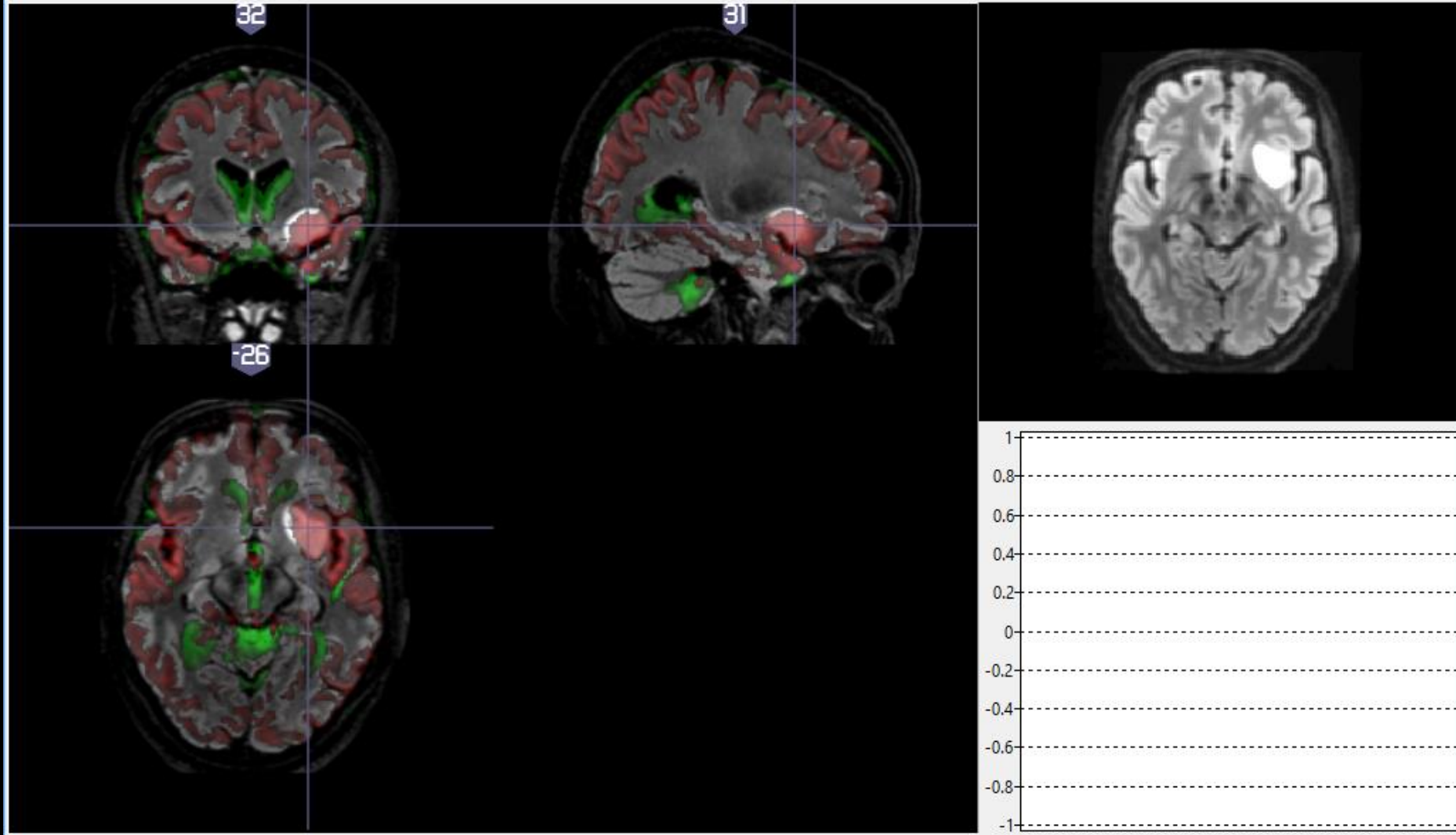


3D T1 FSPGR Gd



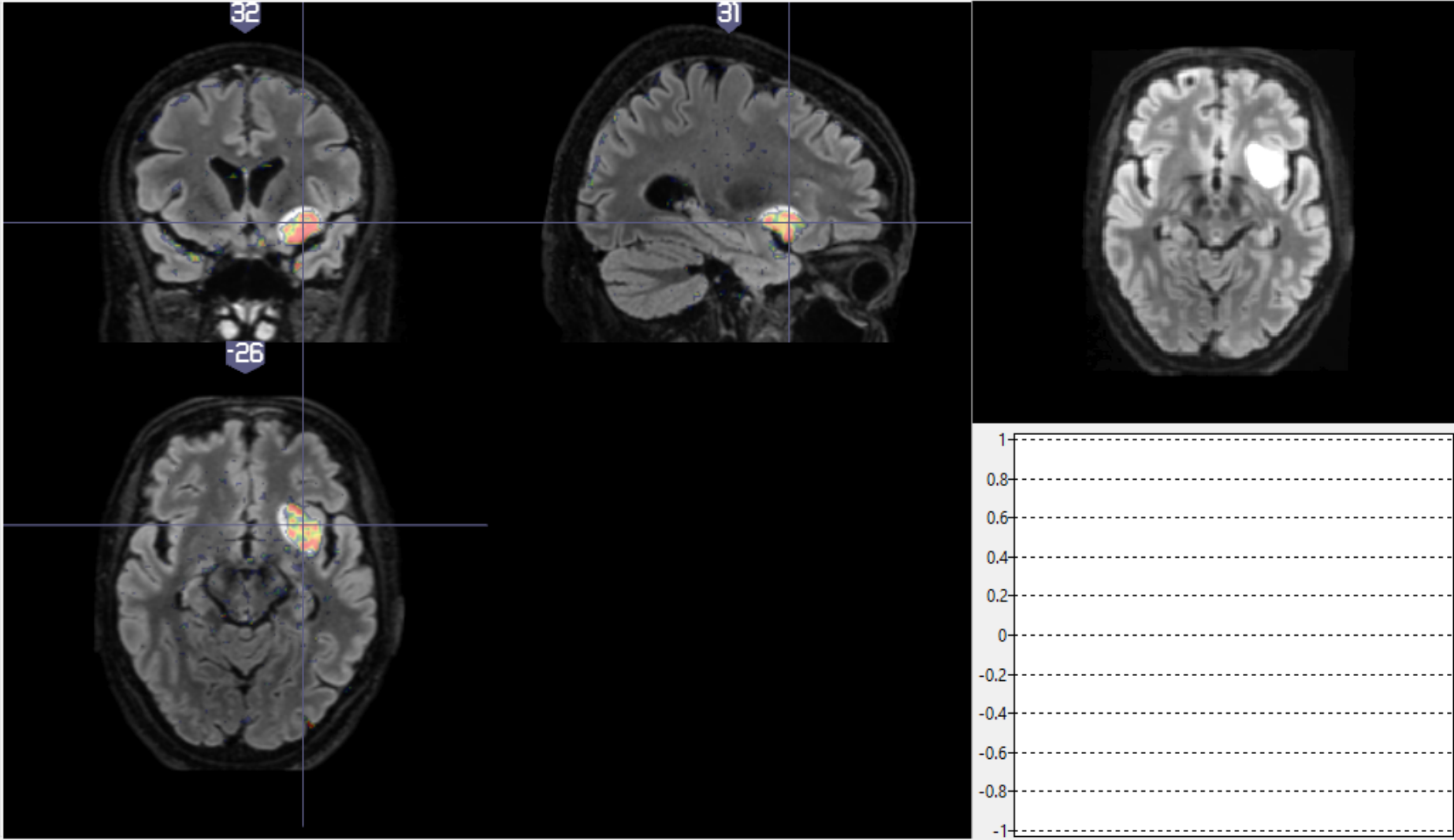
File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality

			20% 40% 50% 60% 80%	0% Opaque 20% 40% 50% 60%					cWM_Reg_Msk_5_Ax cGM_Reg_Msk_5_Ax	Grayscale Red Green Blue Violet [r Yellow [r	Value 0 183.1
---	---	---	--	---------------------------------------	---	---	---	---	--------------------------------------	--	---------------------



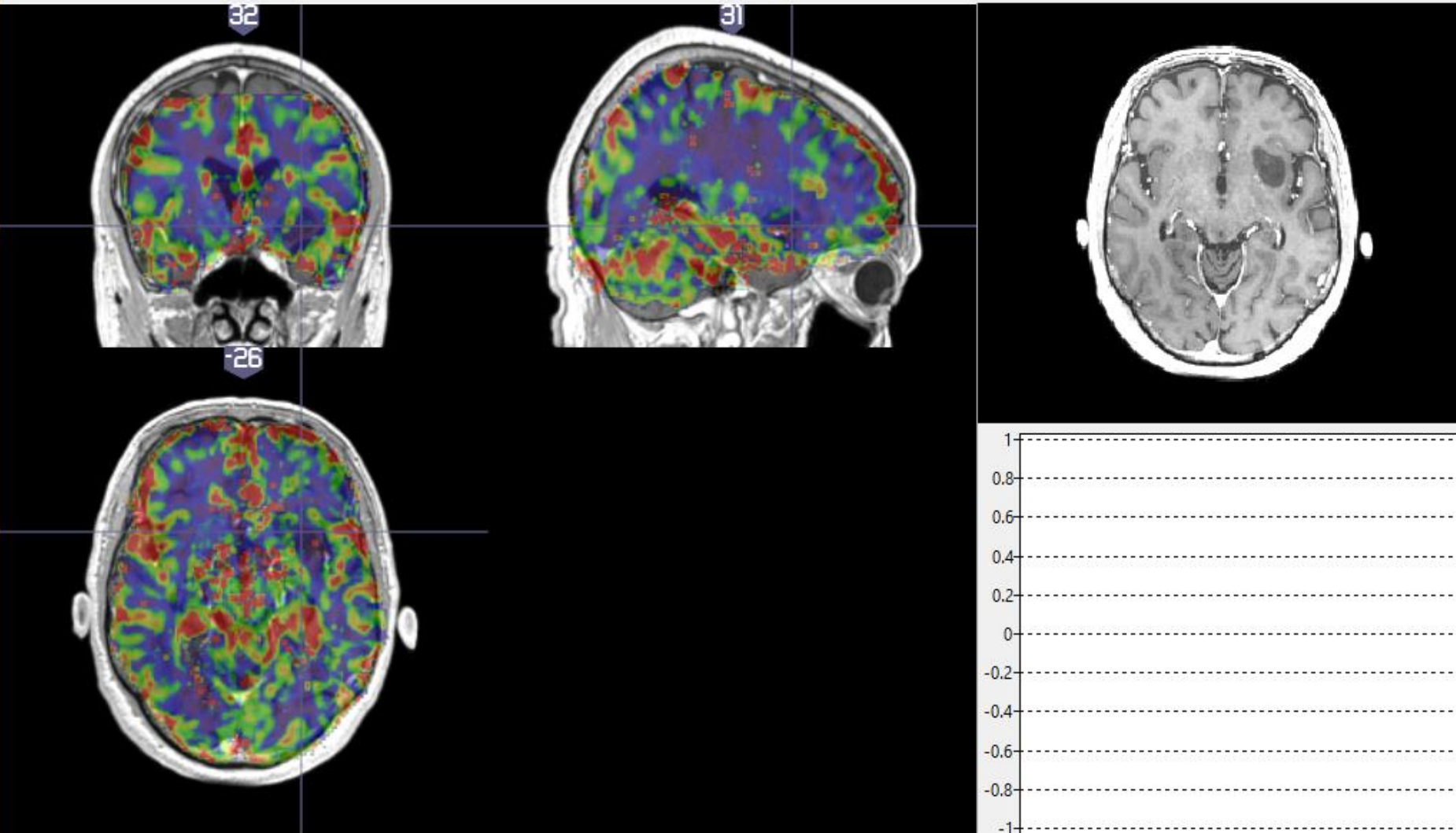
File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality

60% 0% Opaque cFl_Reg_Msk_5_Ax 3warm Value
80% 20% 4cool 35
100% Transparen 40% 5redyell 88.6
Additive 50% 6bluegr
* * * * * 60% 7 * * * * * 8 * * * * * 9 * * * * * 10 * * * * * 11 * * * * * 12 * * * * * 13 * * * * * 14 * * * * * 15 * * * * * 16 * * * * * 17 * * * * * 18 * * * * * 19 * * * * * 20 * * * * * 21 * * * * * 22 * * * * * 23 * * * * * 24 * * * * * 25 * * * * * 26 * * * * * 27 * * * * * 28 * * * * * 29 * * * * * 30 * * * * * 31 * * * * * 32 * * * * * 33 * * * * * 34 * * * * * 35 * * * * * 36 * * * * * 37 * * * * * 38 * * * * * 39 * * * * * 40 * * * * * 41 * * * * * 42 * * * * * 43 * * * * * 44 * * * * * 45 * * * * * 46 * * * * * 47 * * * * * 48 * * * * * 49 * * * * * 50 * * * * * 51 * * * * * 52 * * * * * 53 * * * * * 54 * * * * * 55 * * * * * 56 * * * * * 57 * * * * * 58 * * * * * 59 * * * * * 60 * * * * * 61 * * * * * 62 * * * * * 63 * * * * * 64 * * * * * 65 * * * * * 66 * * * * * 67 * * * * * 68 * * * * * 69 * * * * * 70 * * * * * 71 * * * * * 72 * * * * * 73 * * * * * 74 * * * * * 75 * * * * * 76 * * * * * 77 * * * * * 78 * * * * * 79 * * * * * 80 * * * * * 81 * * * * * 82 * * * * * 83 * * * * * 84 * * * * * 85 * * * * * 86 * * * * * 87 * * * * * 88 * * * * * 89 * * * * * 90 * * * * * 91 * * * * * 92 * * * * * 93 * * * * * 94 * * * * * 95 * * * * * 96 * * * * * 97 * * * * * 98 * * * * * 99 * * * * * 100 * * * * *

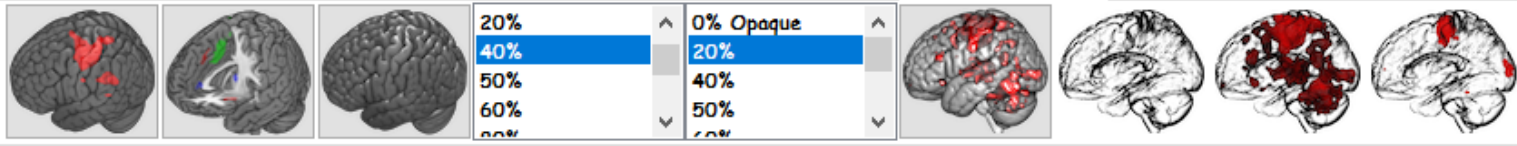


File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality

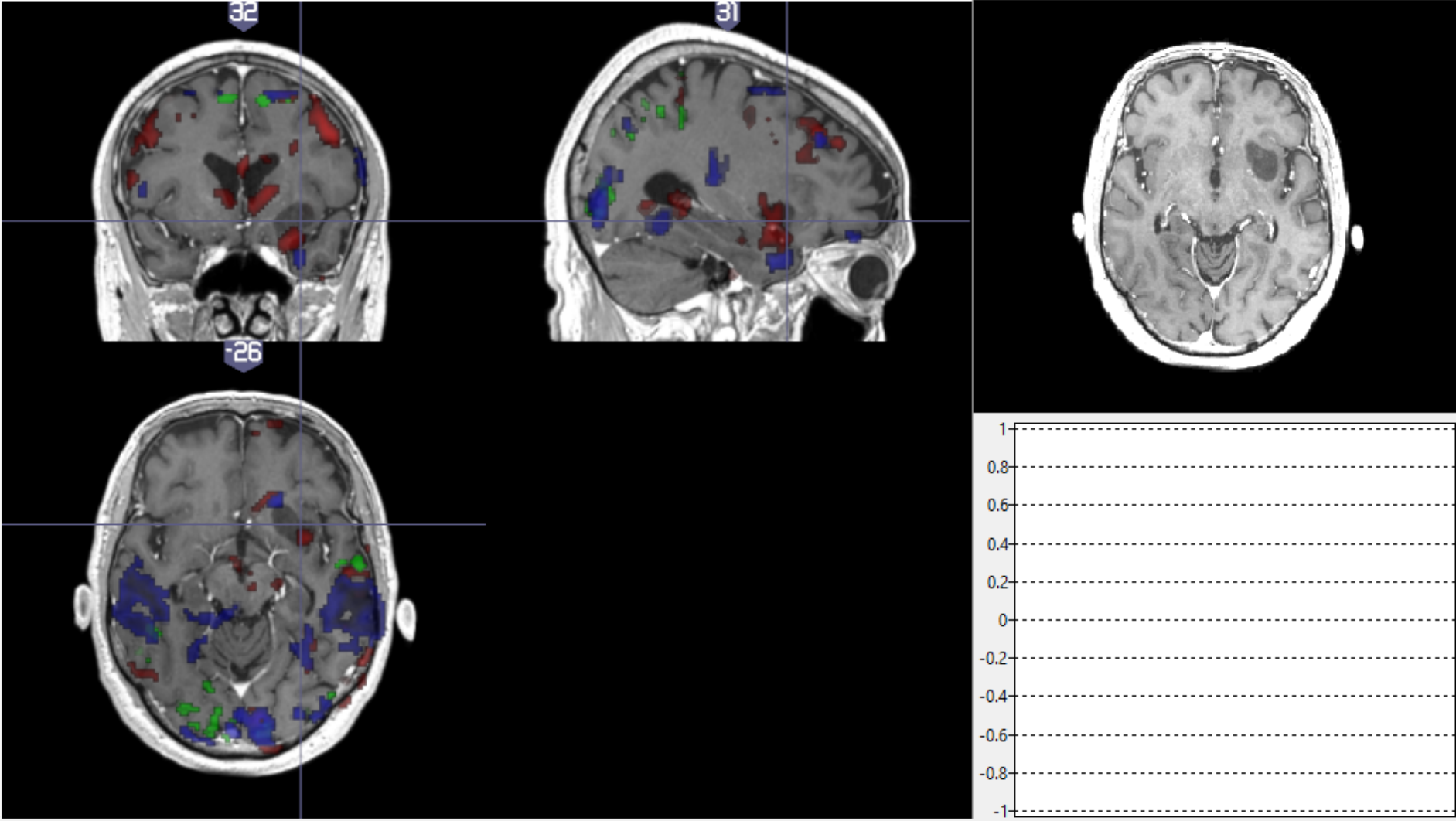
50% 60% 80% 100% Transparen
0% Opaque 20% 40% 50%
CBV_Reg_MoC_Msk Grayscale Value
Red Green Blue Violet [r
Value



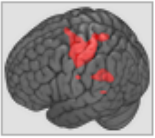
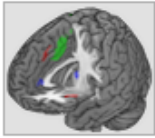
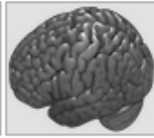
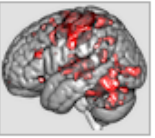

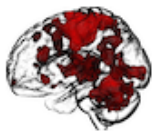
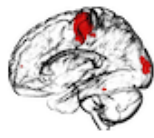
File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality

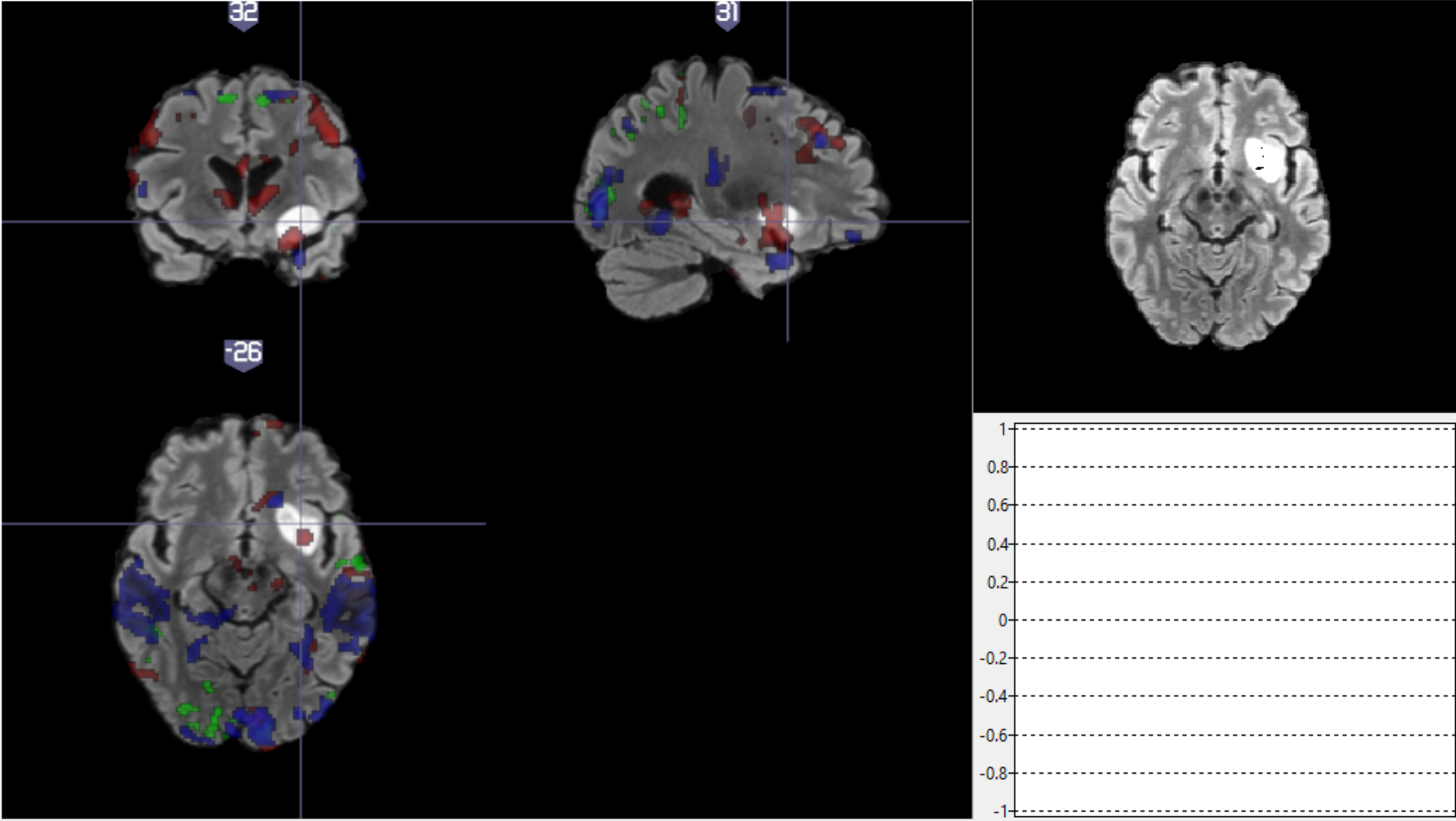


20% 0% Opaque fMRI Map Map Grayscale Value
 40% 20% fMRI Map Map Red 0
 50% 40% fMRI Map Map Green 0.57
 60% 50% Blue
 80% 80% Violet



File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality

			20% 40% 50% 60%	0% Opaque 20% 40% 50%					fMRIMap Map fMRIMap Map fMRIMap Map	Grayscale Red Green Blue Violet	Value 0 0.57
---	---	---	--------------------------	--------------------------------	---	---	---	---	---	---	--------------------



File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality

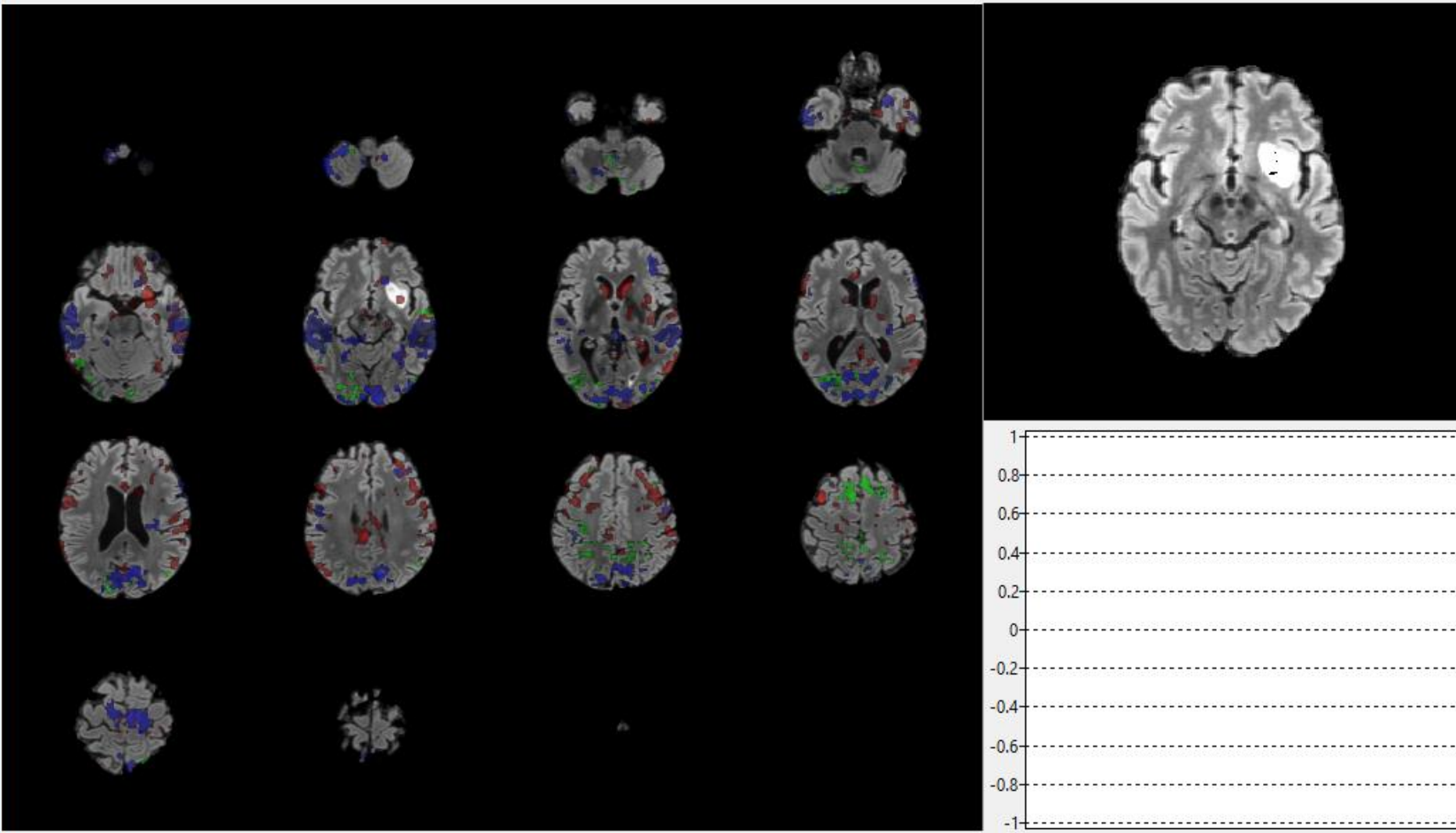
20% 40% 50% 60% 80%

0% Opaque 20% 40% 50% 60%

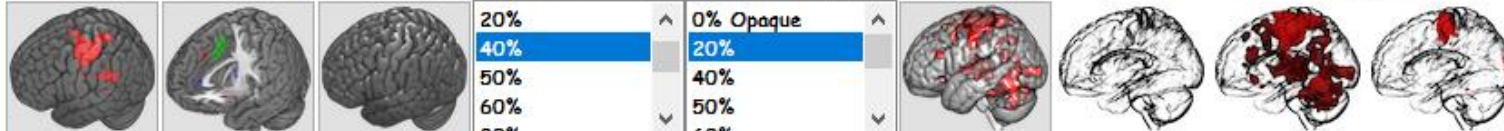
fMRI Map Map
fMRI Map Map
fMRI Map Map

Grayscale
Red
Green
Blue
Violet

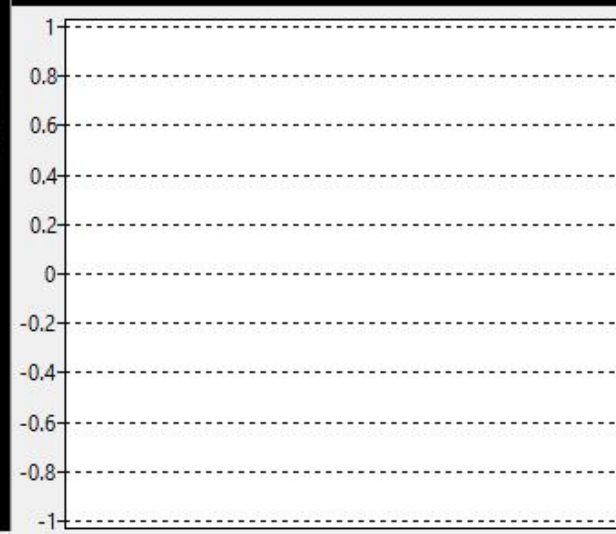
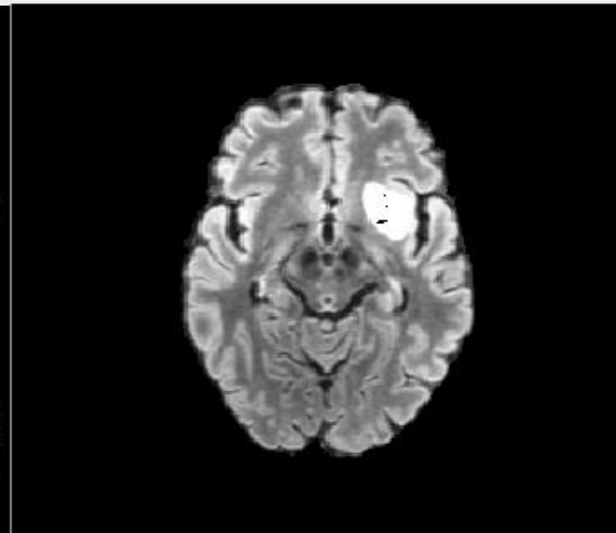
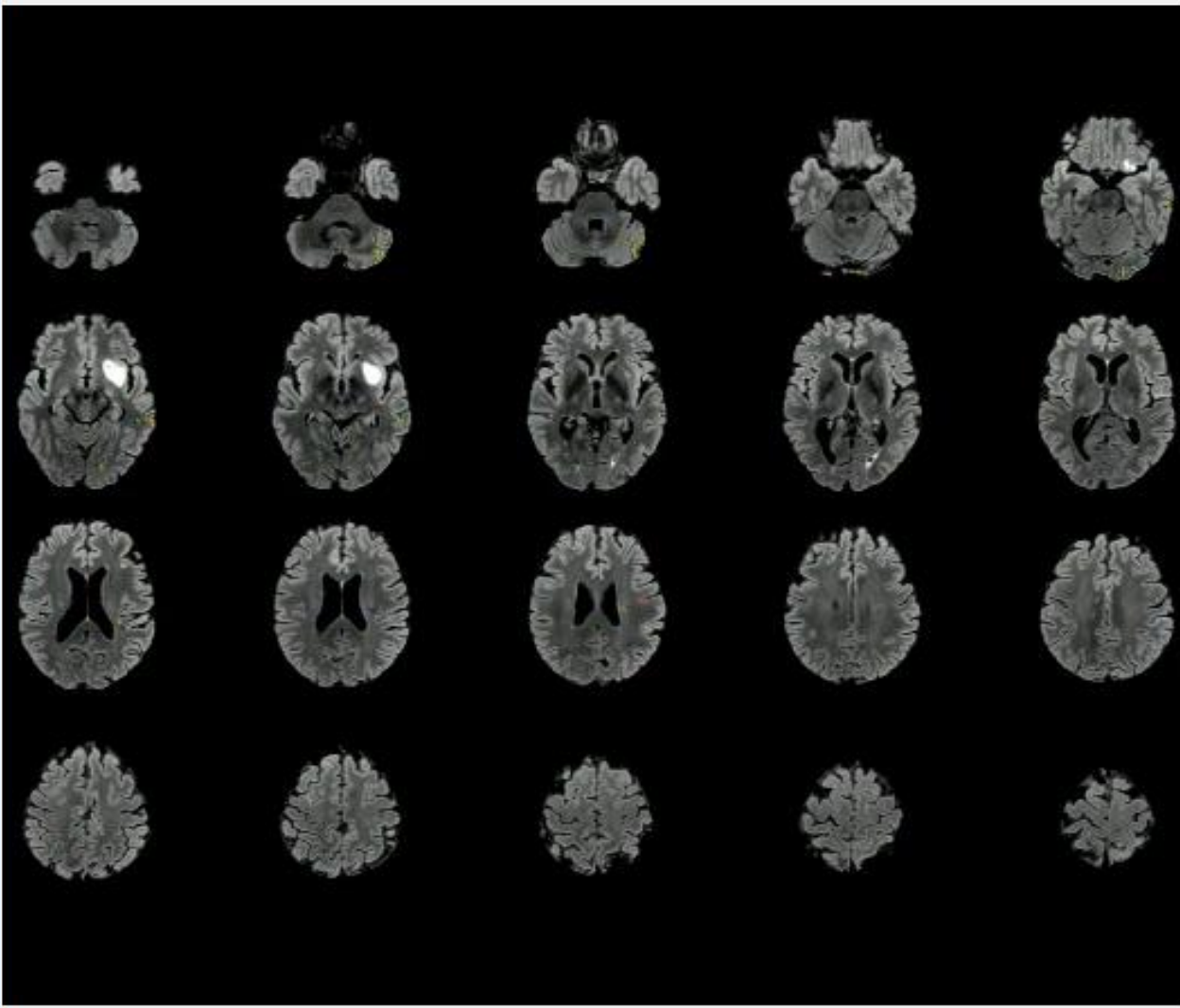
Value
0
0.57

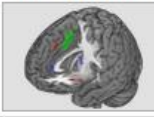
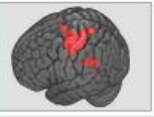


File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality



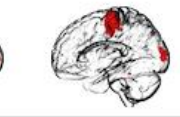
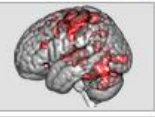
20% 0% Opaque fMRI Map Map Grayscale Value
 40% 20% fMRI Map Map Red 0
 50% 40% fMRI Map Map Green 0.57
 60% 50% Blue
 80% 80% Violet [r
 Yellow [r





0% Opaque
20%
40%
50%

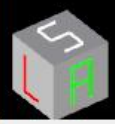
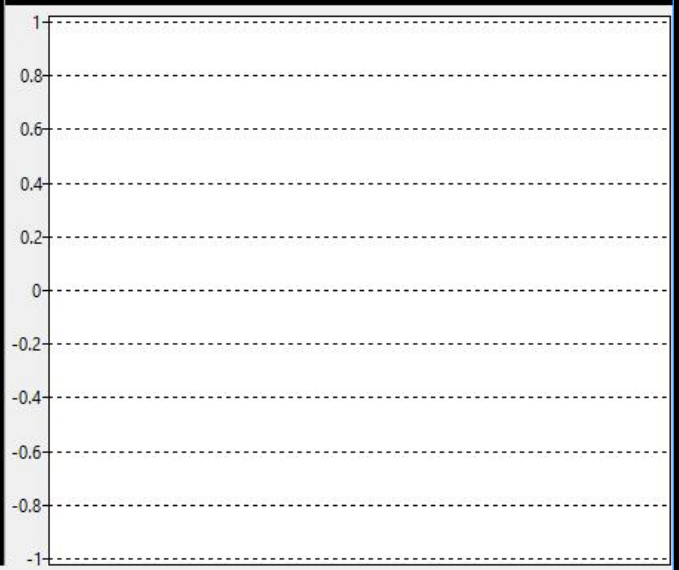
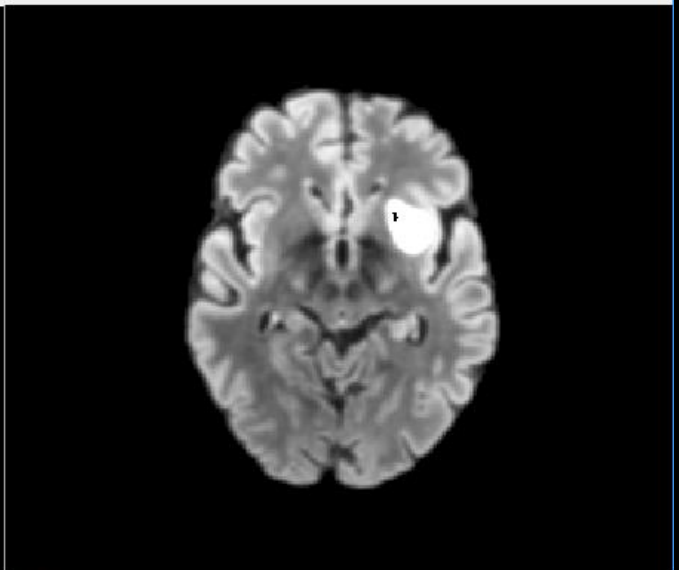
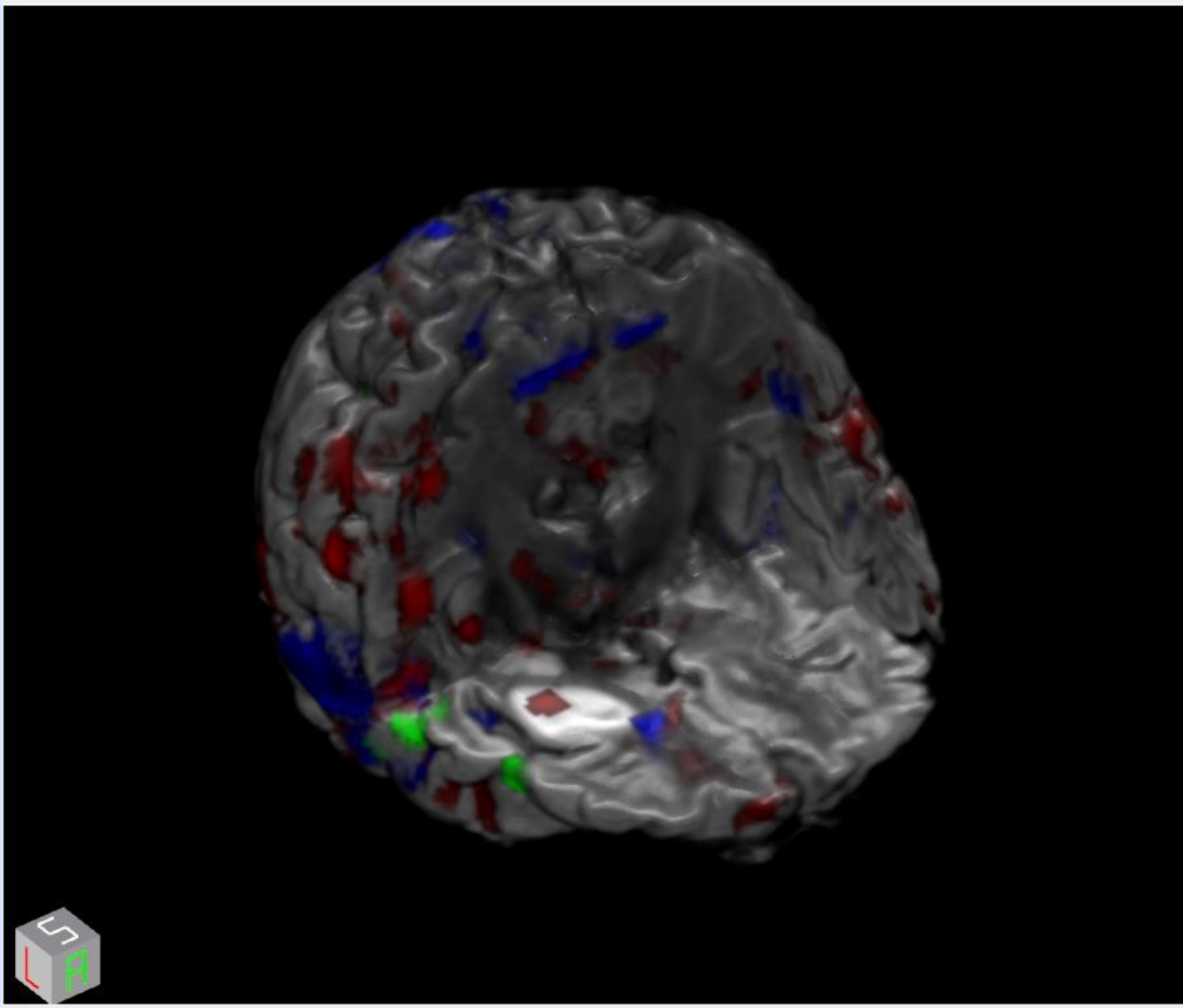
0% Opaque
20%
40%
50%

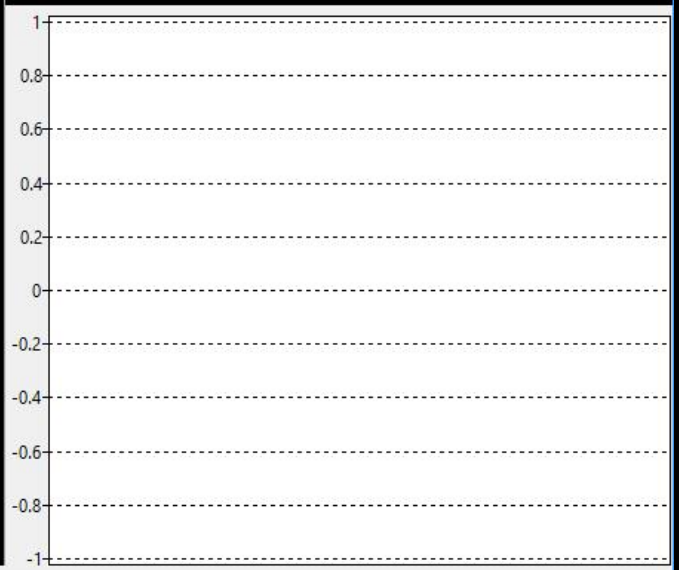
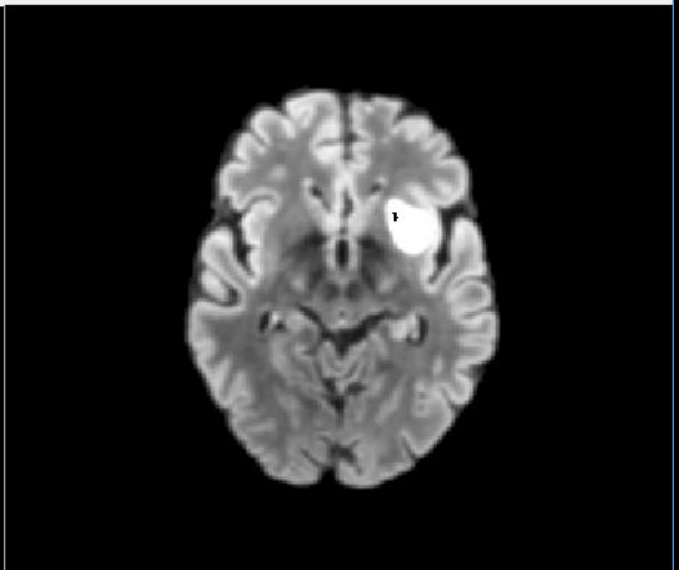
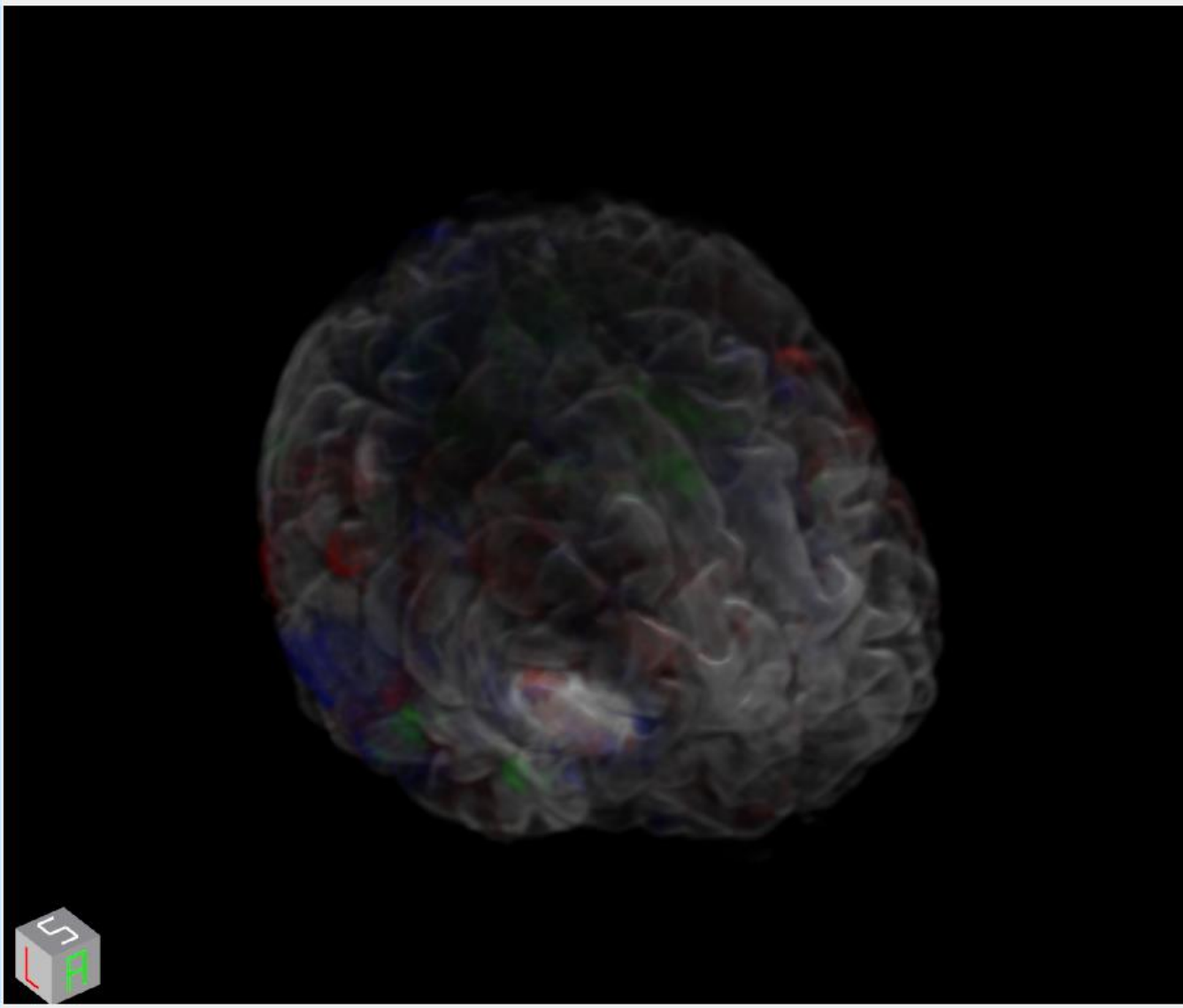


fMRIMap Map
fMRIMap Map
fMRIMap Map

Grayscale
Red
Green
Blue
Violet [r+b]

Value
-0
0.5761





File I/O Color/Contrast Image Tools MPR/3D Display Overlays ROI/VOI Drawing Virtual Reality

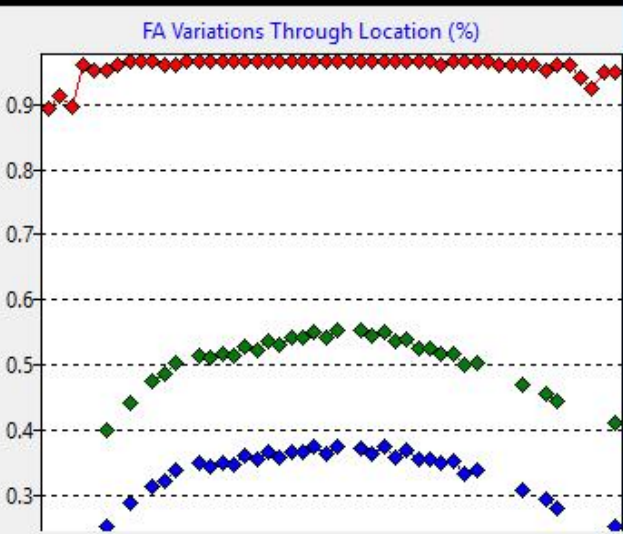
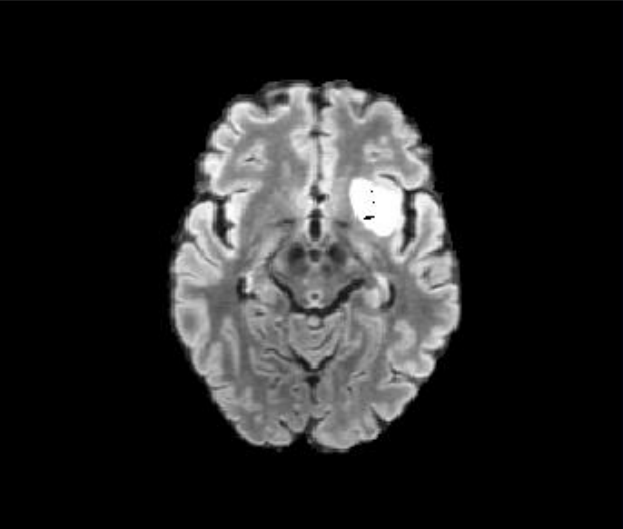
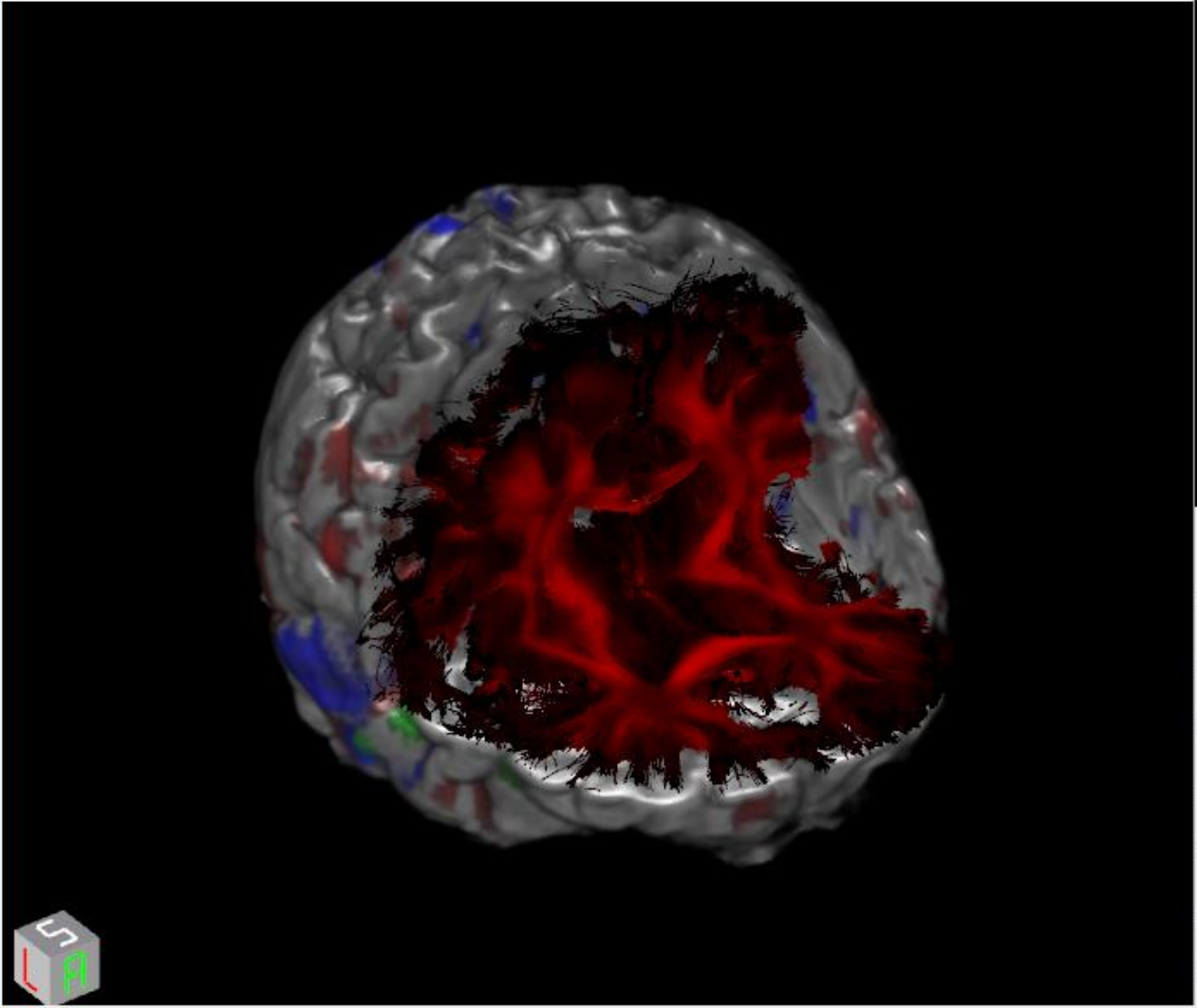
20% 40% 50% 60% 70%

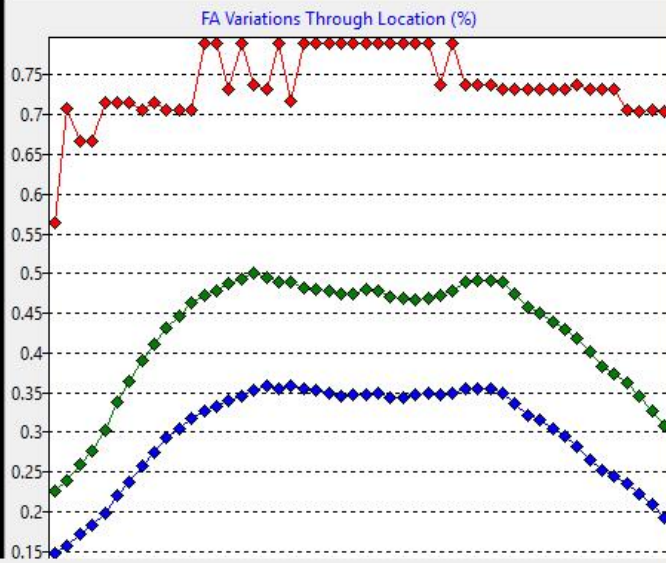
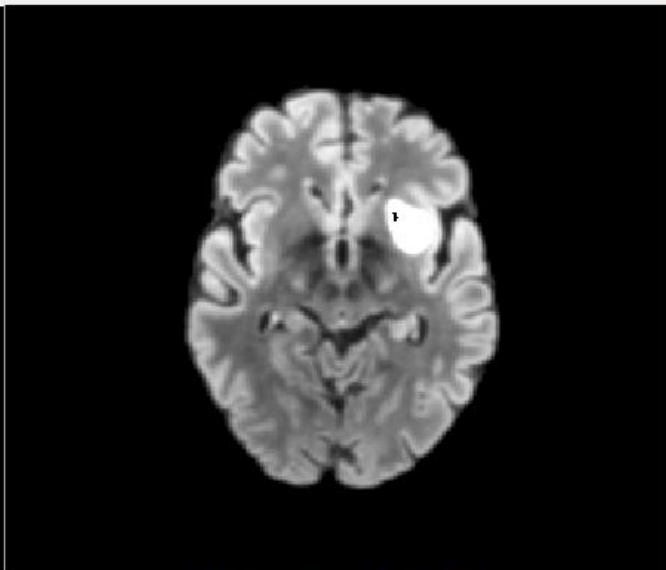
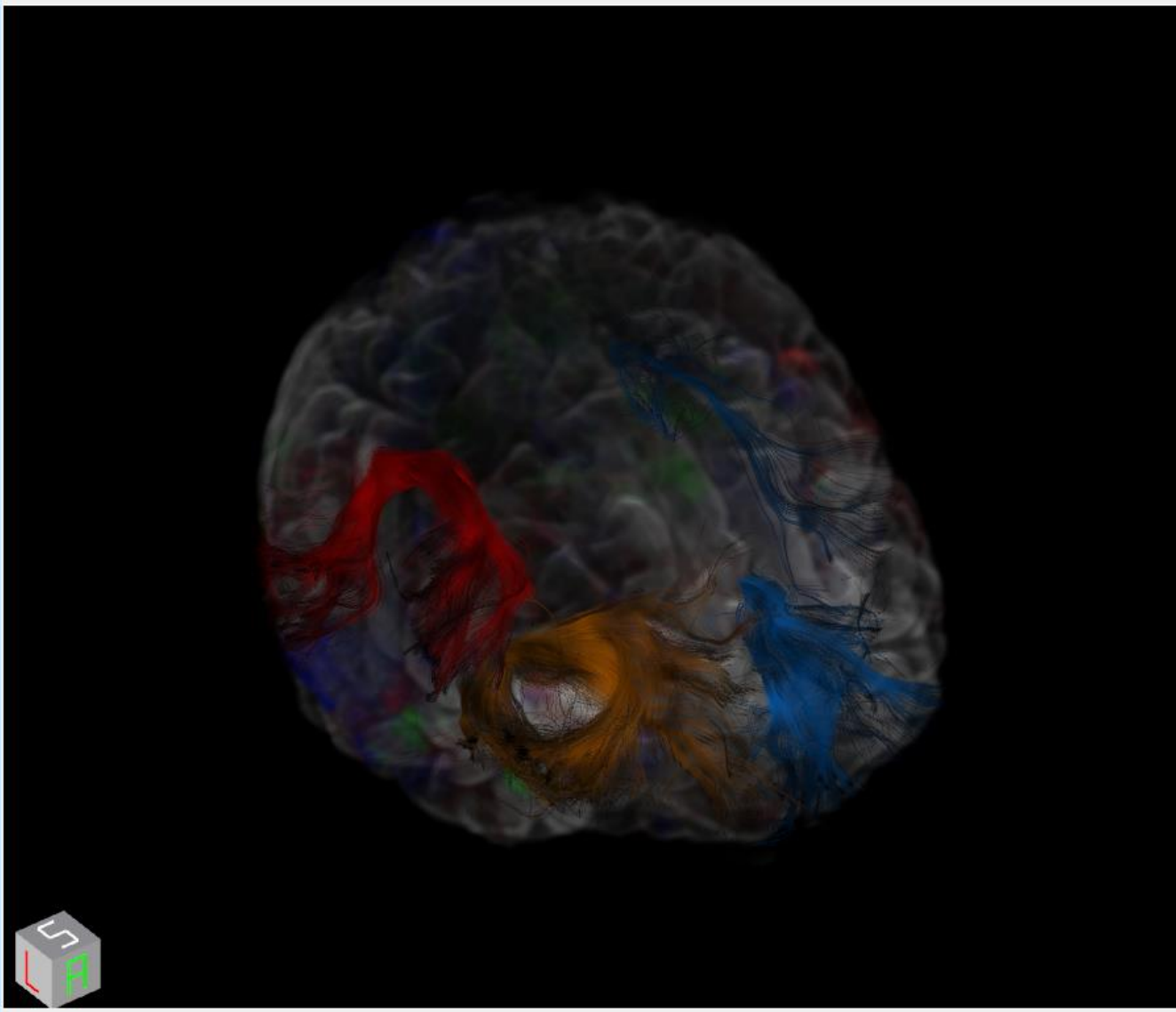
0% Opaque 20% 40% 50% 60%

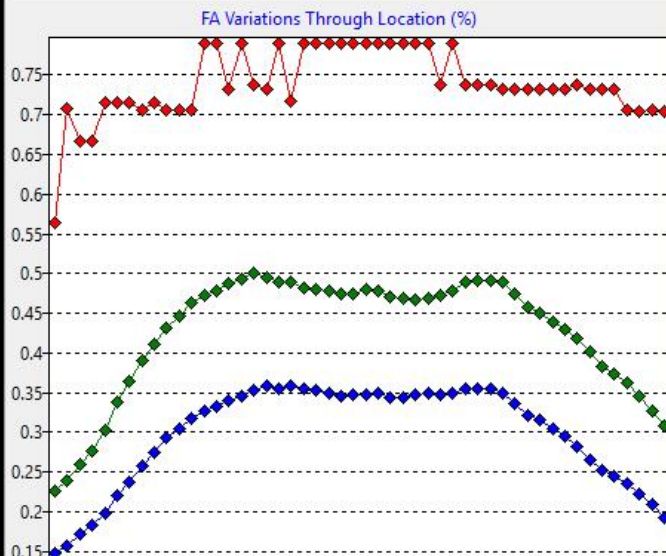
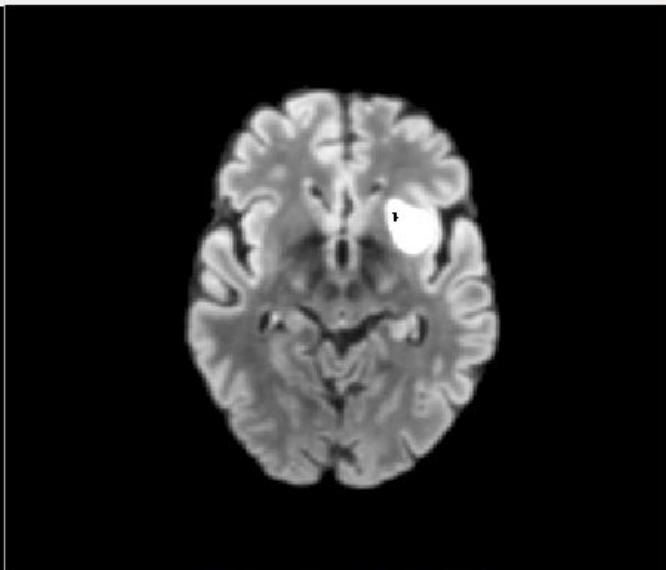
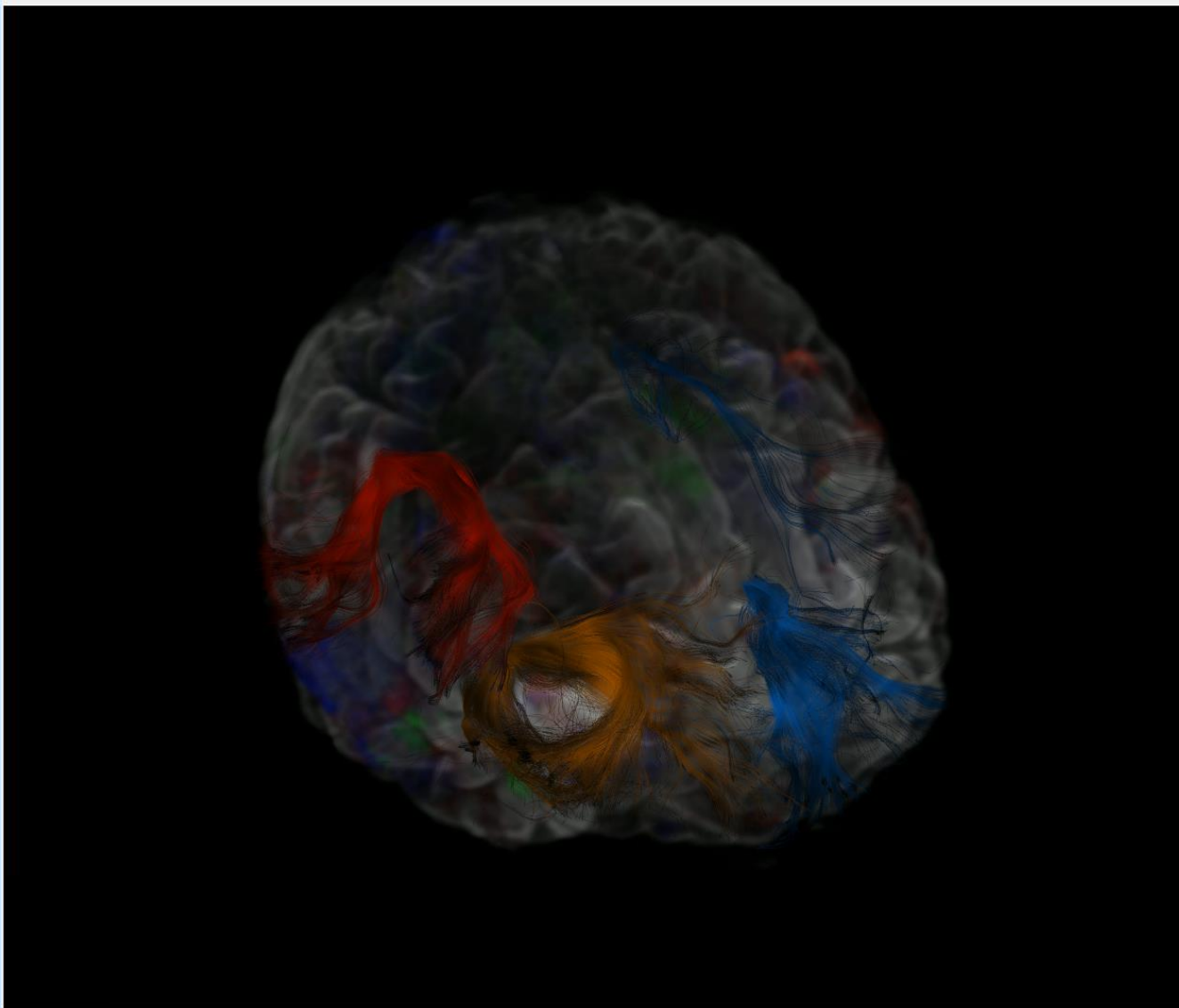
fMRI Map Map
fMRI Map Map
fMRI Map Map

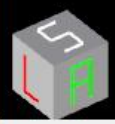
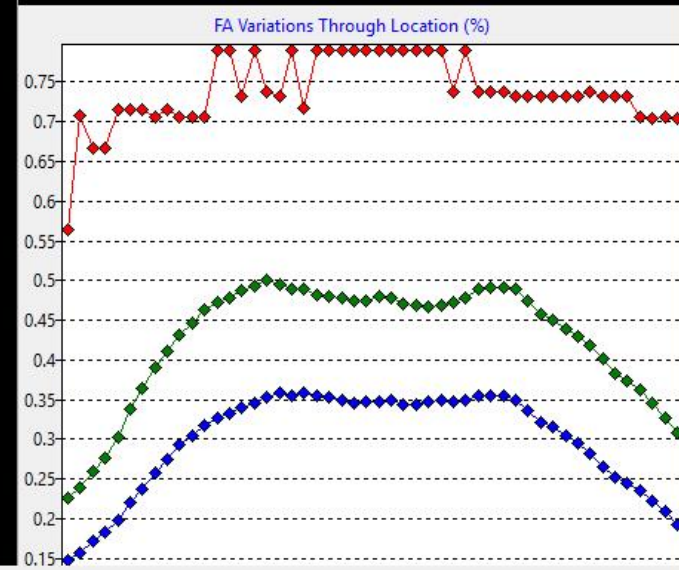
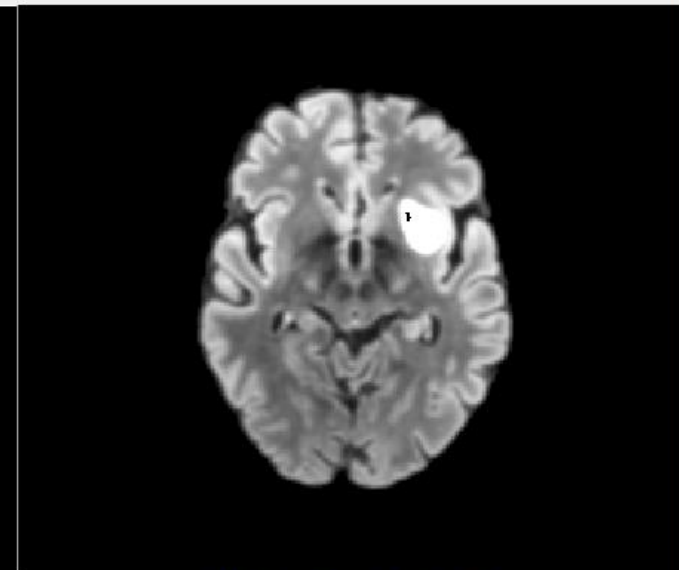
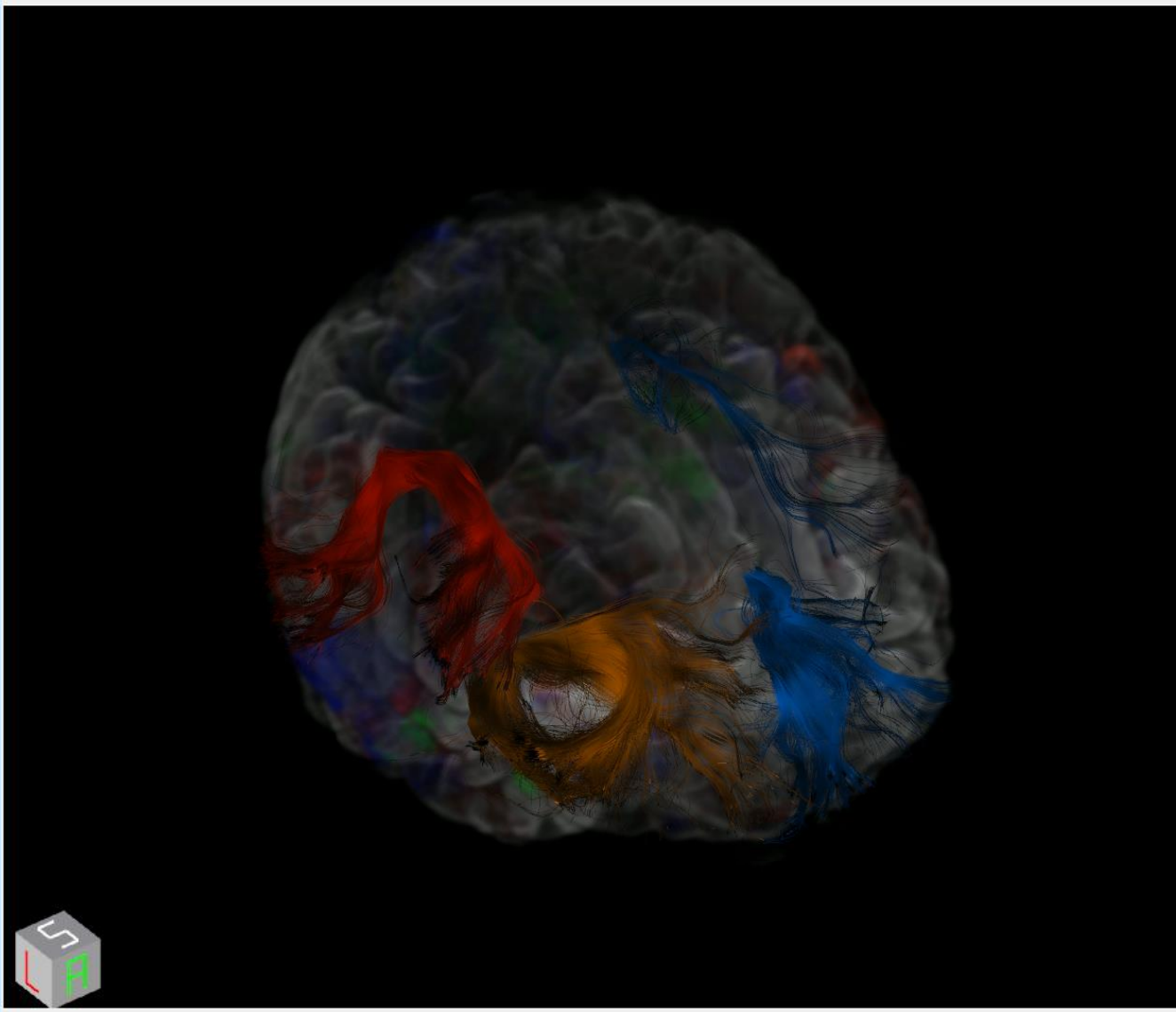
Grayscale
Red
Green
Blue
Violet

Value
-0
0.43

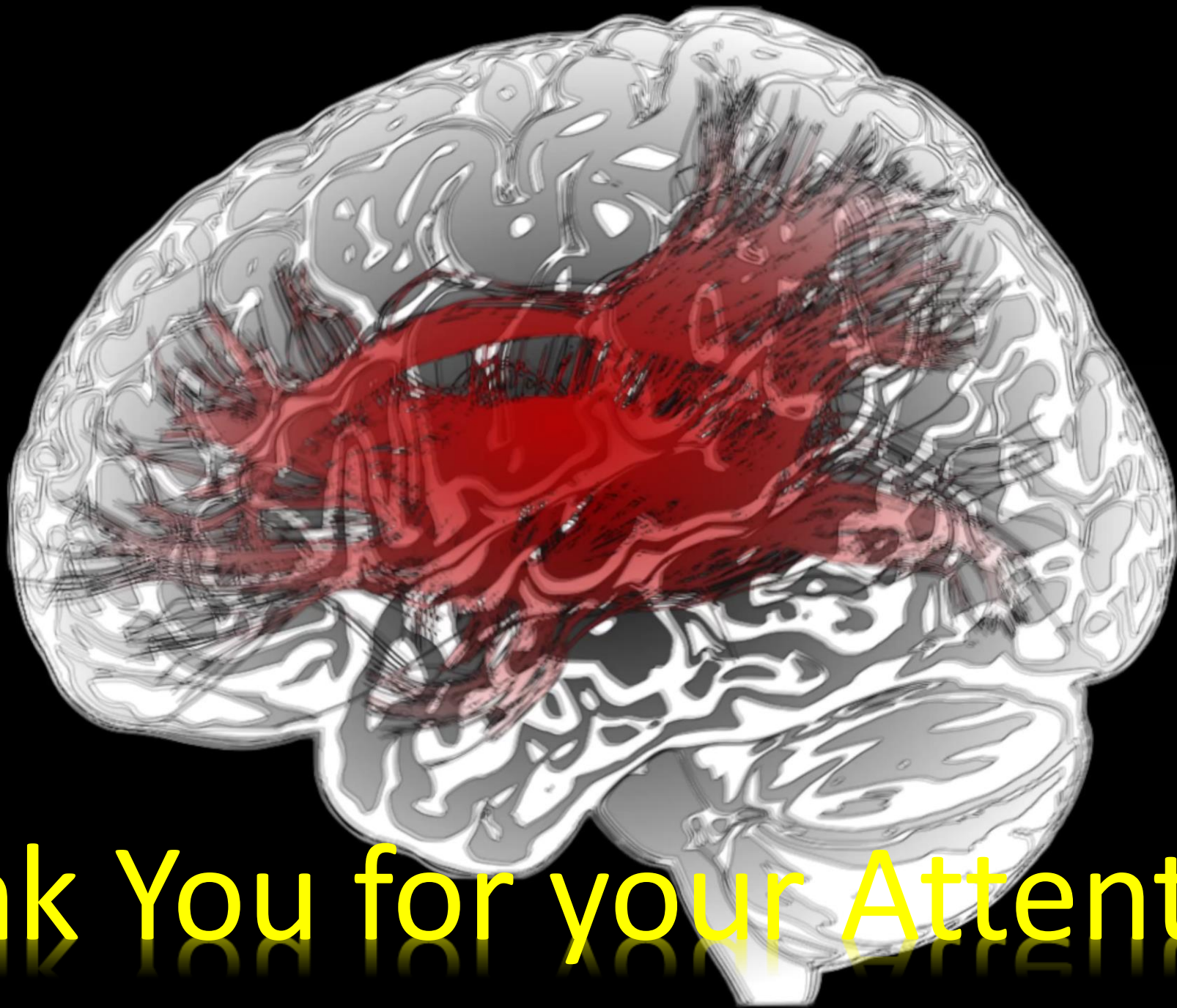








So, Refined Diagnosis:
Accurate Functional
Sequences & Processings!



Thank You for your Attention !