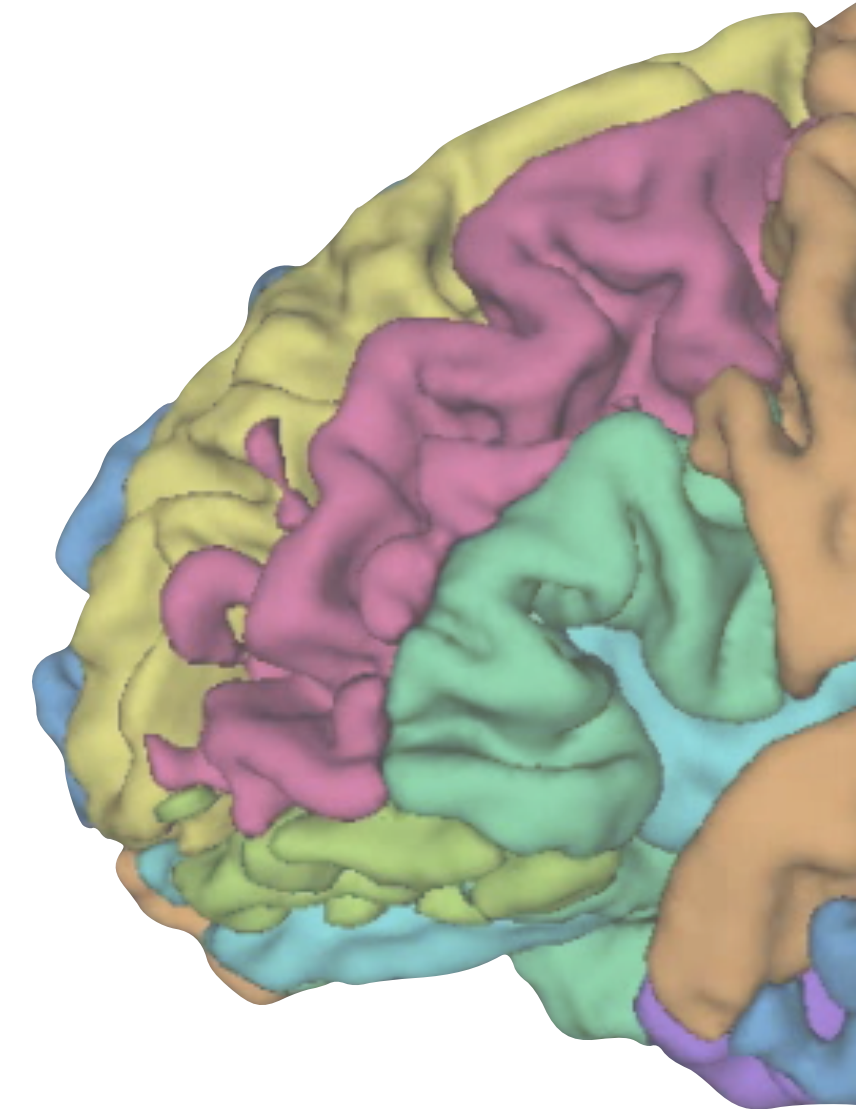
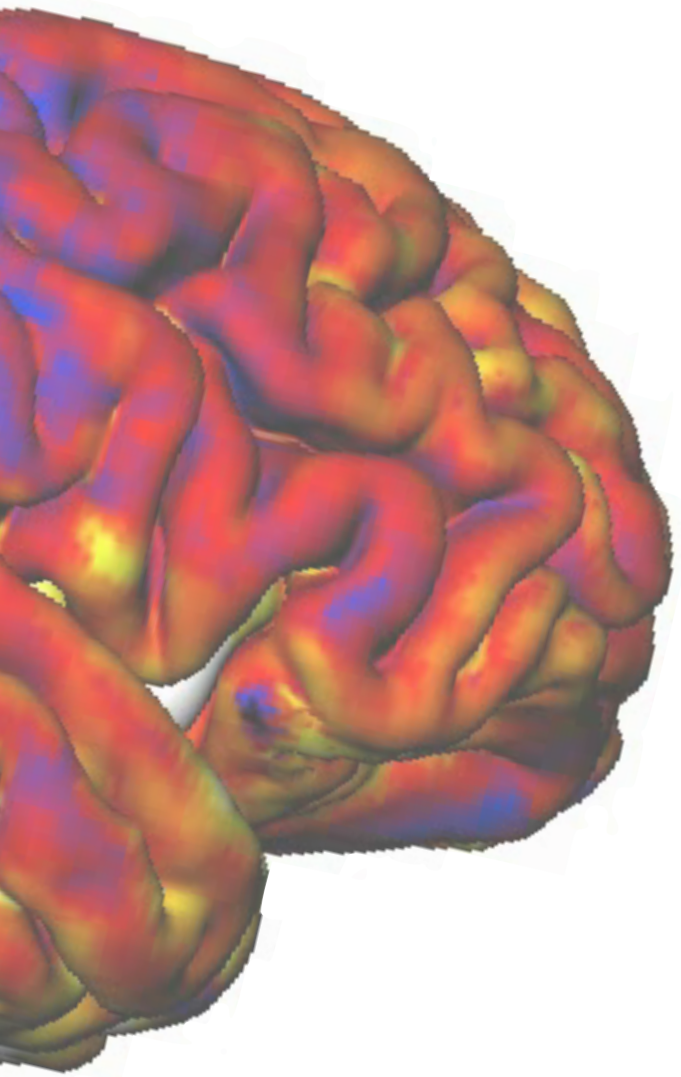
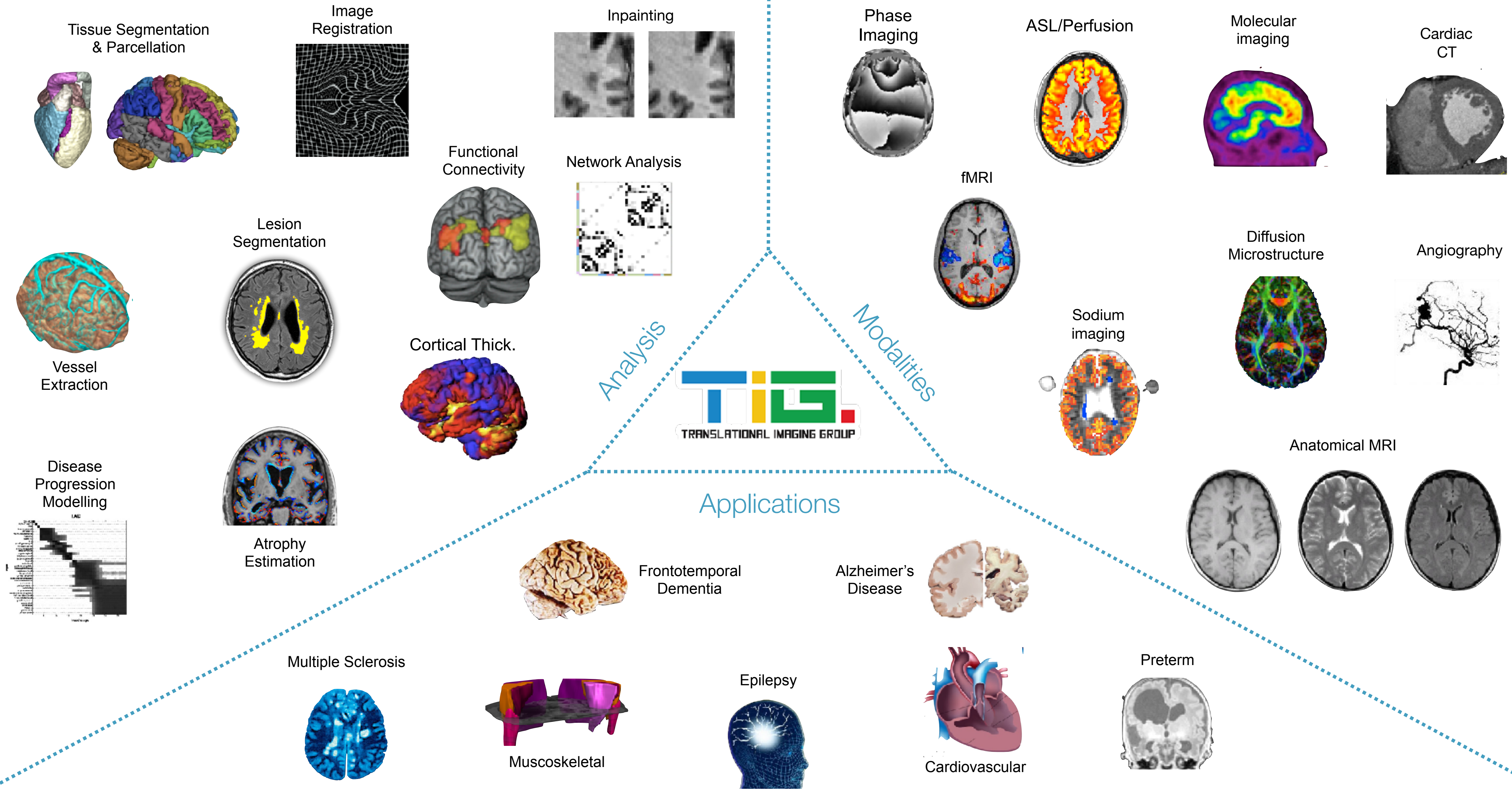


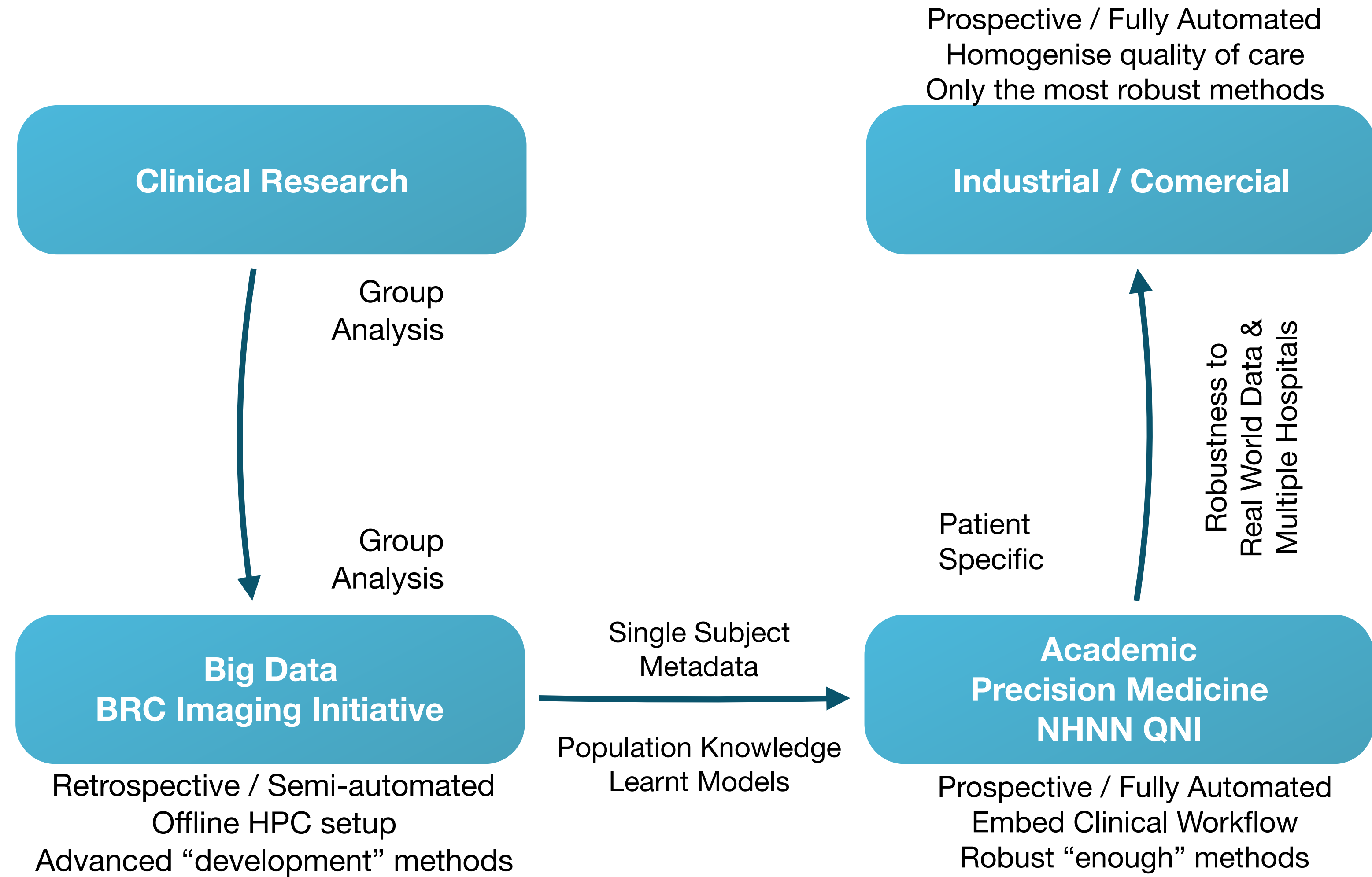
Quantitative Neuroradiology

Machine Learning for Improved Patient Care

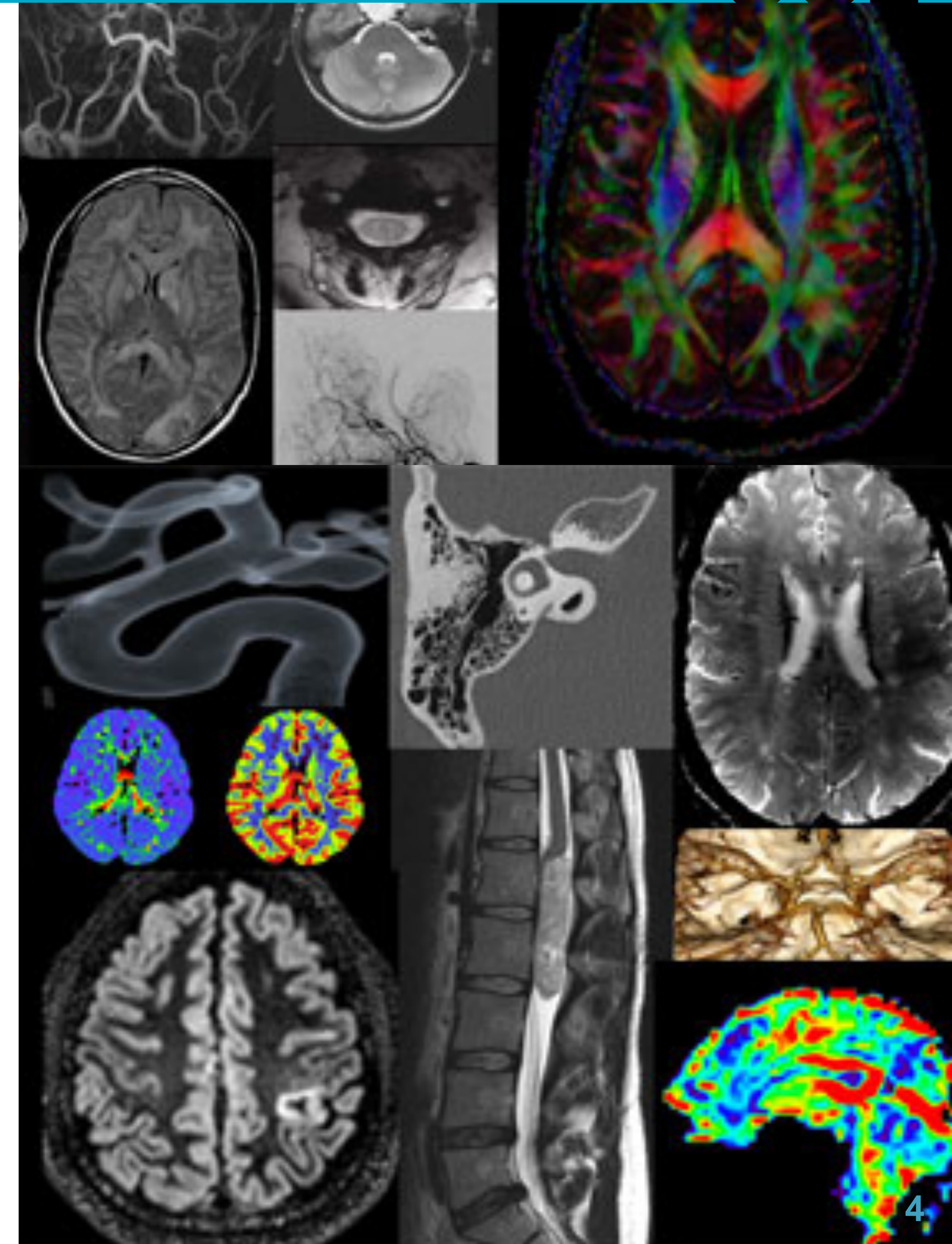
M. Jorge Cardoso



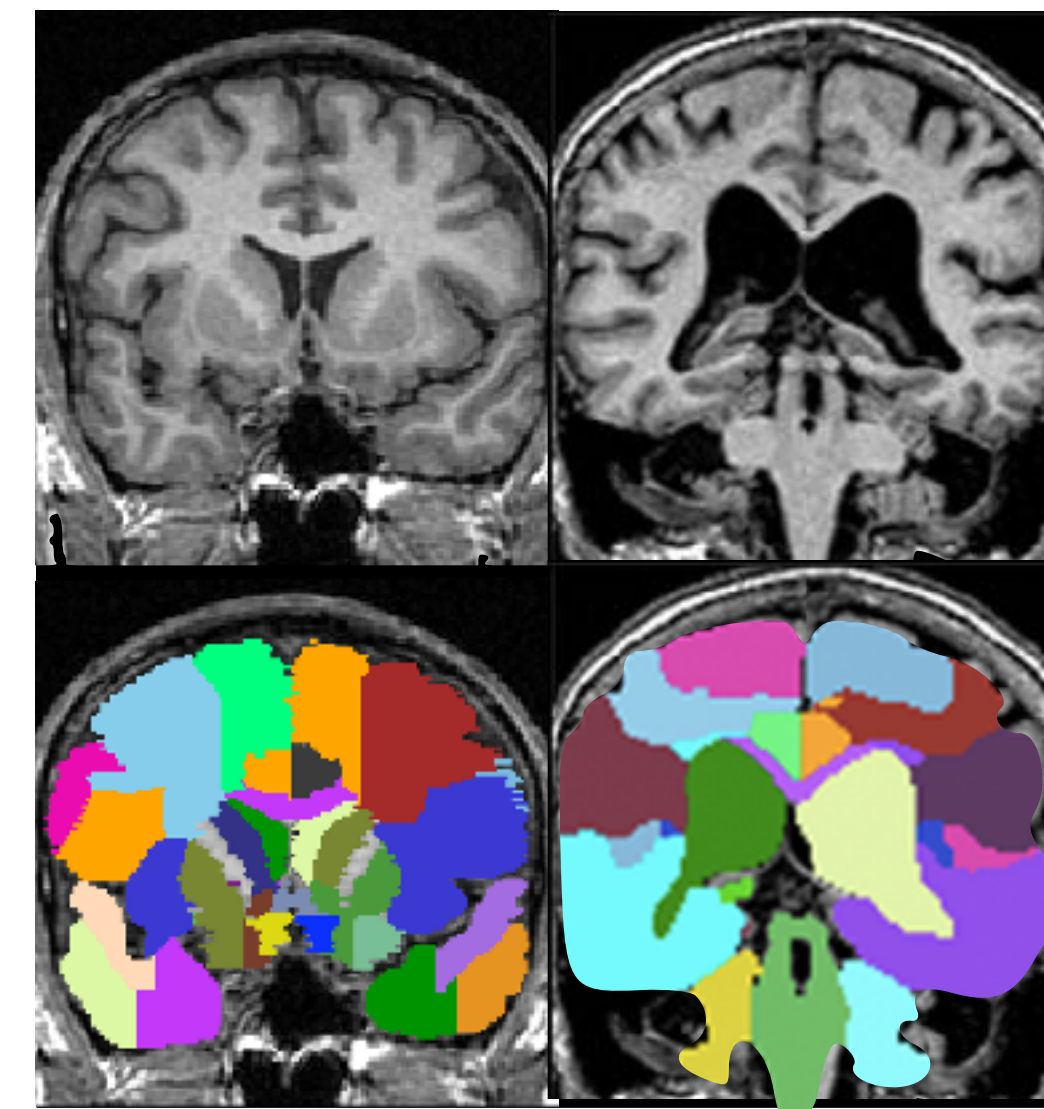
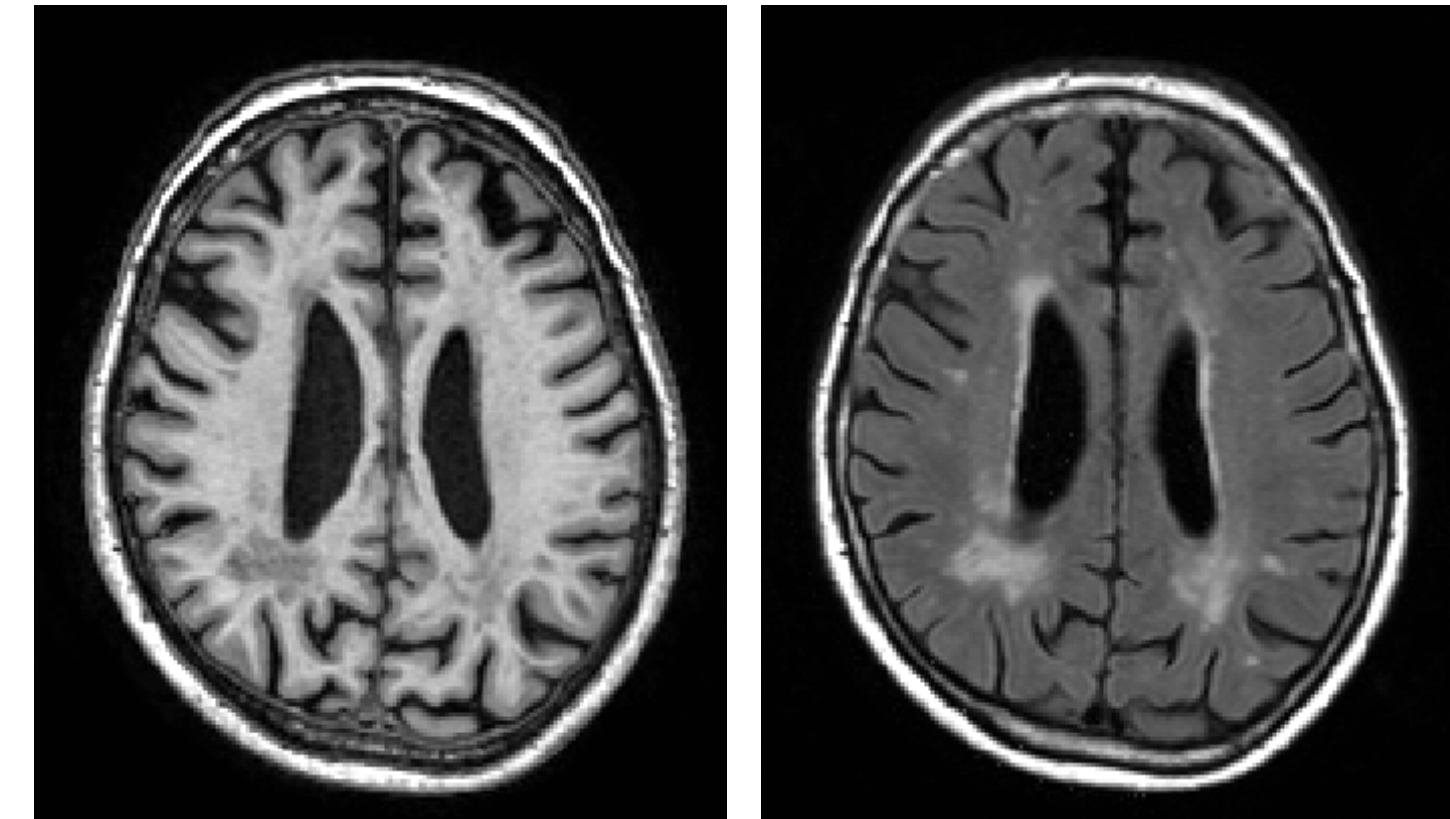




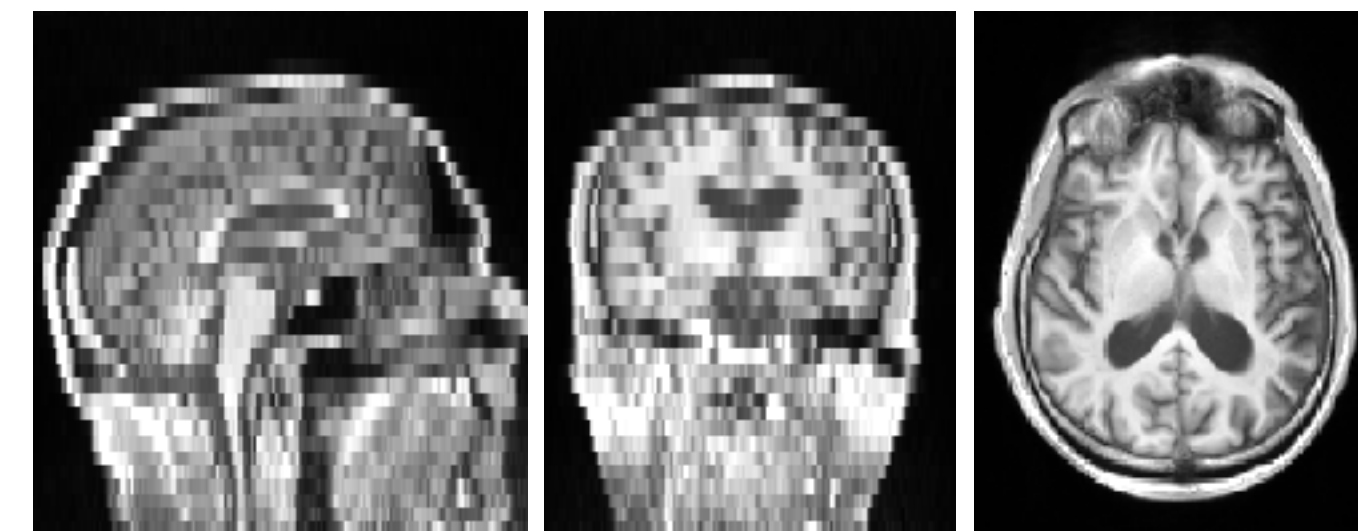
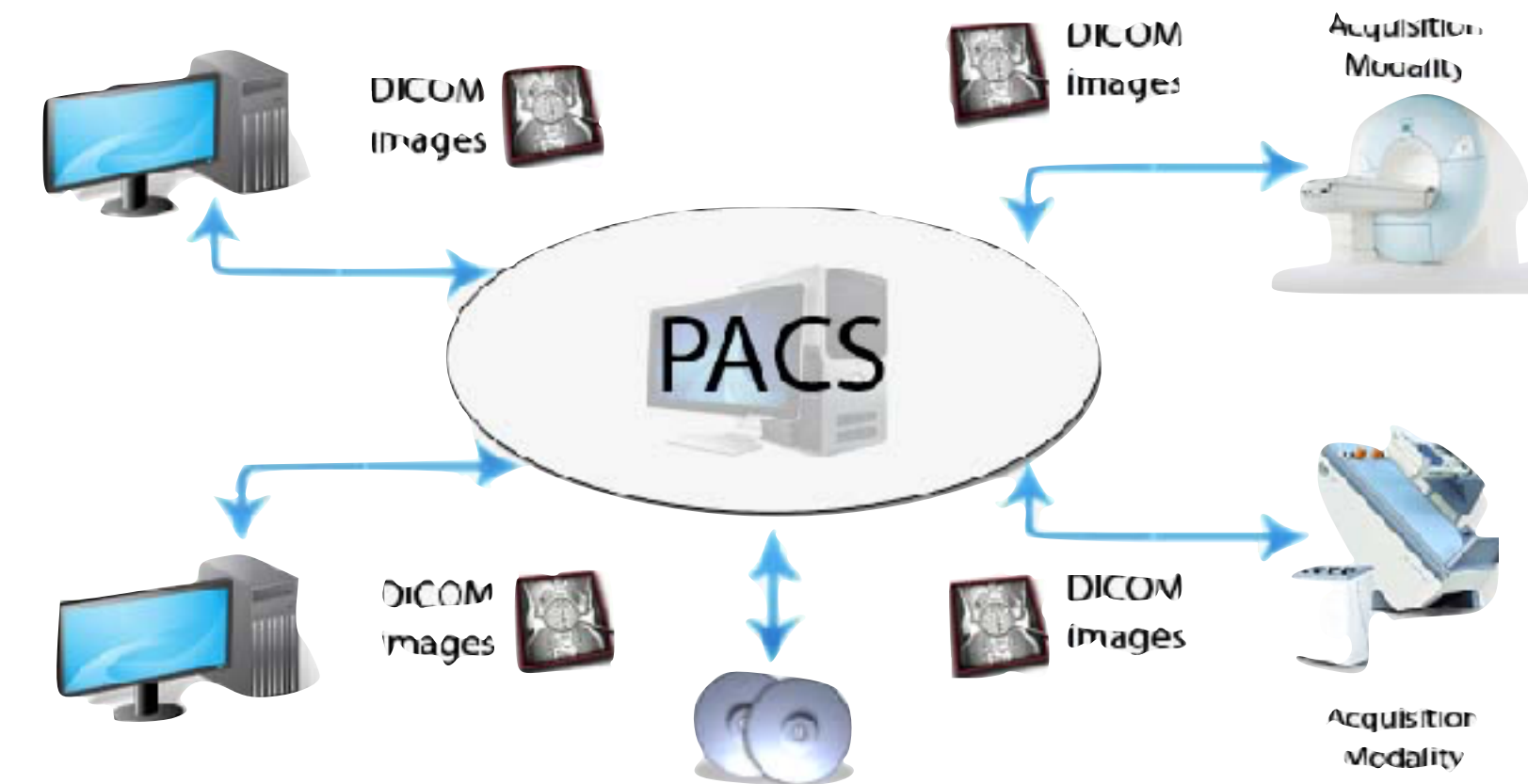
- Neuroradiologists interpret or "read" the acquired images and produce a report of their findings and impression or diagnosis.
- Referring physician reinterprets the findings against symptoms to obtain the final integrated diagnosis.
- Neuroradiology has a problem:
 - MRI & CT increase 10-12% per year compounded
 - Radiologists increase 1-3% per year
 - Limited NHS funding, no increase in training rates, escalating data complexity



- Normally small training datasets
- Very variable input data
- Accuracy is paramount
- Speed is not important (with exceptions)
- Ability to extrapolate
- Problem specific solutions
- No ground truth
- Large unstructured data
- Ethics and clinical adoption



- **300.000 sessions - +2.5M Volumes**
 - Many images & follow-up data
 - 2.5M Volumes
 - 14k “different” sequences
 - 15+ different scanners
 - From 0.5 - 7T (mostly 1.5T and 3T)
- **RIS - Radiological reports**
- **CDR - ICD-10 codes**
- **Blood tests**



- **What questions can we ask?**

- Epidemiology and learning disease structure
- Service optimisation:
 - Workflow: Triage, Prioritisation, Recall
 - Management: Auditing, Bed usage, Cost-code optimisation, etc.
- Surveillance/Diagnosis/Prognosis

How do we learn from an unbalanced pool of pathologies given
a largely non-overlapping set of sequences?

ValidationGUI.txt

Reports

Select a report at random

Open

4288

40571484 - 9494 - 0001 - 21091307 - 01120010 11.02 - 52988

Original Report

4552235 01/12/2010 MR Head 4552235 01/12/2010 MR+c MRA Carotid 4552235 01/12/2010 MR+c Head

Indication: A small peripheral left parietal bleed, not typical of hypertensive bleed ?Underlying tumour or amyloid angiopathy There is no previous imaging available for comparison. A small subacute haematoma is noted within the left parietal subcortical white matter with mild perilesional oedema and causing minimal mass effect on adjacent brain parenchyma. There are no associated enlarged feeding vessels or draining veins to suggest underlying pial AVM and there is no pathological enhancement to suggest an underlying parenchymal tumour. There is background moderate small vessel disease with bilateral supratentorial white matter lesions, scattered infarcts in the basal ganglia thalamus and signal change in the pons. No microhemorrhages. The CEMRA study demonstrates irregularity at the carotid bifurcations bilaterally, right greater than left in keeping with atherosclerotic disease of less than 50% stenosis. Normal appearances of the remaining intracranial and extracranial vessels, although the origins of the vertebral arteries are not well visualised bilaterally. Repeat MRI in 6-8 weeks recommended. Dr Harpreet Hyare Consultant Neuroradiologist 1st Dec 2010

Assessed Pathologies

Pathology	#	Location	Assessed	Feature
1. Atherosclerosis	1		115	
2. Haematoma	2	White matter	5000	
3. Haematoma	1		100	
4. Infarction	1	Basal ganglia	0200	
5. Infarction	1	Thalamus	0010	
6. Infarction	1		339	
7. Lesion	1	White matter	5090	
8. Lesion	1		50	
9. Mass effect	1		220	
10. Parenchymal swelling	1		22	
11. Signal abnormality	1	Pons	7011	
12. Signal abnormality	1	Anterior circulation	5631	
13. Signal abnormality	2		31	
14. Small vessel disease	1		310	
15. Stenosis	4		342	

Derived Pathologies

Pathology	#	Location	Details	Feature
1. AVM	1		41	
2. Enhancement	1		101	
3. Enlargement	1		107	
4. Microhemorrhage	1		65	
5. Tumour	1	Parenchyma	50031	
6. Tumour	1		331	

Diagnosis

Derived Report

There is no previous imaging available for comparison. A small subacute haematoma is noted within the left parietal subcortical white matter with mild perilesional oedema and causing minimal mass effect on adjacent brain parenchyma. There are no associated enlarged feeding vessels or draining veins to suggest underlying pial AVM and there is no pathological enhancement to suggest an underlying parenchymal tumour. There is background moderate small vessel disease with bilateral supratentorial white matter lesions, scattered infarcts in the basal ganglia thalamus and signal change in the pons. No microhemorrhages. The CEMRA study demonstrates irregularity at the carotid bifurcations bilaterally, right greater than left in keeping with atherosclerotic disease of less than 50% stenosis. Normal appearances of the remaining intracranial and extracranial vessels, although the origins of the vertebral arteries are not well visualised bilaterally. Repeat MRI in 6-8 weeks recommended. Dr Harpreet Hyare Consultant Neuroradiologist 1st Dec 2010

Revised and Tipped Report

There is no previous imaging available for comparison. A subacute [P1120] within the [A2004] with mild perilesional [P300P] and causing minimal [P120P] an adjacent brain [A2004]. There are no associated [P120P] feeding vessels or draining veins to suggest underlying pial [P300P] and there is no pathological [P300P] to suggest an underlying [A2004] [P300P]. There is background moderate [P1120] with [A2004] [P300P], scattered [P300P] in the [A2004] and [P300P] in the [A2004]. No [P300P]. The CEMRA study demonstrates [P1120] at the [A2004] bilaterally, greater than in keeping with [P1120] of less than 50% [P1120]. Normal appearances of the remaining intracranial and extracranial vessels, although the origins of the [A2004] are not well visualised bilaterally. Repeat MRI in 6-8 weeks recommended. Dr Harpreet Hyare Consultant Neuroradiologist 1st Dec 2010

Derived and Tipped Report Where Pathologies are Mapped to Anatomical Locations

There is no previous imaging available for comparison. A subacute [P1120] within the [A2004] with mild perilesional [P300P] and causing minimal [P120P] on adjacent brain [A2004]. There are no associated [P120P] feeding vessels or draining veins to suggest underlying pial [P300P] and there is no pathological [P300P] to suggest an underlying [P1120] [P300P]. There is background moderate [P1120] with [P1120] scattered [P300P] [P300P] and [P300P] [P300P]. No [P300P]. The CEMRA study demonstrates [P1120] bilaterally, greater than in keeping with [P1120] of less than 50% [P1120]. Normal appearances of the remaining intracranial and extracranial vessels, although the origins of the [P1120] are not well visualised bilaterally. Repeat MRI in 6-8 weeks recommended. Dr Harpreet Hyare Consultant Neuroradiologist 1st Dec 2010

Picture Path's Entry

Further Diagnostics

Points of Assessment and Details

	1	2	3	4
1	0	0	0	0
2	1	1	1	0
3	-1	-1	-1	-1
4	1	1	1	1
5	-1	0	0	0
6	1	1	1	0

Scoring

Final (yes positive)

Final (yes negative)

Final (total)

Final (pathologies missed)

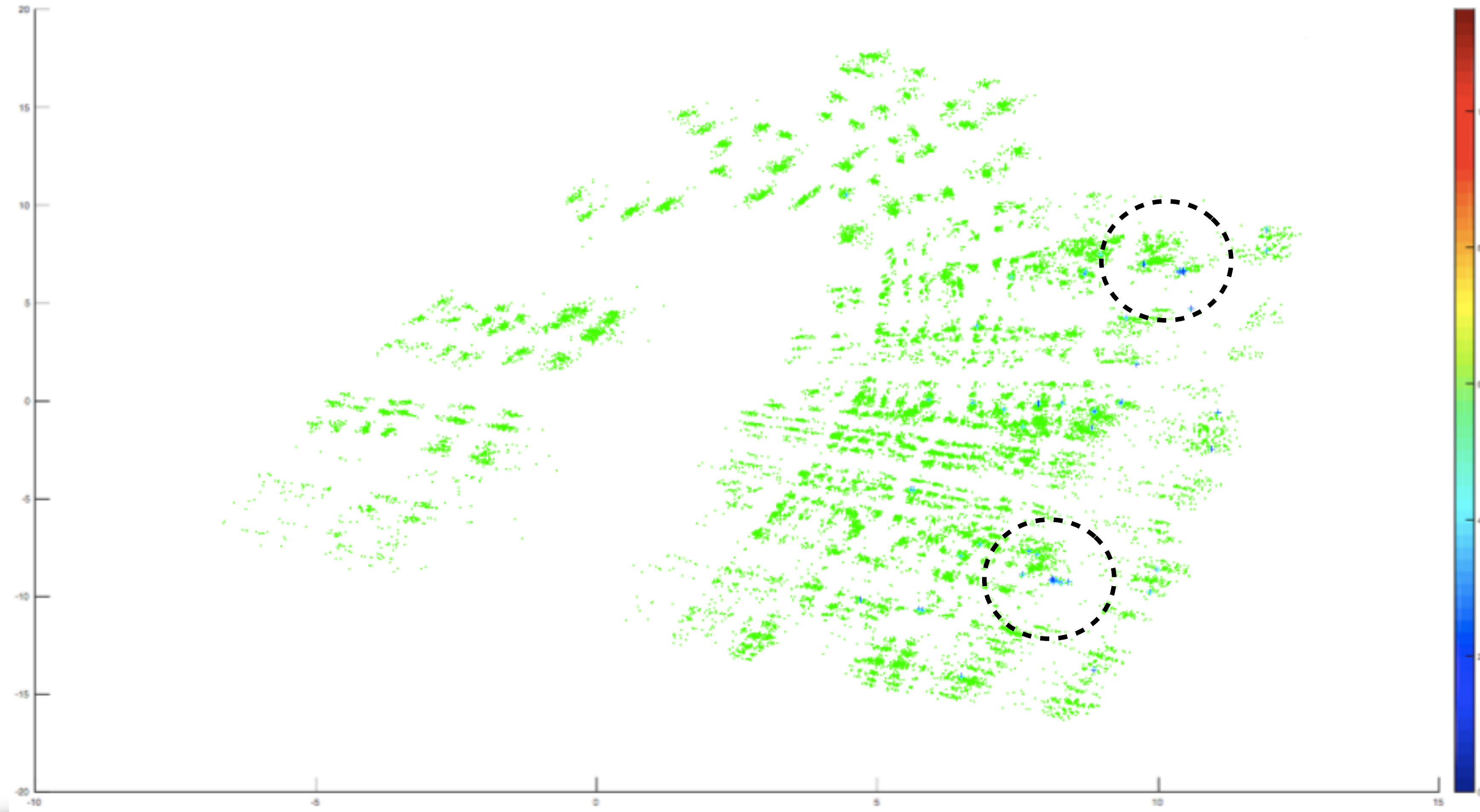
Final (anatomical mislocated)

Open

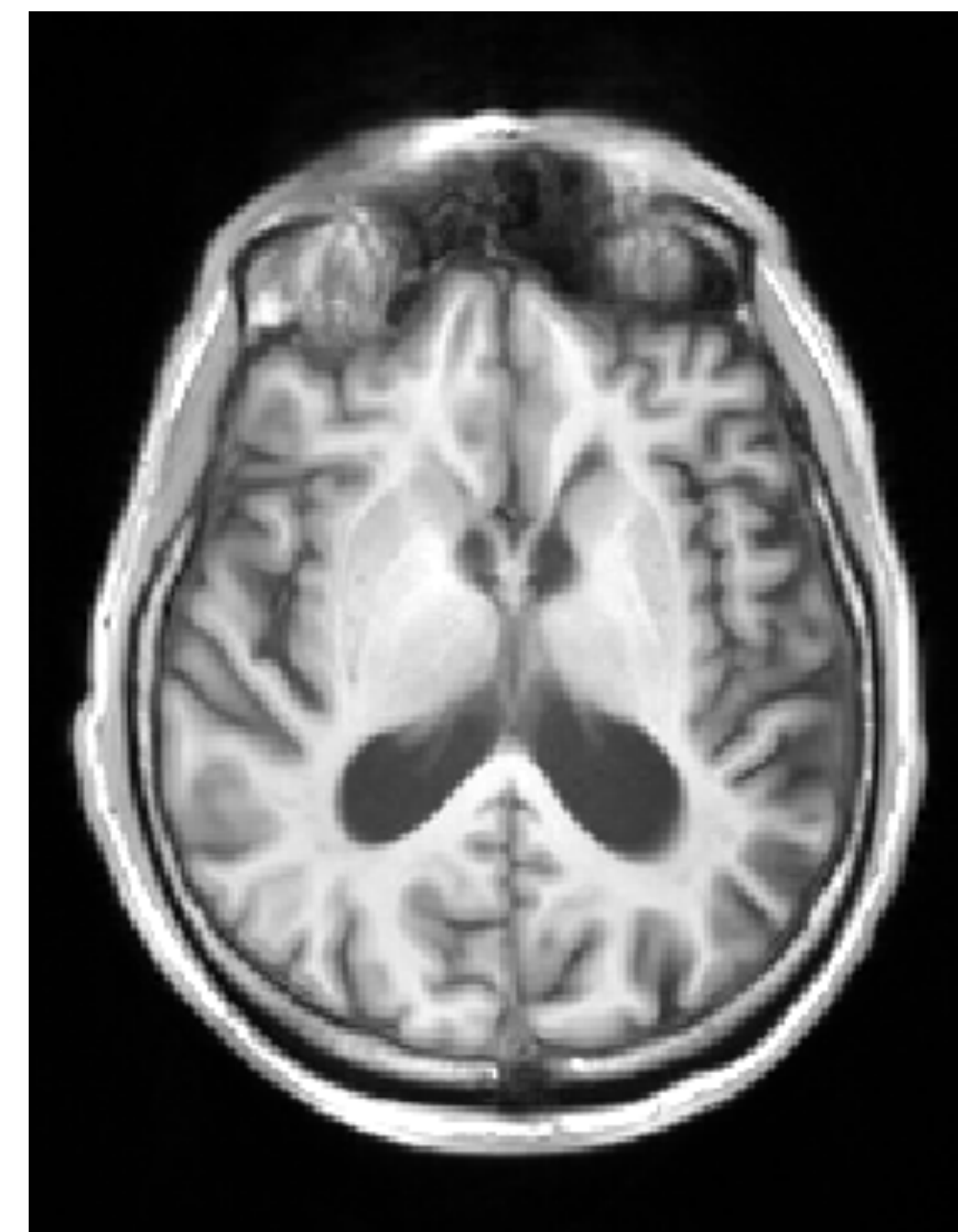
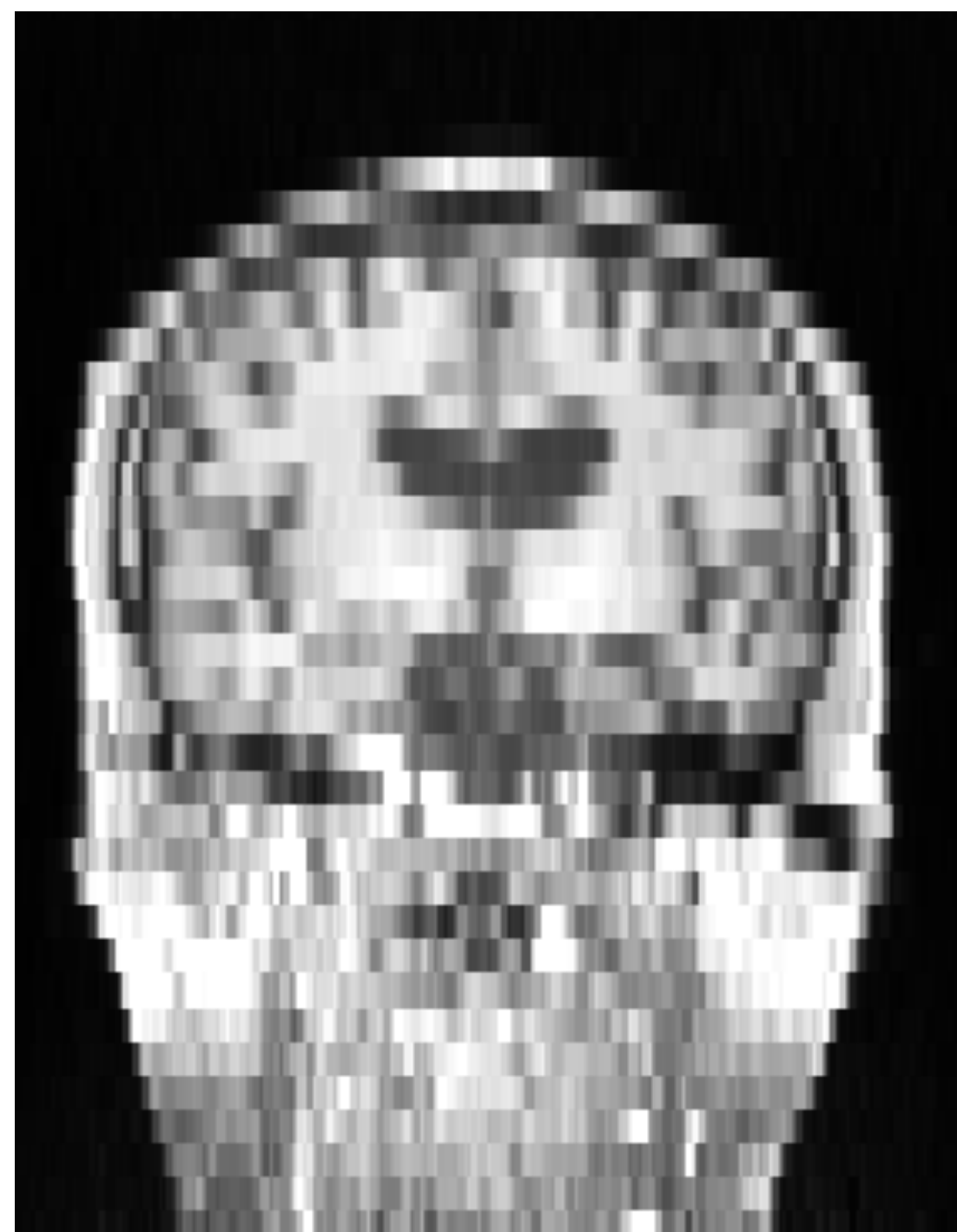
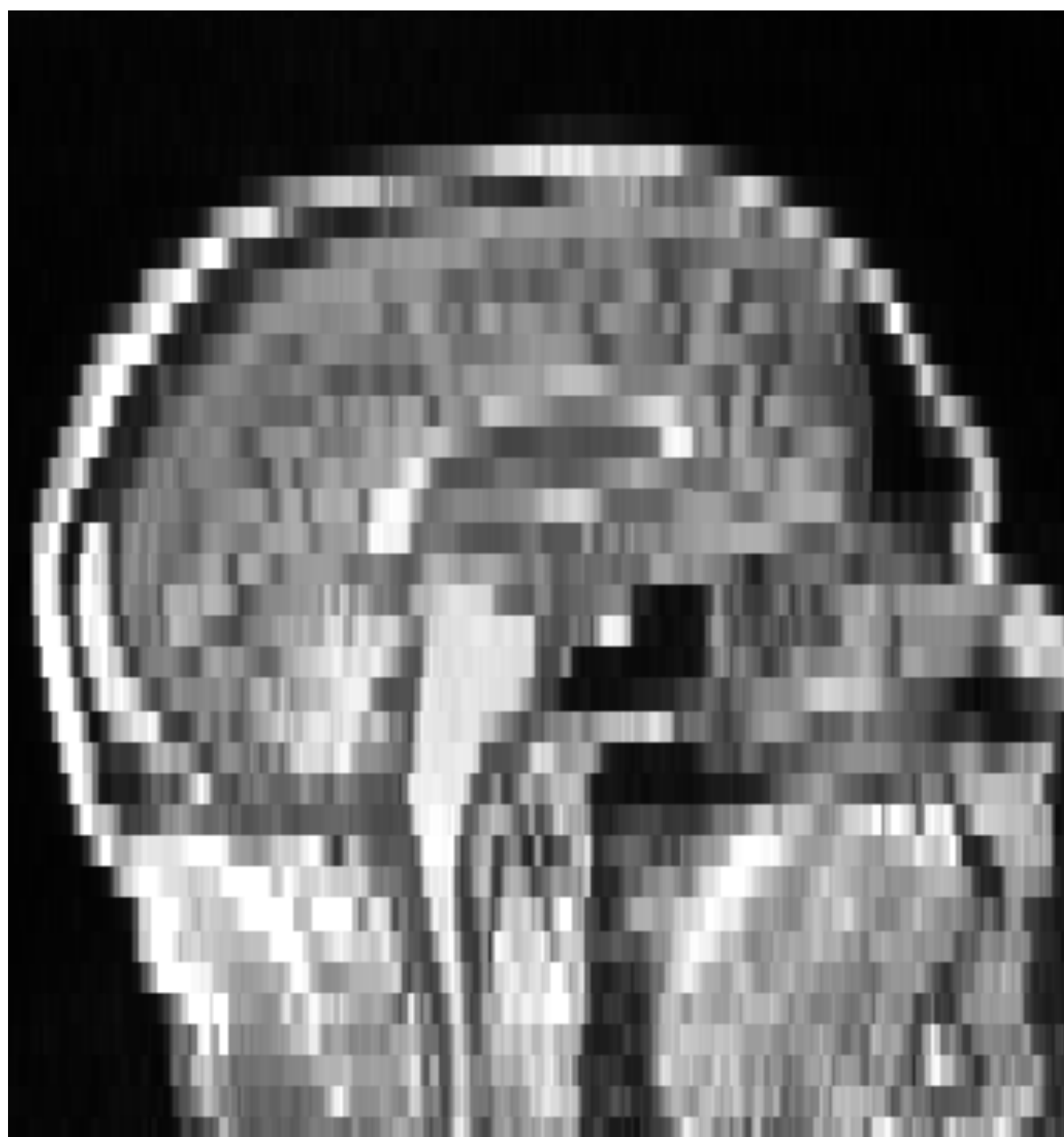
Report	Score	Comment
4552235 01/12/2010 MR+c MRA Carotid 4552235 01/12/2010 MR+c Head	1	

Save scores

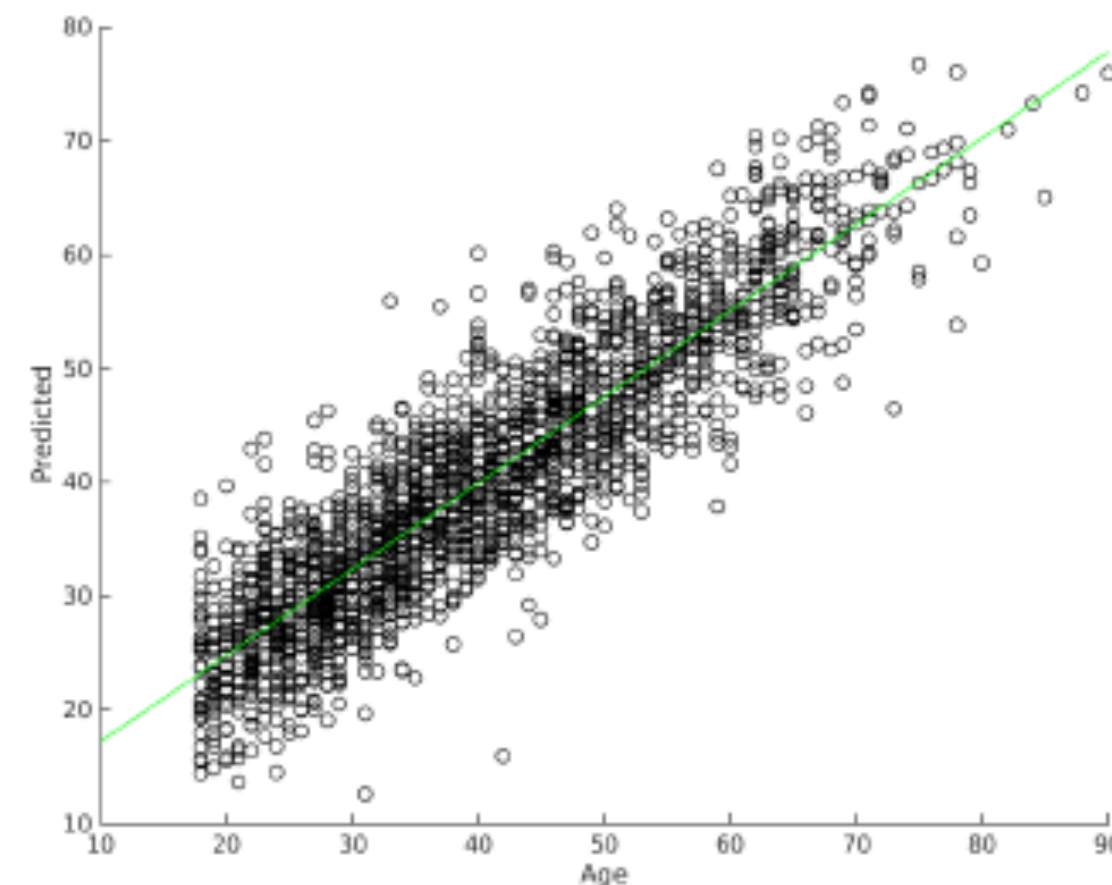
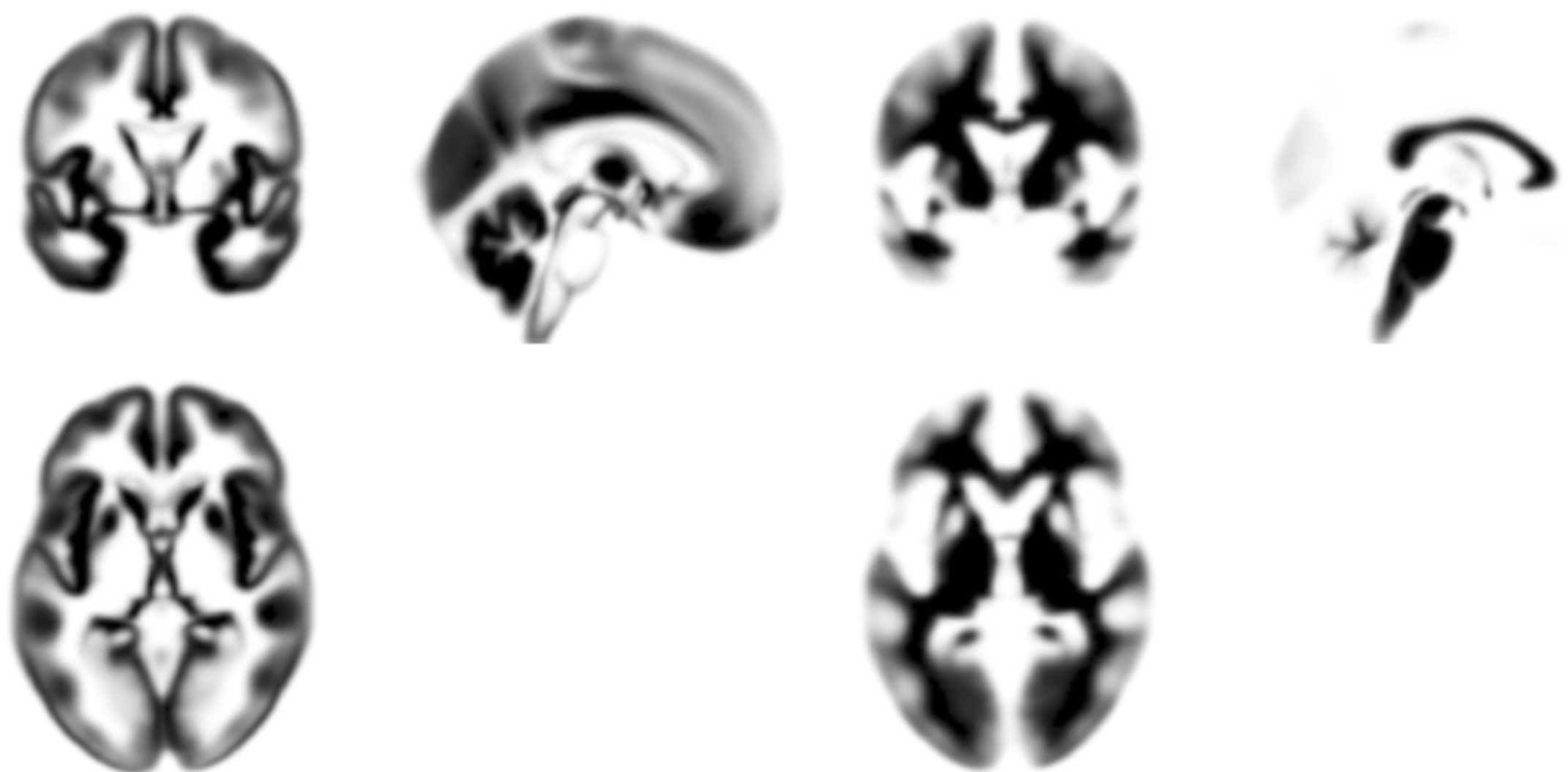
- Deep Autoencoding - Low dimensional (2D) projection of Rad Report vs “Ataxia”
 - Reporting is consistent with regards to “appearance” and non-trivial (Cerebellum vs Sensory)



- 20000 radiologically normal → 6207 Asserted Normals
- Do standard Neuro pipelines work?
 - ... with this “beautiful” data



- 40000 radiologically normal
 - 6207 Asserted Normals



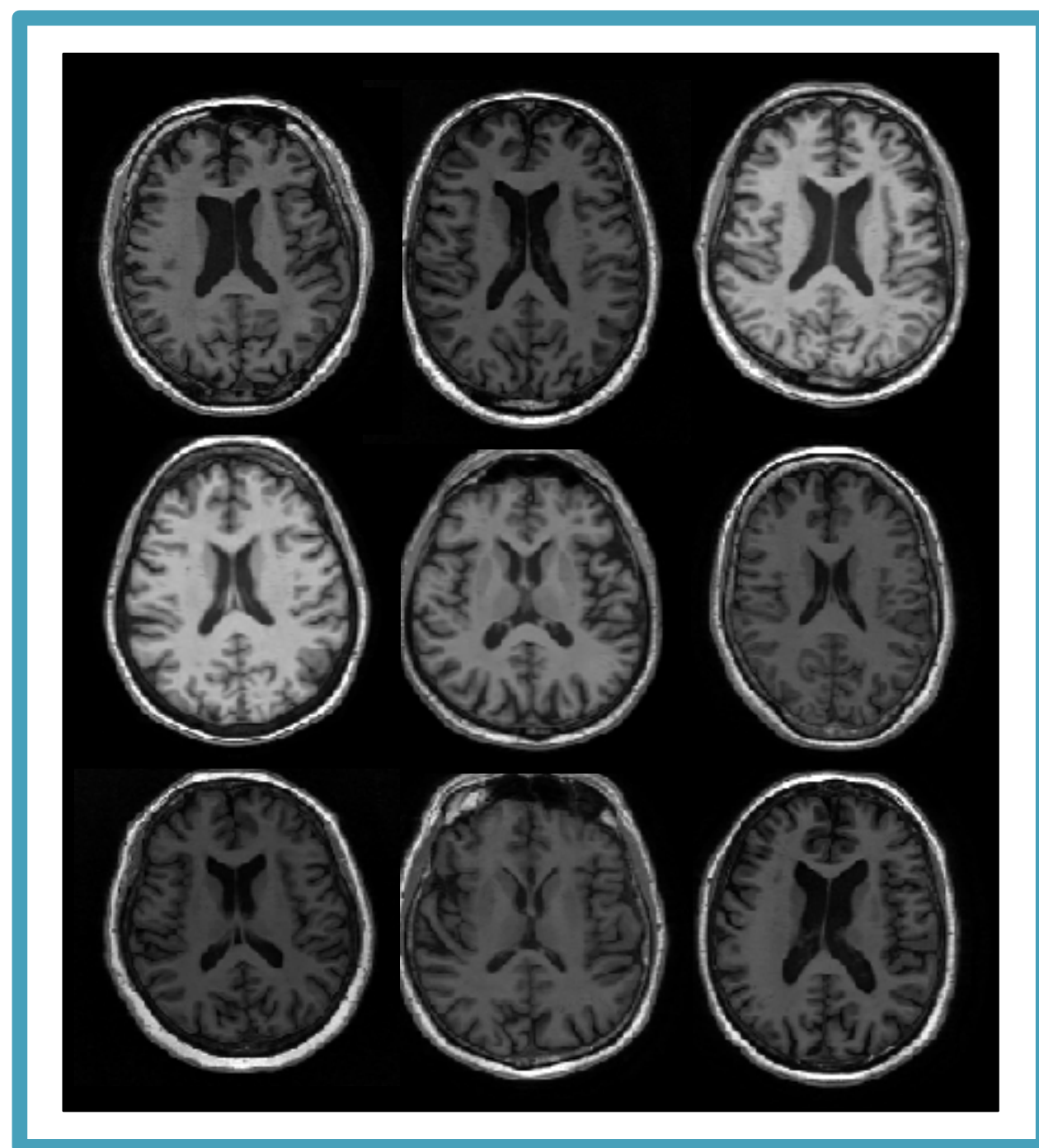
Age: $R=0.897$, $RMSE=6.246$ years

M	2375	108
F	142	3582
	M	F

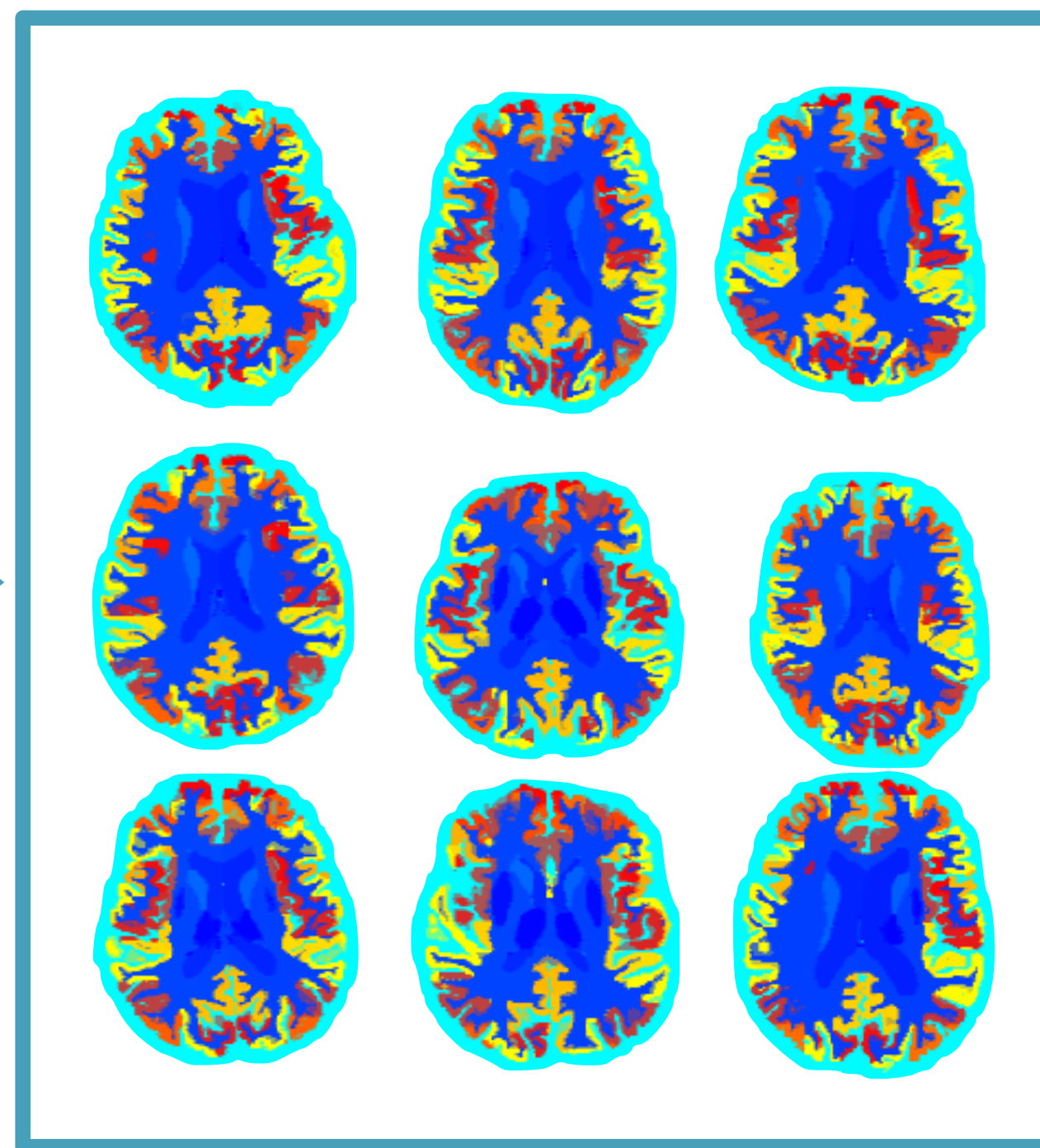
Sex: 95.97% accuracy

- 40000 radiologically normal
 - 6207 Asserted Normals
- Region statistics

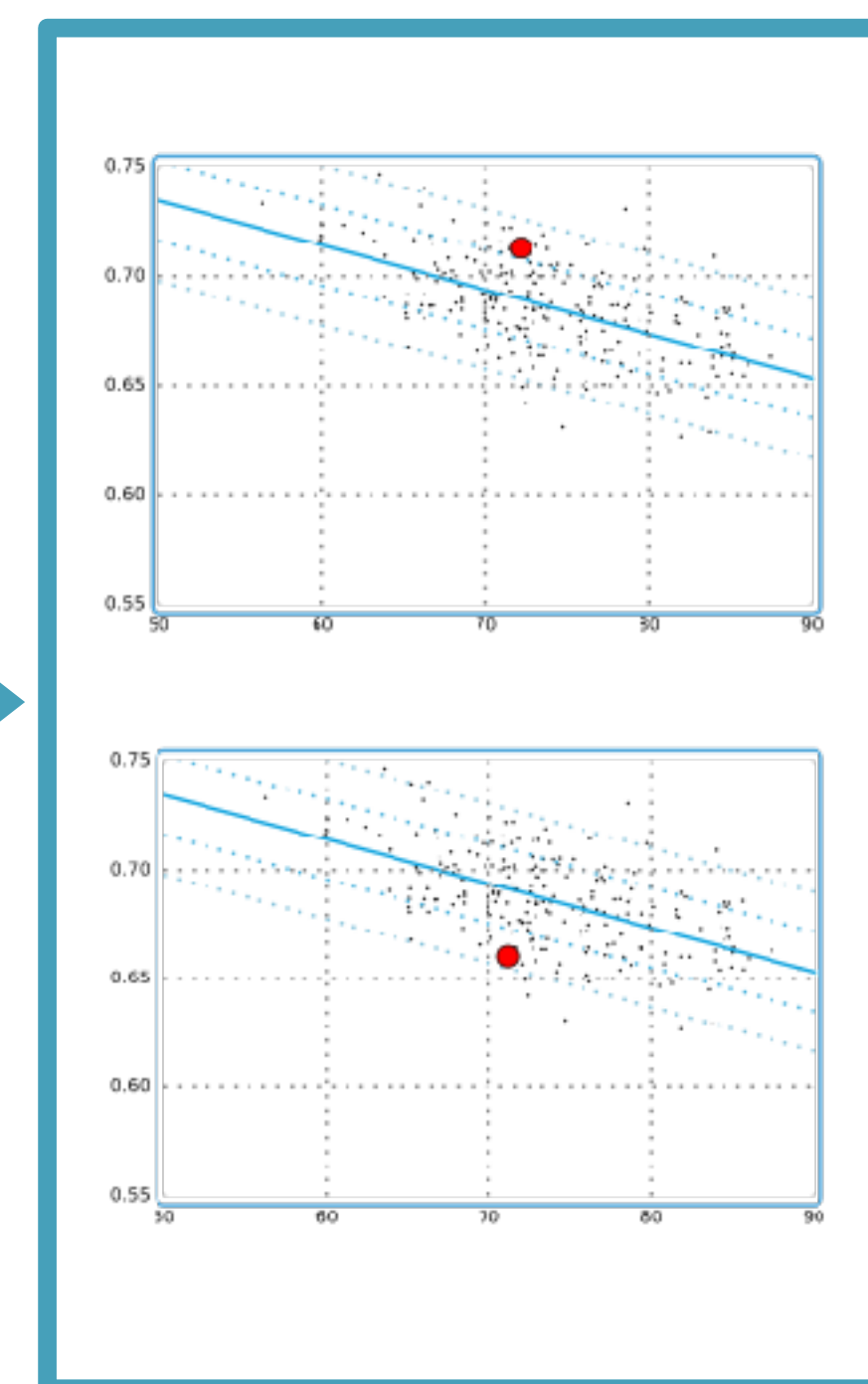
MRI Imaging



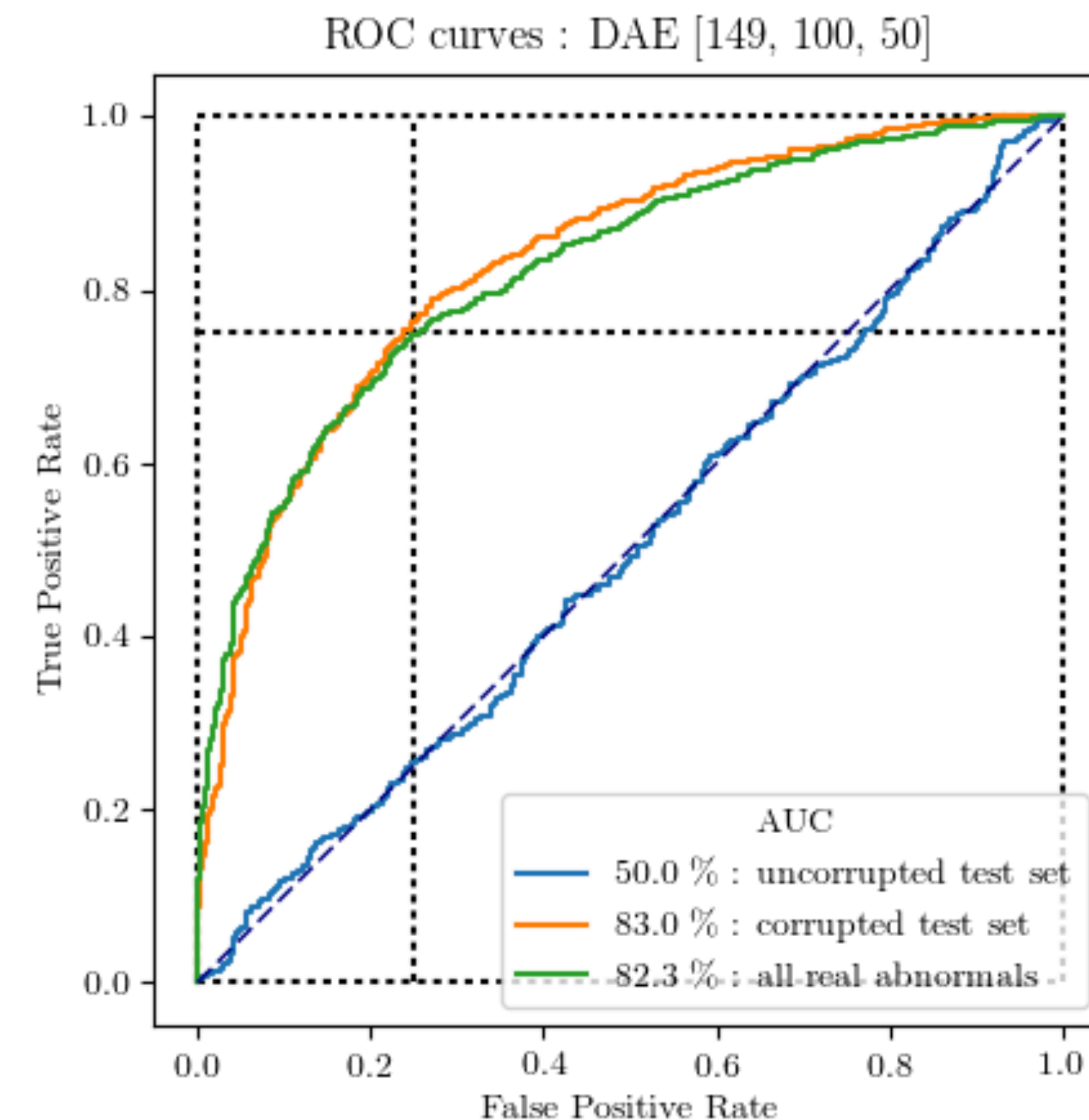
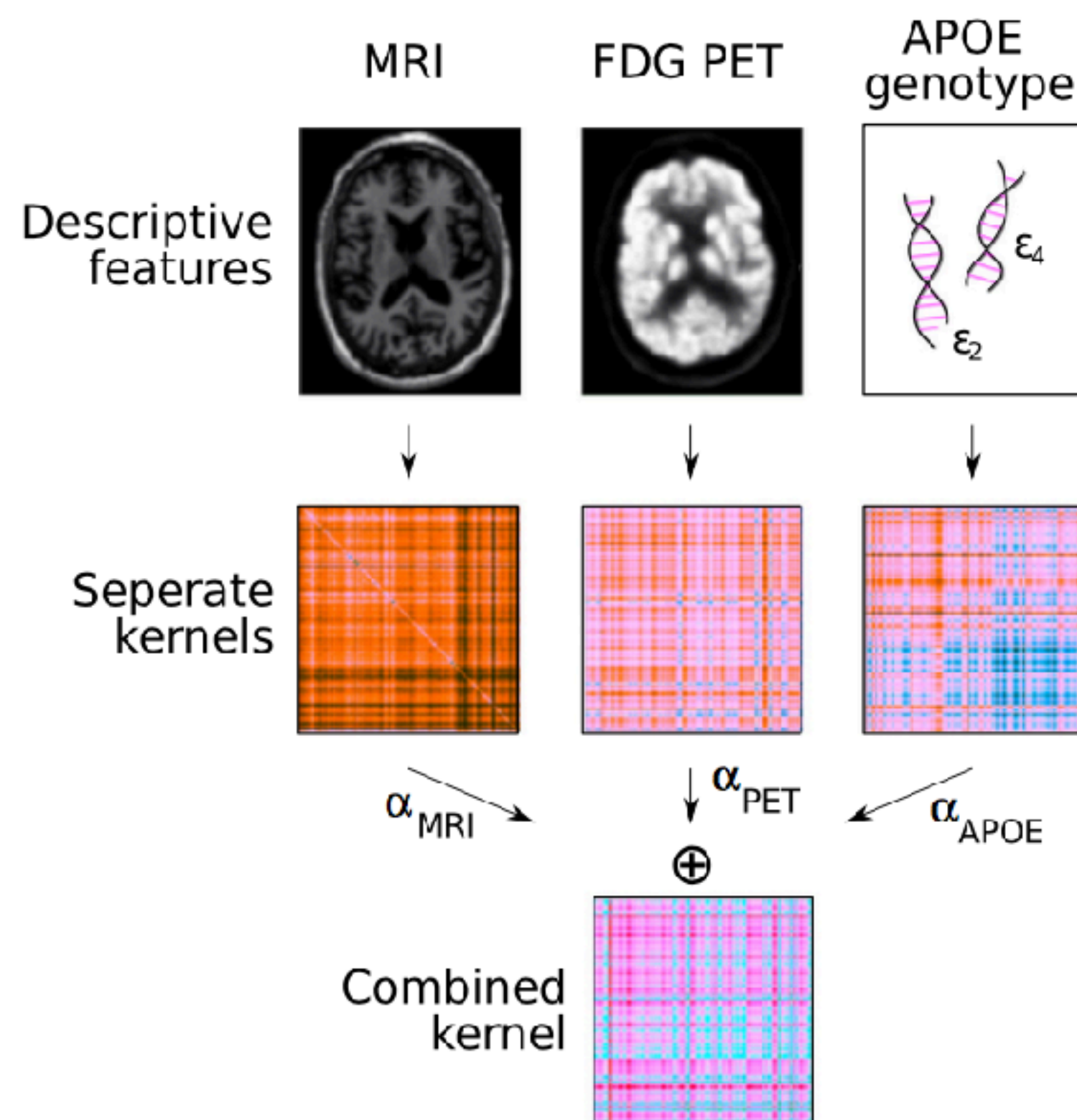
Delineation

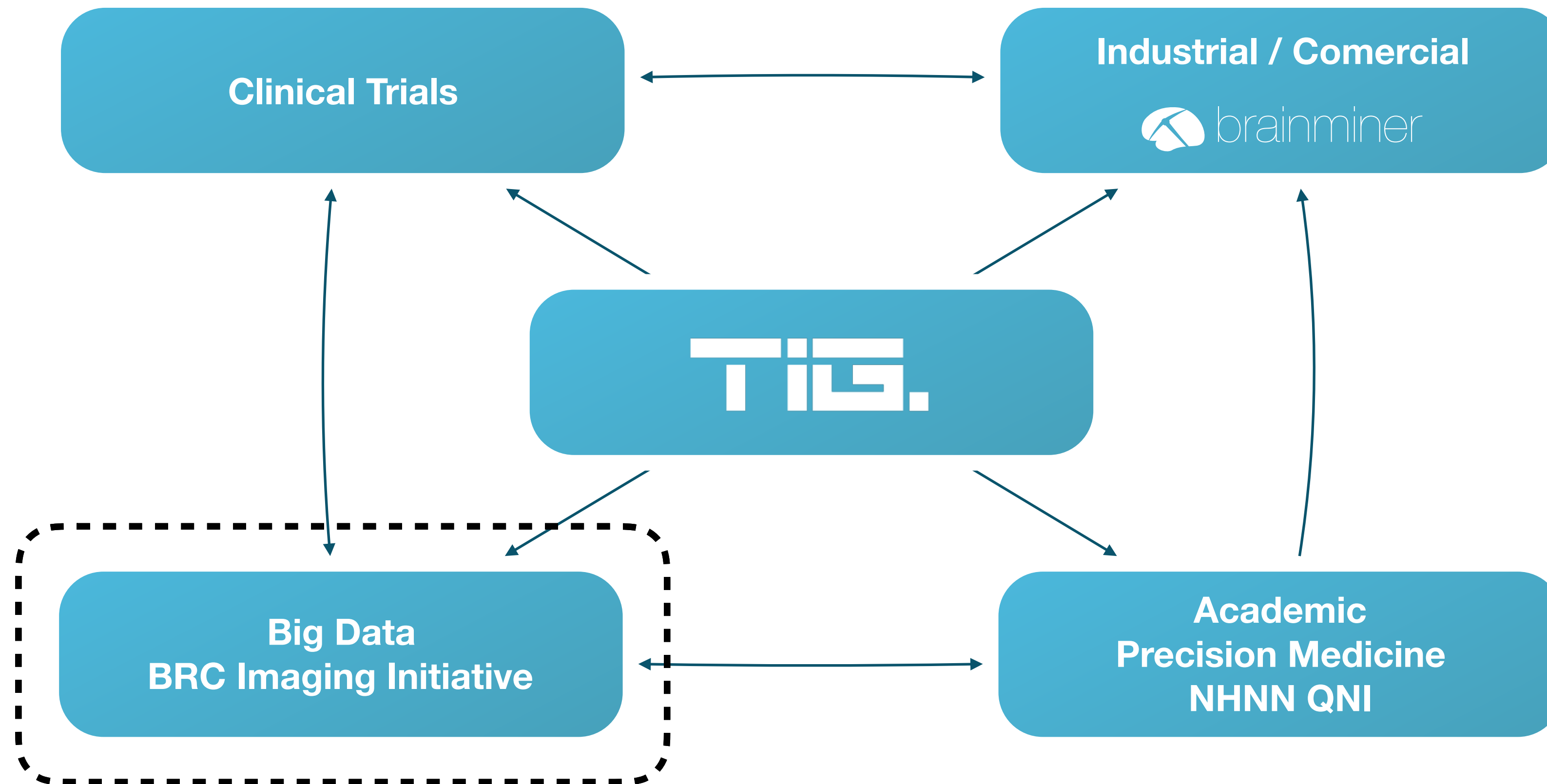


Population Distribution

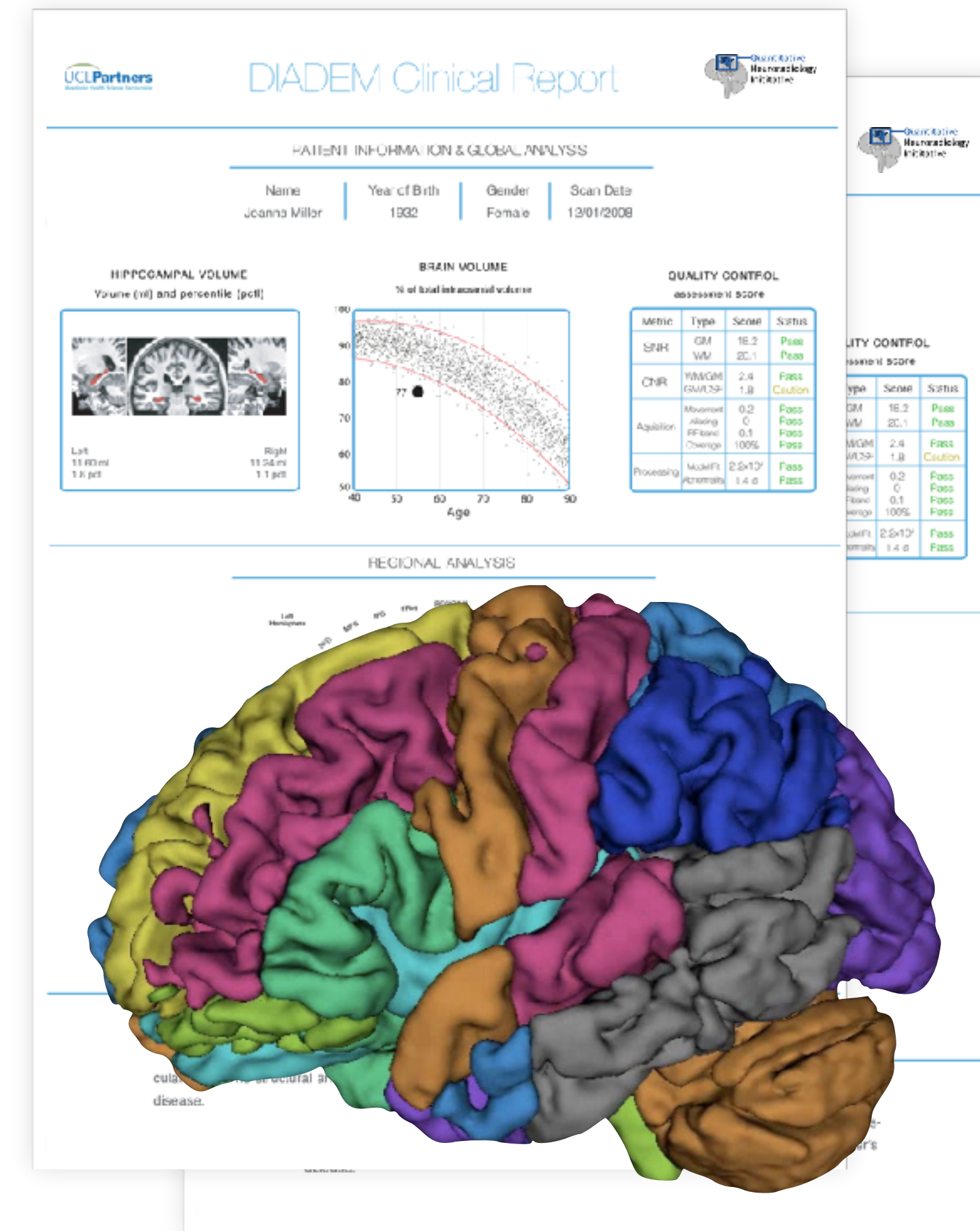


- Gaussian process (GP) - Probabilistic classification/predictions
- Variational/Denoising Auto-encoders for abnormality detection





- Patient-specific phenotyping tools for clinical data
- The Data
 - Can be low resolution (slice thick. 3/5/7mm)
 - Artefacts
 - Inconsistent scanning parameters
 - 1400 different “sequences”
 - Inconsistent availability of modalities
- Homogenising data acquisition across sites
 - Quality Control/Assurance, data identification
- Extracted metadata is integrated into a clinical report
- Collaboration with ION & NHNN





1 - Image Acquisition



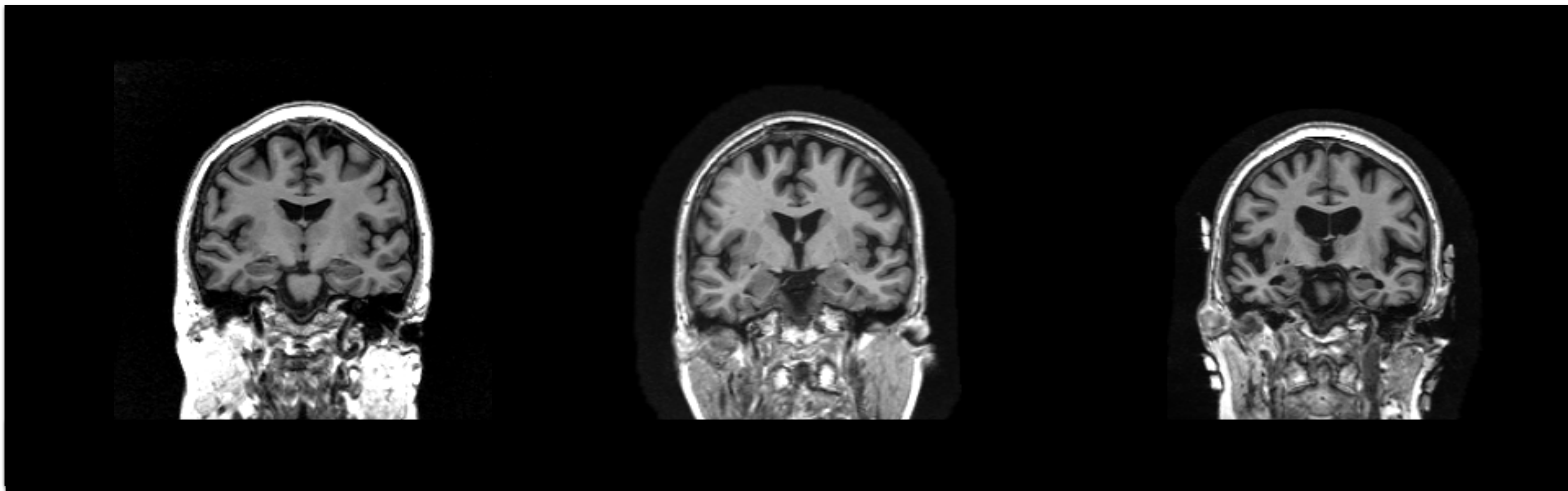
2 - Automated quality control & biomarker estimation



3 - Automated clinical report & comparison to healthy population



4 - Quantitative neuroimaging & improved patient care



Healthy

Early Alzheimer's Disease

Alzheimer's Disease 16



1 - Image Acquisition



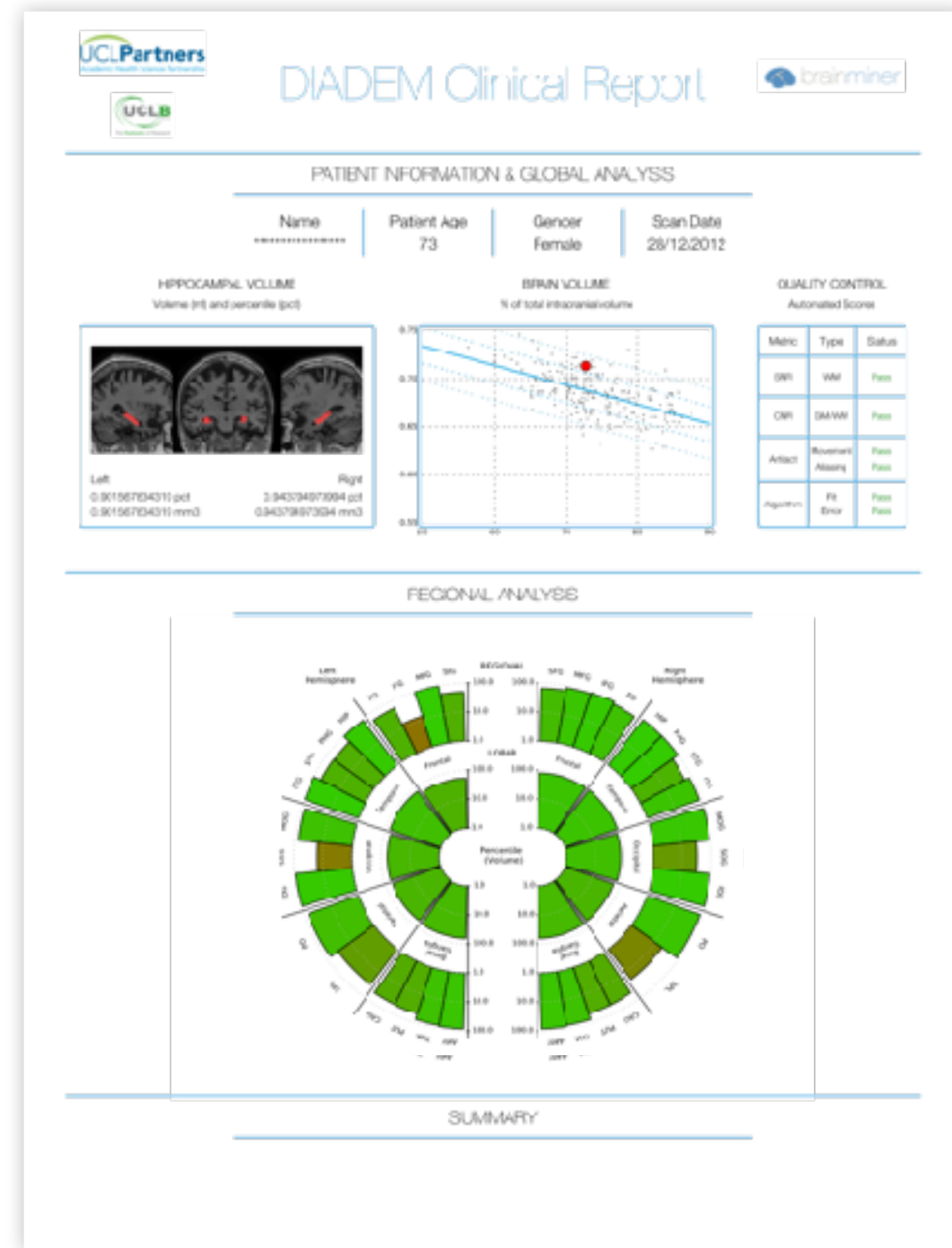
2 - Automated quality control & biomarker estimation



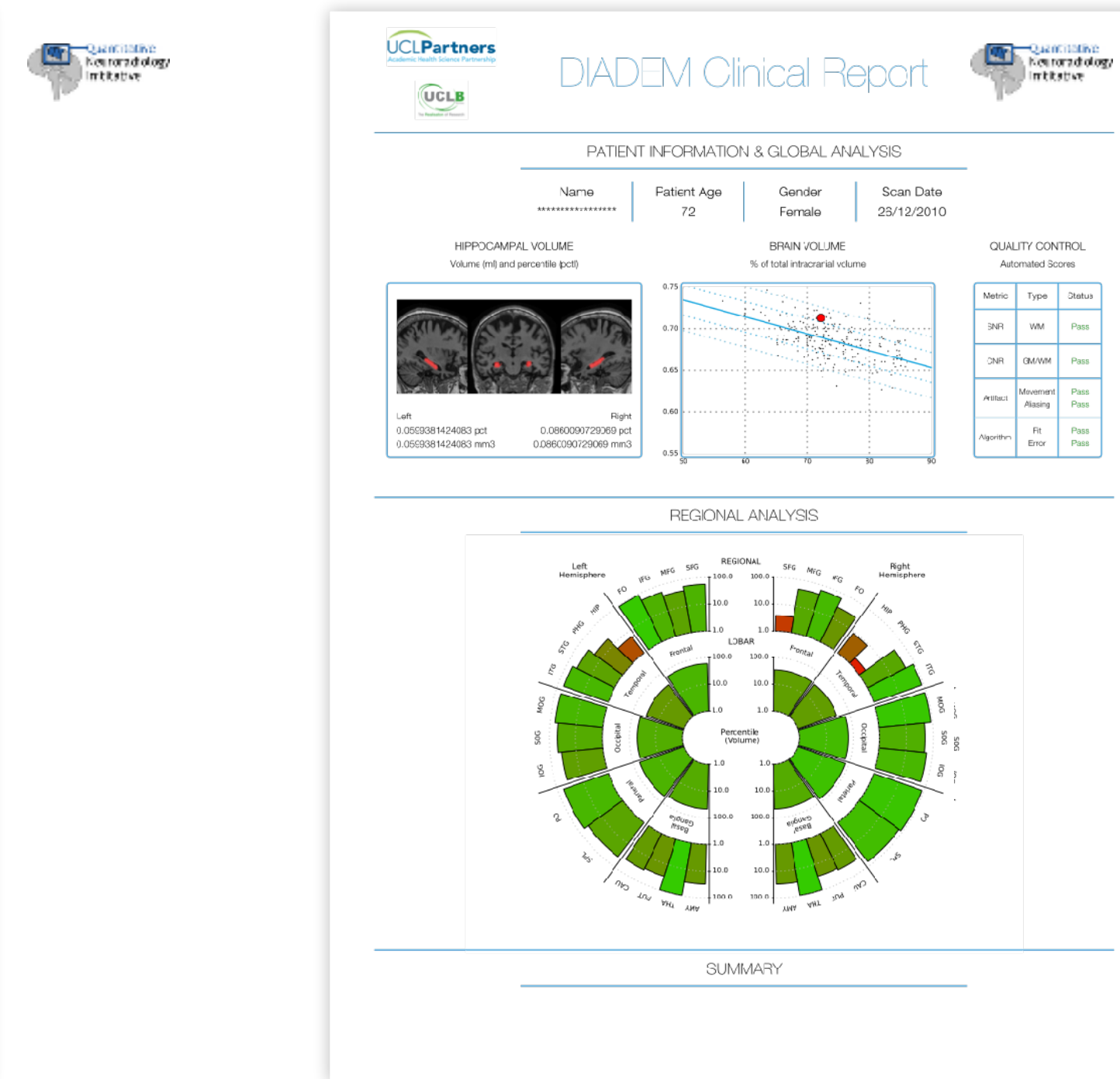
3 - Automated clinical report & comparison to healthy population



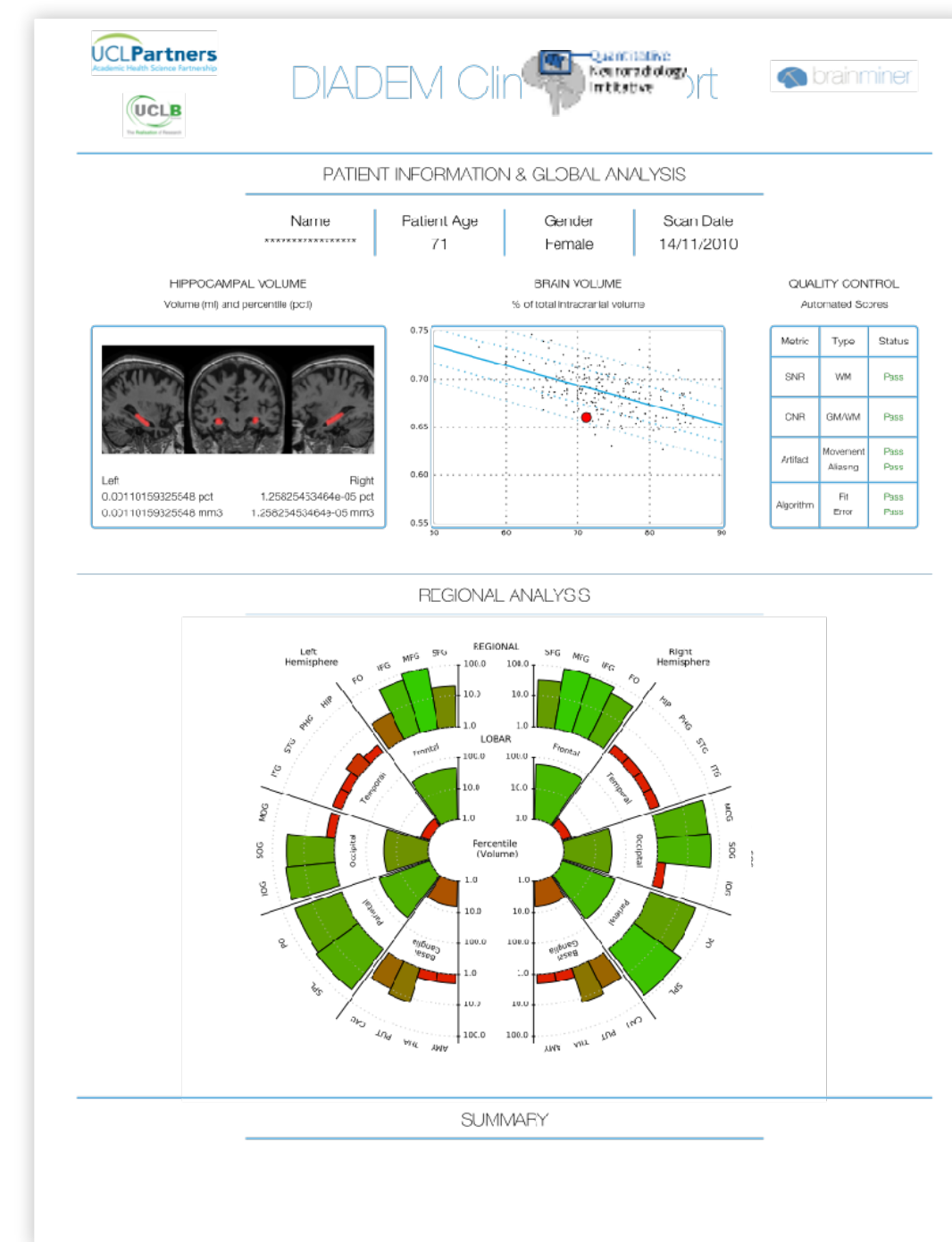
4 - Quantitative neuro-radiology & improved patient care



Healthy



Early Alzheimer's Disease



Alzheimer's Disease 17



1 - Image Acquisition



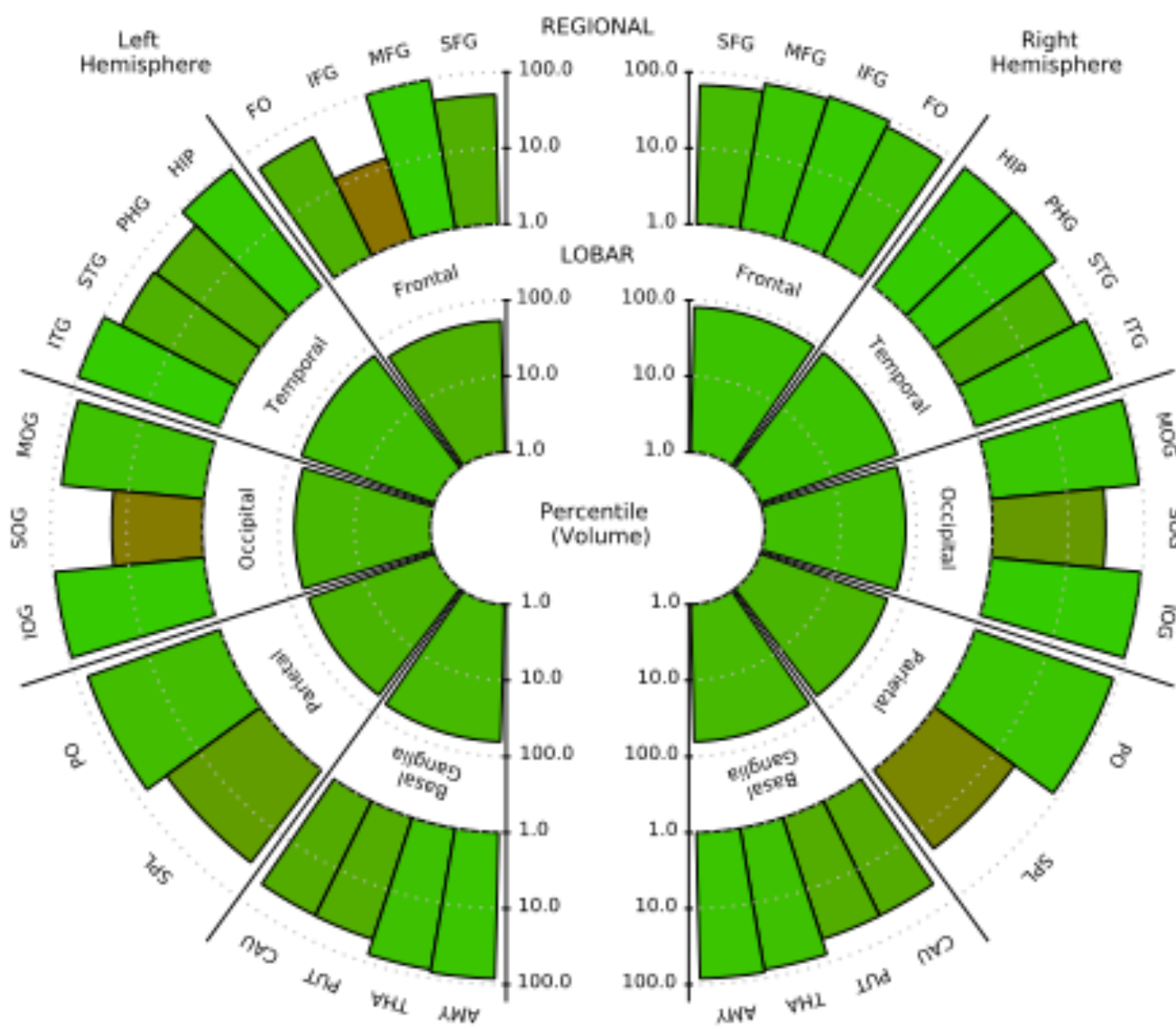
2 - Automated quality control & biomarker estimation



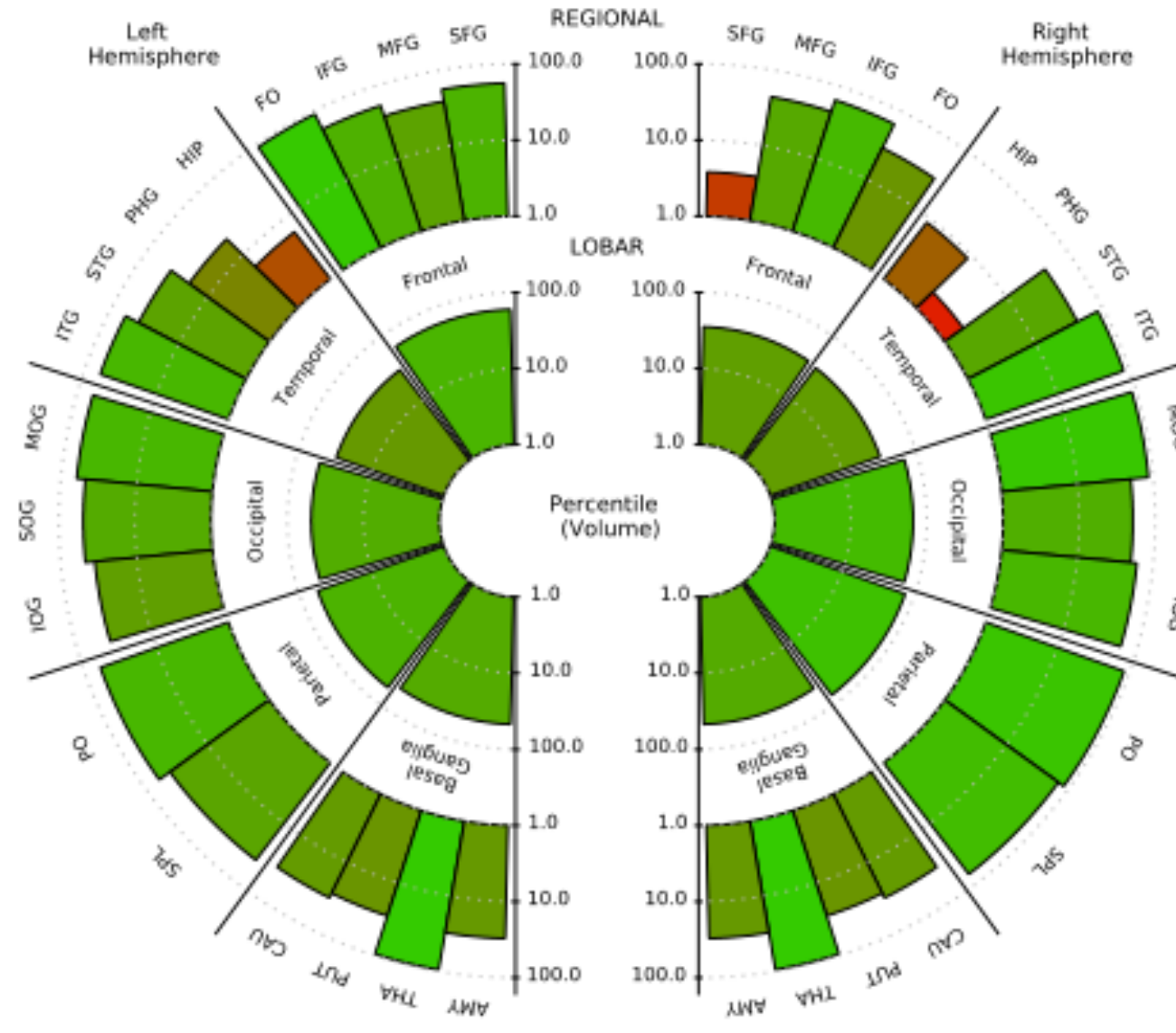
3 - Automated clinical report & comparison to healthy population



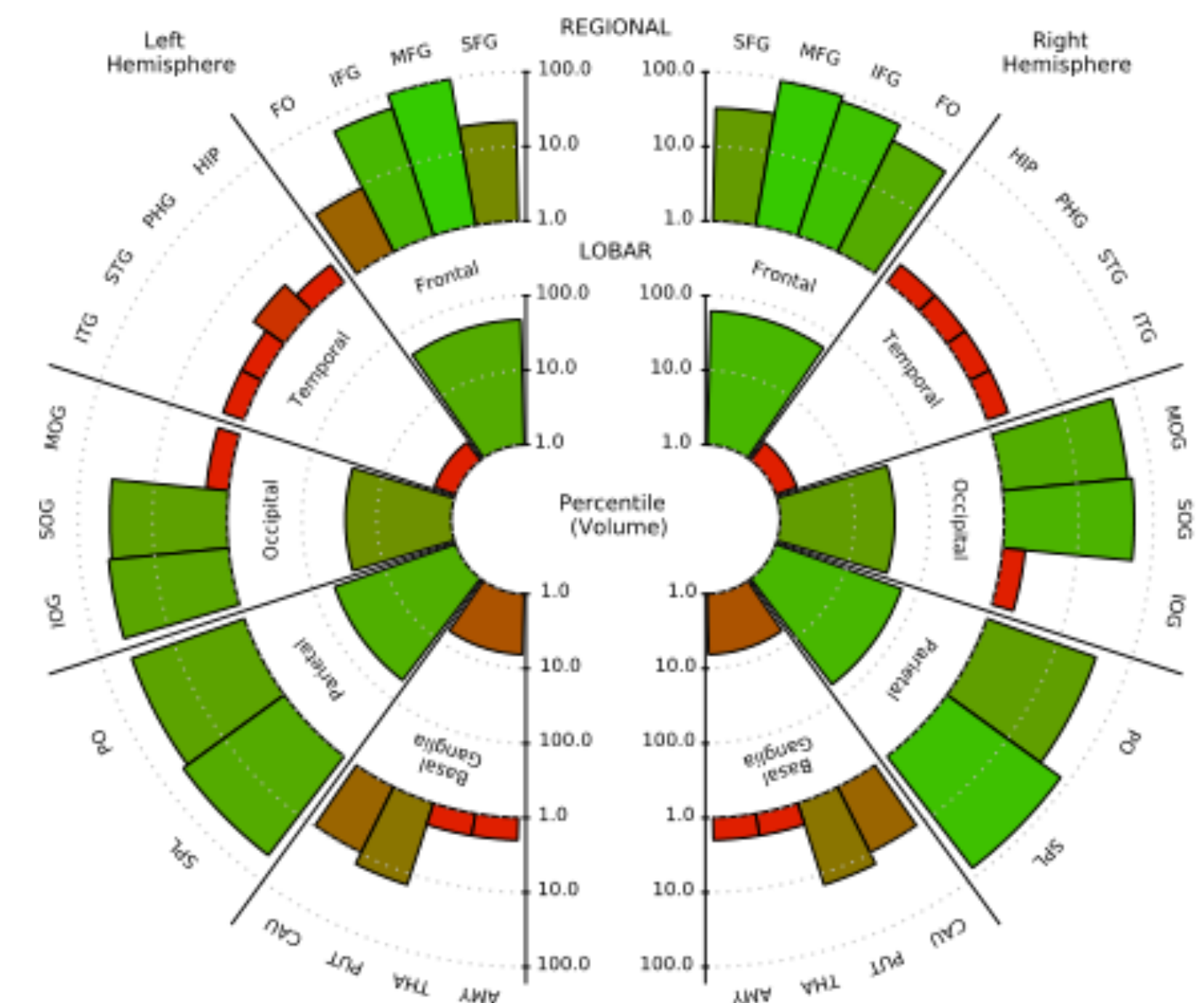
4 - Quantitative neuroimaging & improved patient care



Healthy



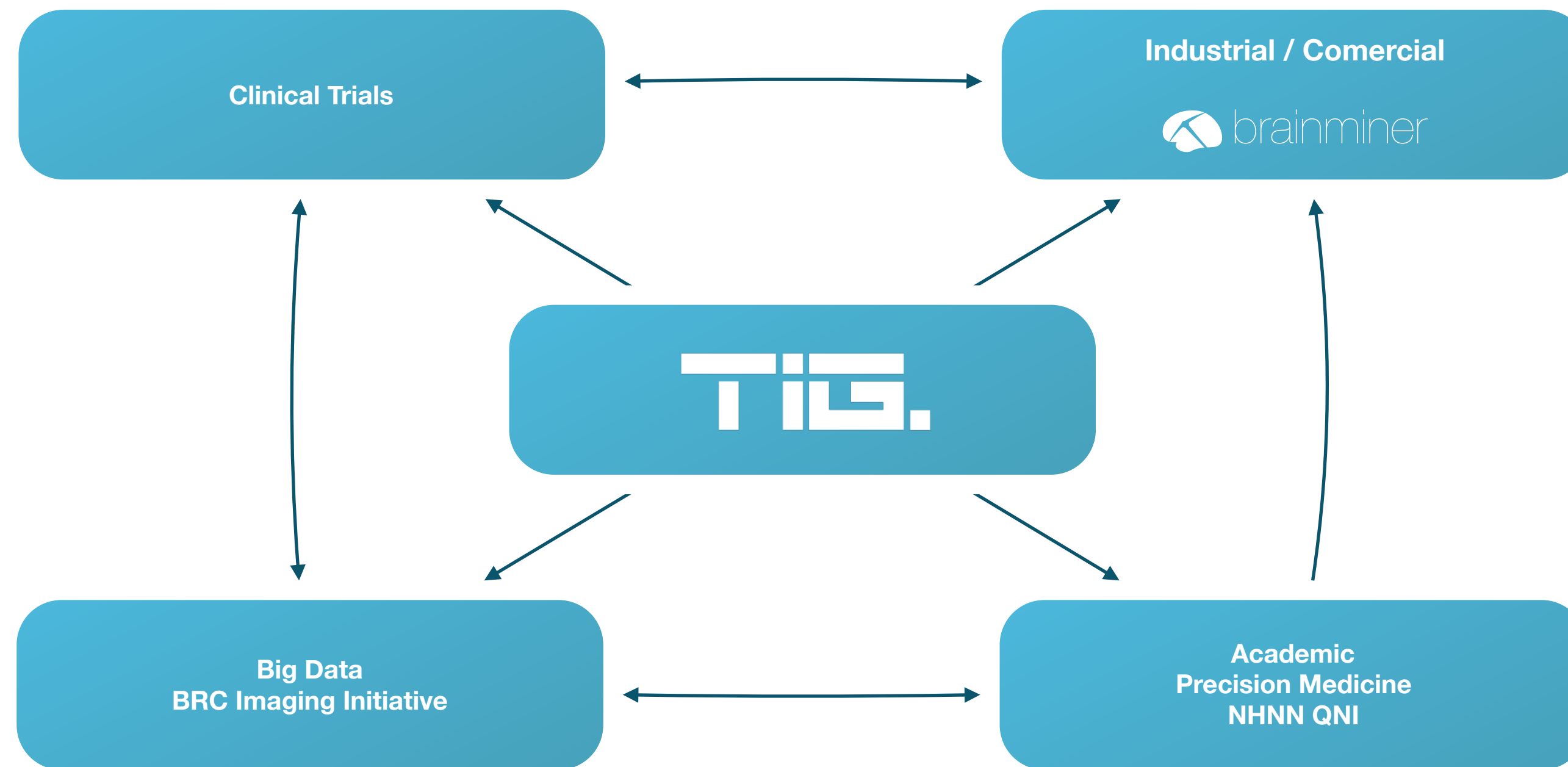
Early Alzheimer's Disease



Alzheimer's Disease 18

- Translation to Clinics: Neuroradiological workflow
 - Deploy results into reporting platform
 - Disease specific biomarkers
 - Available at reporting time (HPC)
 - Push to patient health care record
 - Available to referring physician
 - Retrievable for longitudinal analysis
- Translation to industry: BrainMiner
 - UCL spinoff
 - Translate TIG/QNI beyond UCL
 - SBRI award £1.1M
 - Build CE marked/FDA approved software





Questions?