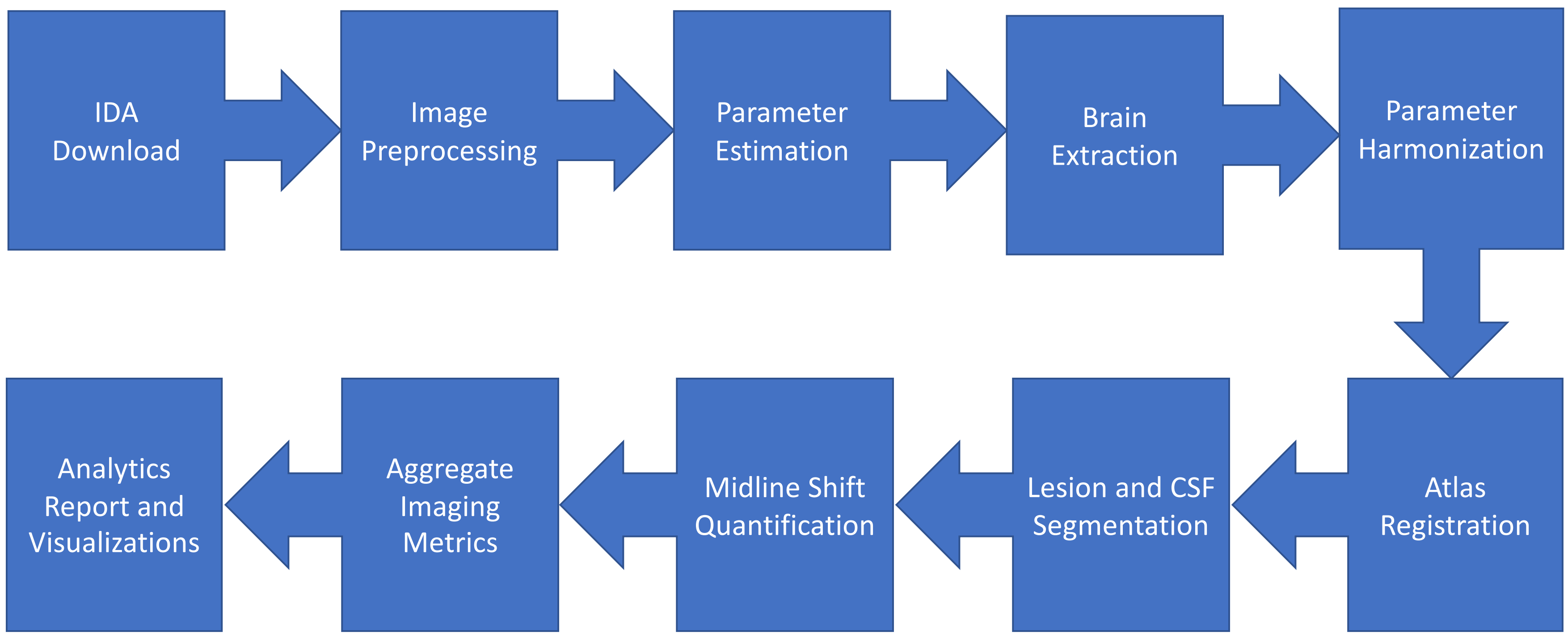
SPAN Image Analytics Stage One Update

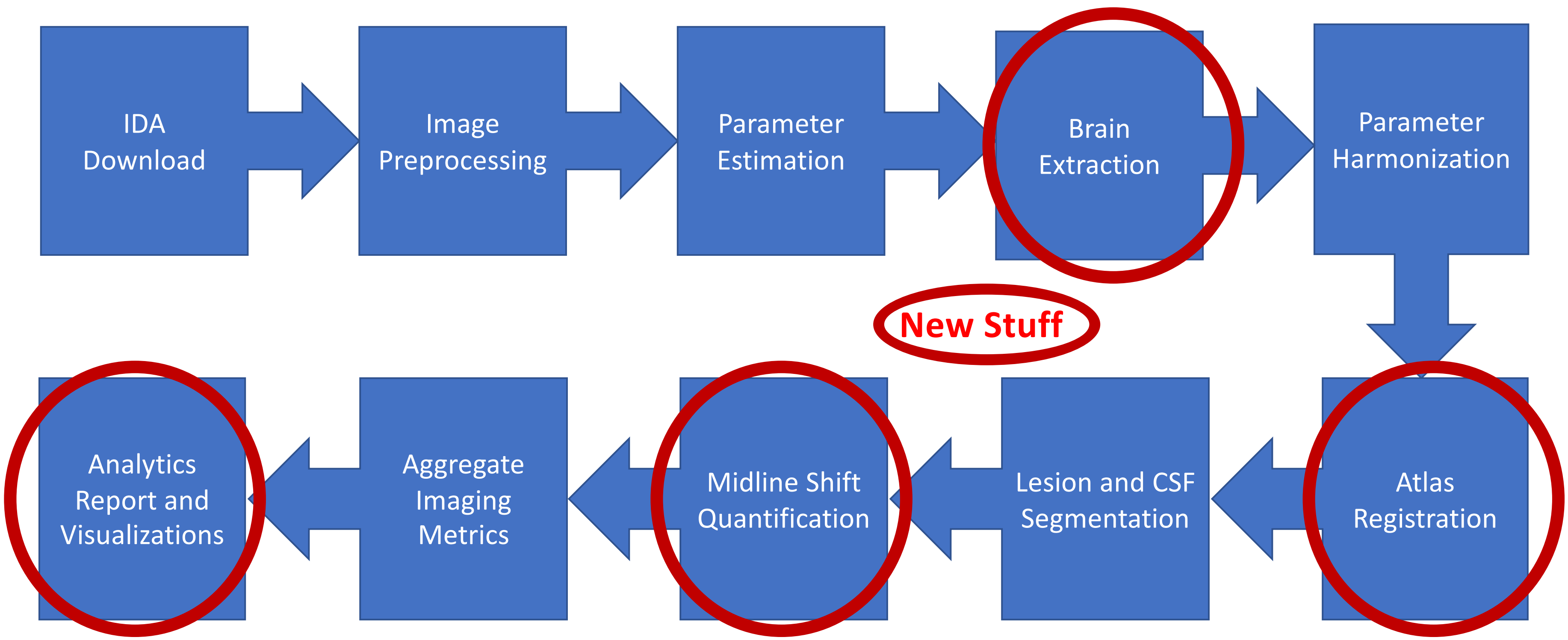
Ryan P. Cabeen

March 31, 2021

Analytics Pipeline Overview



Analytics Pipeline Overview



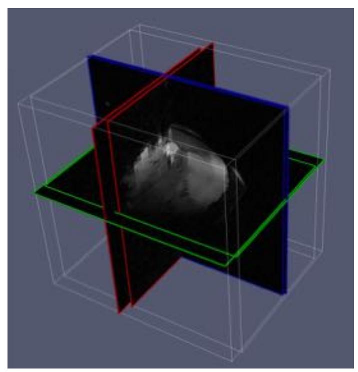
Preprocessing Step: Data Wrangling

File Format Conversion DICOM to NIfTI → Extract Meta-data (site & scan parameters) → Harmonize 3D Image orientation and resolution → Collect, Sort and Harmonize Scans → …

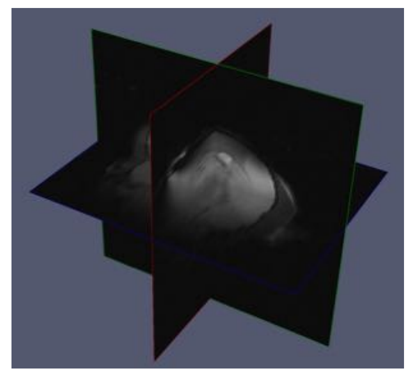
```
ADC_map/0001.dcm
ADC_map/0002.dcm
[...]
T2star_map_10ms/0001.dcm
T2star_map_10ms/0002.dcm
[...]
T2_map_65ms/0001.dcm
T2_map_65ms/0002.dcm
[...]
RARE_anatomy/0001.dcm
RARE_anatomy/0002.dcm
[...]
```

(note: DICOM names shortened for clarity)

```
ADC_map_851969.json
ADC_map_851969.nii.gz
RARE_anatomy_589825.json
RARE_anatomy_589825.nii.gz
T2_map_15ms_655361.json
T2_map_15ms_655361.nii.gz
[...]
T2star_map_5ms_1048577.json
T2star_map_5ms_1048577.nii.gz
[...]
```



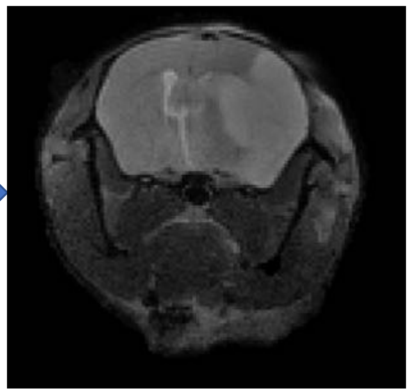
(some sites use a different FOV within a single session)



(we harmonize the data to remove these differences)

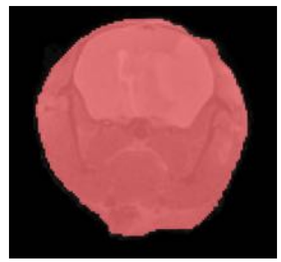
```
adc.nii.gz
adc.txt
rare.nii.gz
t2.nii.gz
t2.txt
t2star.nii.gz
t2star.txt
```

Preprocessing Step: Quality Assessment

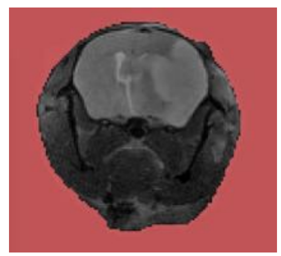


Input Scan
(repeat for ADC, T2, T2-star)

Foreground



Background



Signal Mean (μ) and Std. Deviation (σ) of
Foreground (FG) and Background (BG)

Metrics

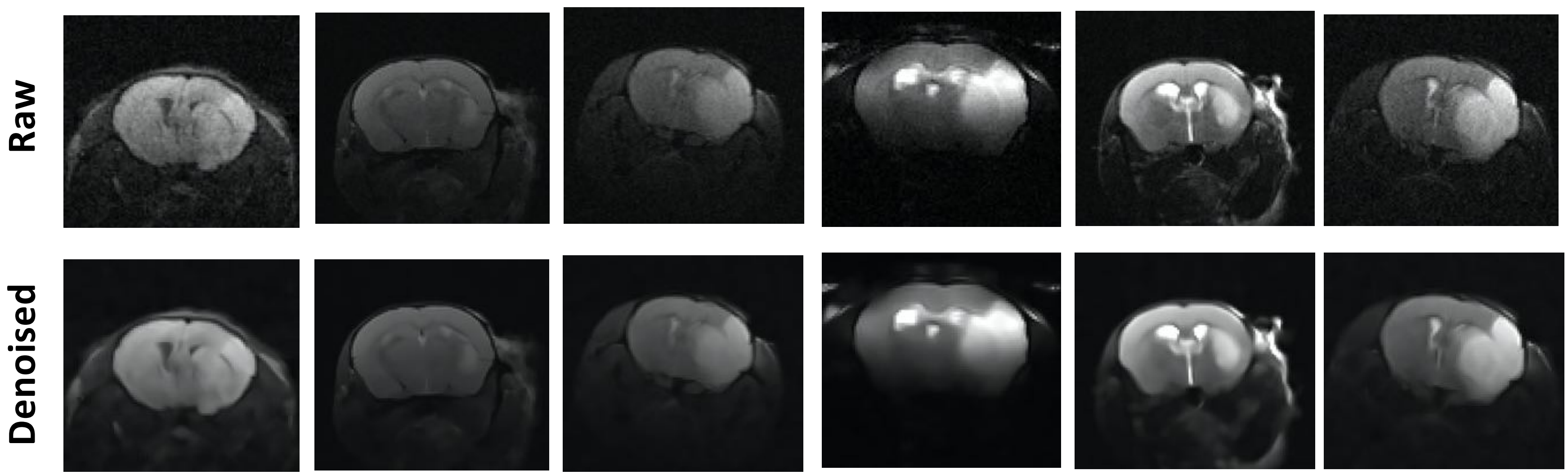
name	value
fg_mean	3.8290756070771788
fg_std	3.6273226197529964
bg_mean	0.38494717974999465
bg_std	0.25308983839709687
snr	9.9470156128017
cnr	9.422909974580861
svnvr	205.41064734152235

$SNR = \mu_{FG} / \mu_{BG}$

$CNR = \sigma_{FG} / \mu_{BG}$

$SVNVR = \sigma_{FG} / \sigma_{BG}$

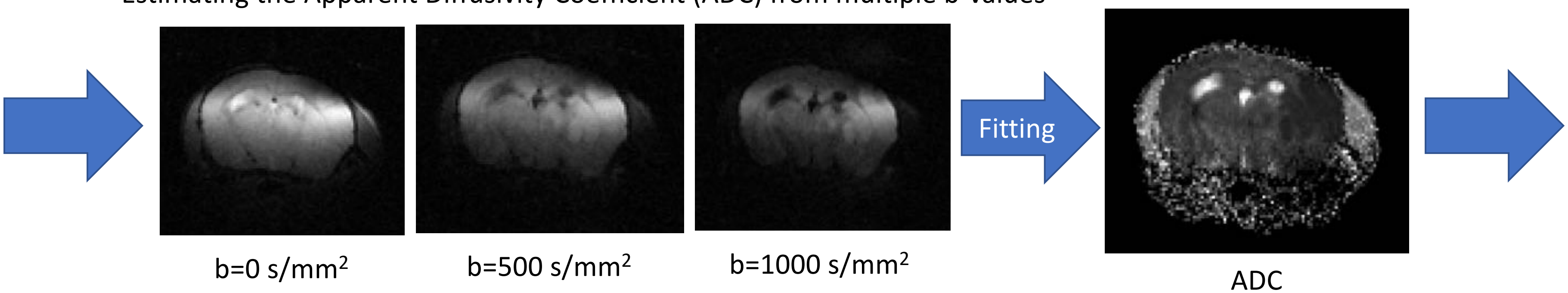
Preprocessing Step: Denoising



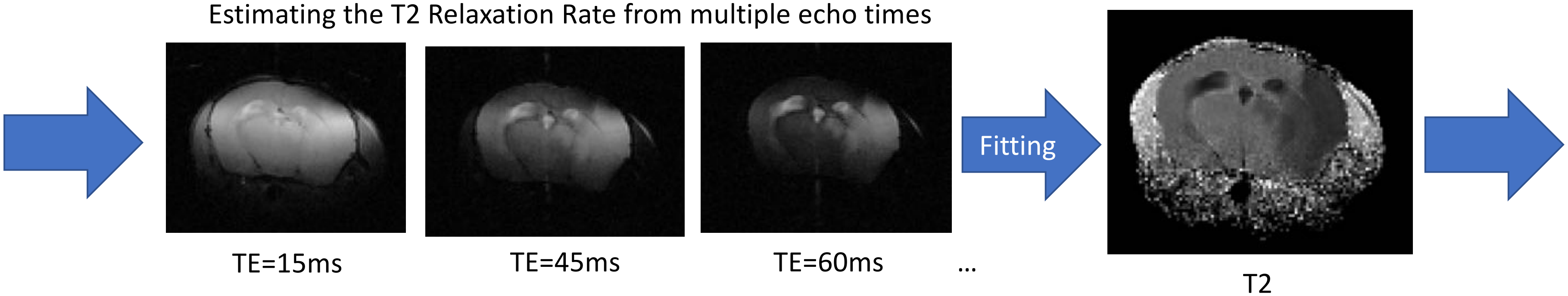
Approach: Non-local means denoising with local noise estimation, applied to each component scan

Parameter Estimation

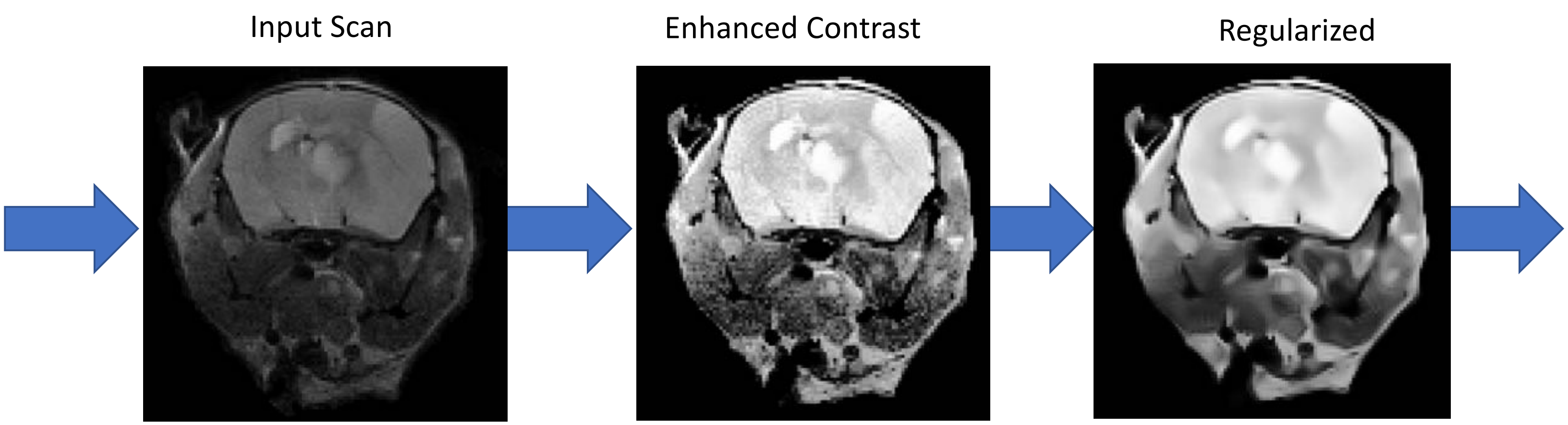
Estimating the Apparent Diffusivity Coefficient (ADC) from multiple b-values

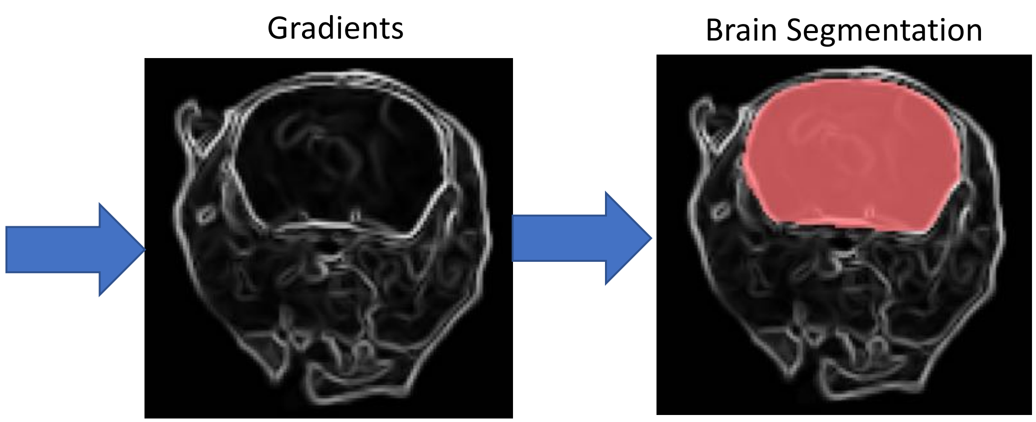


Estimating the T2 Relaxation Rate from multiple echo times



Brain Extraction with a Traditional Approach





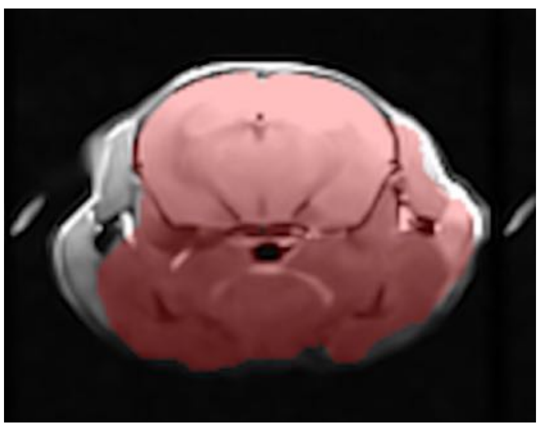
Approach:

Use traditional brain extraction pipeline:

- Contrast enhancement
- Edge-preserving smoothing
- Gradient magnitude
- Component segmentation

Robust Brain Extraction with Deep Learning

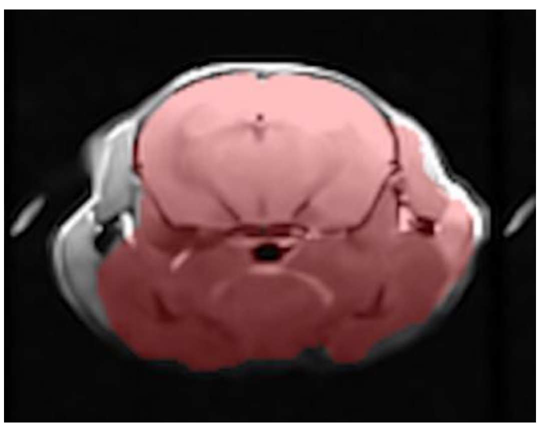
Problem:
Our first brain extraction algorithm works well, but with a 5% error rate, due to blurring at skull-brain boundary causing “leaking”, irrespective of site/time

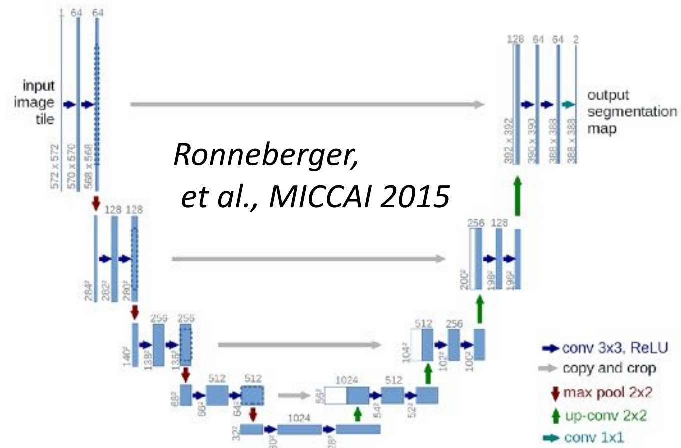


Robust Brain Extraction with Deep Learning

Problem:

Our first brain extraction algorithm works well, but with a 5% error rate, due to blurring at skull-brain boundary causing “leaking”, irrespective of site/time





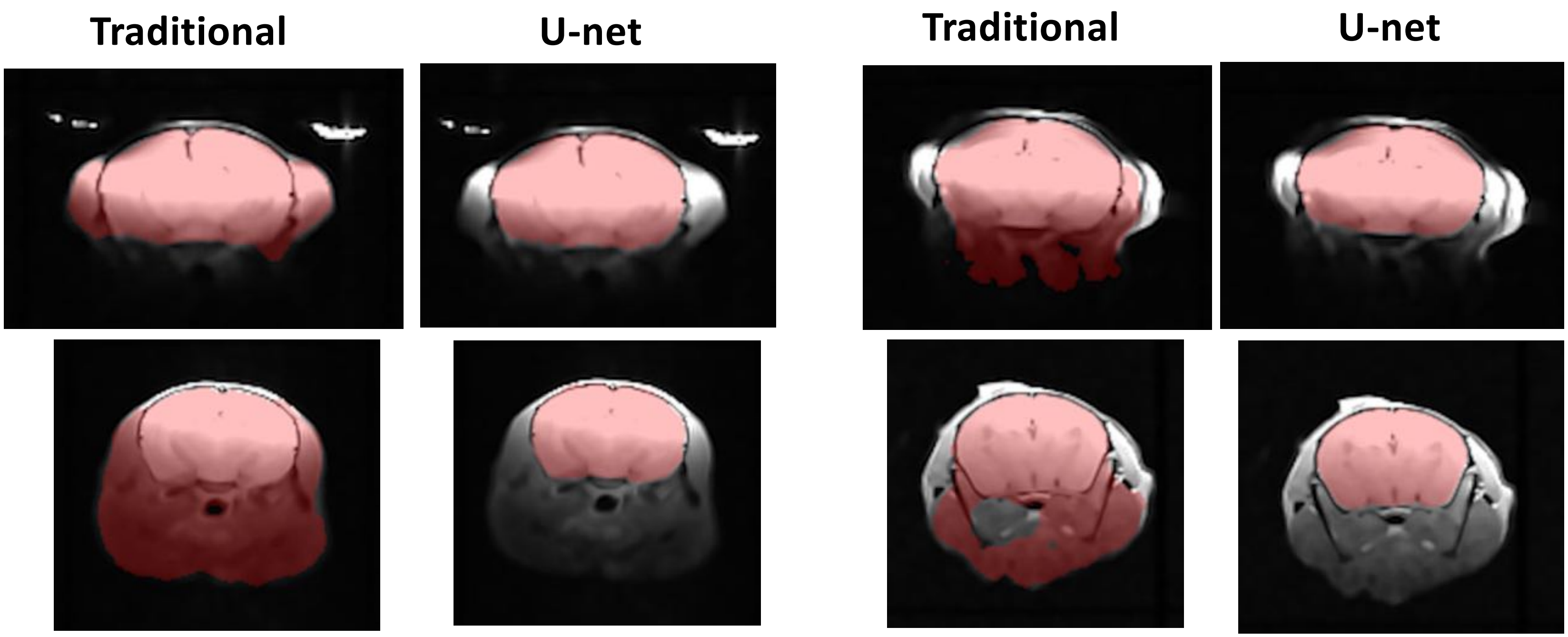
Ronneberger, et al., MICCAI 2015

Solution:

Use a U-net deep learning algorithm:

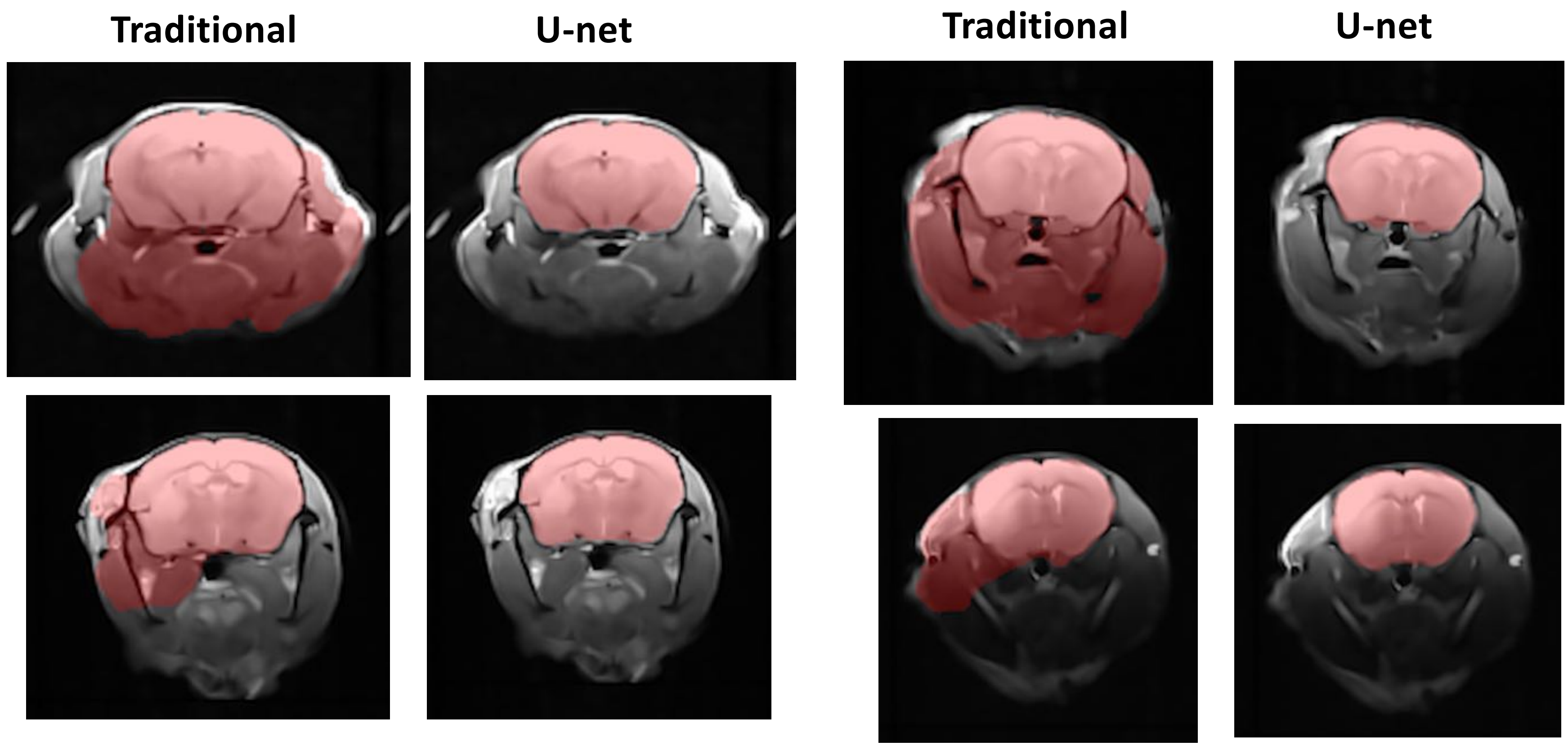
- select the 300 best example results
- balanced by site and timepoint,
- use them to train, validate, and test
- collect and test failure cases

Robust Brain Extraction with Deep Learning



<u>Results:</u> Neural network approach accurately reproduces previous approach with 96% accuracy and **fixes all failed cases**

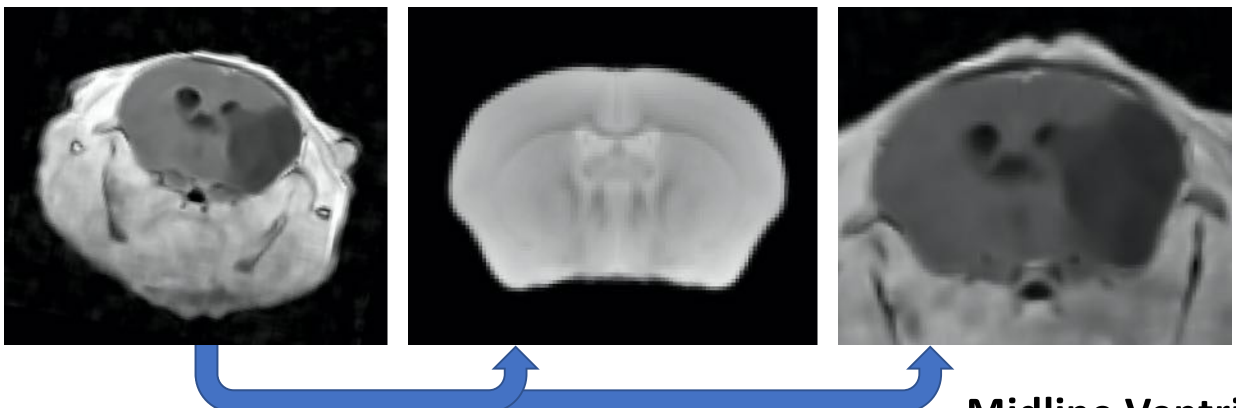
Robust Brain Extraction with Deep Learning

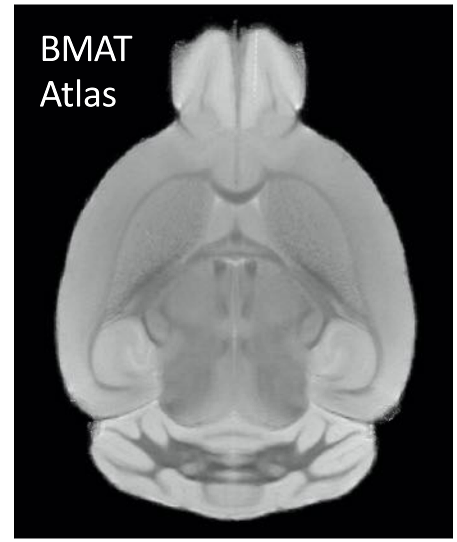


MacKenzie-Graham, et al. (2007). Epilepsia

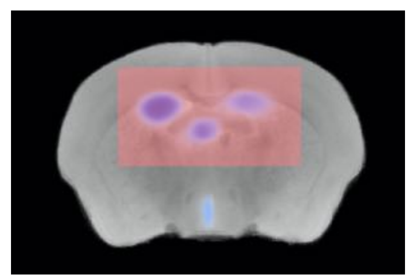
Atlas registration

Native Space **Atlas** **Normalized**

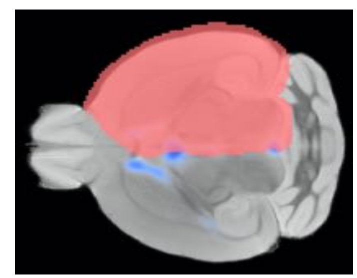




Midline Ventricle Limit

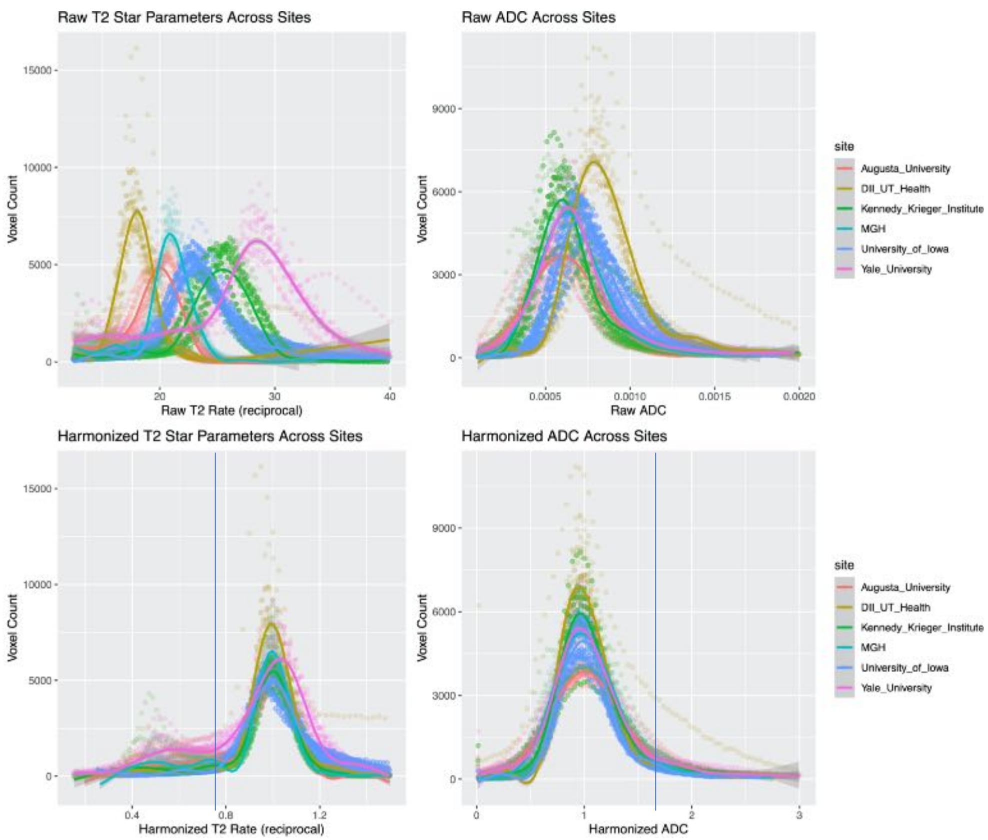


Lesion Limit



Approach: Perform rigid registration to the atlas to preserve morphometry, standardize head pose, and provide limits on lesion and ventricle (shown on right)

Parameter Harmonization Across Sites

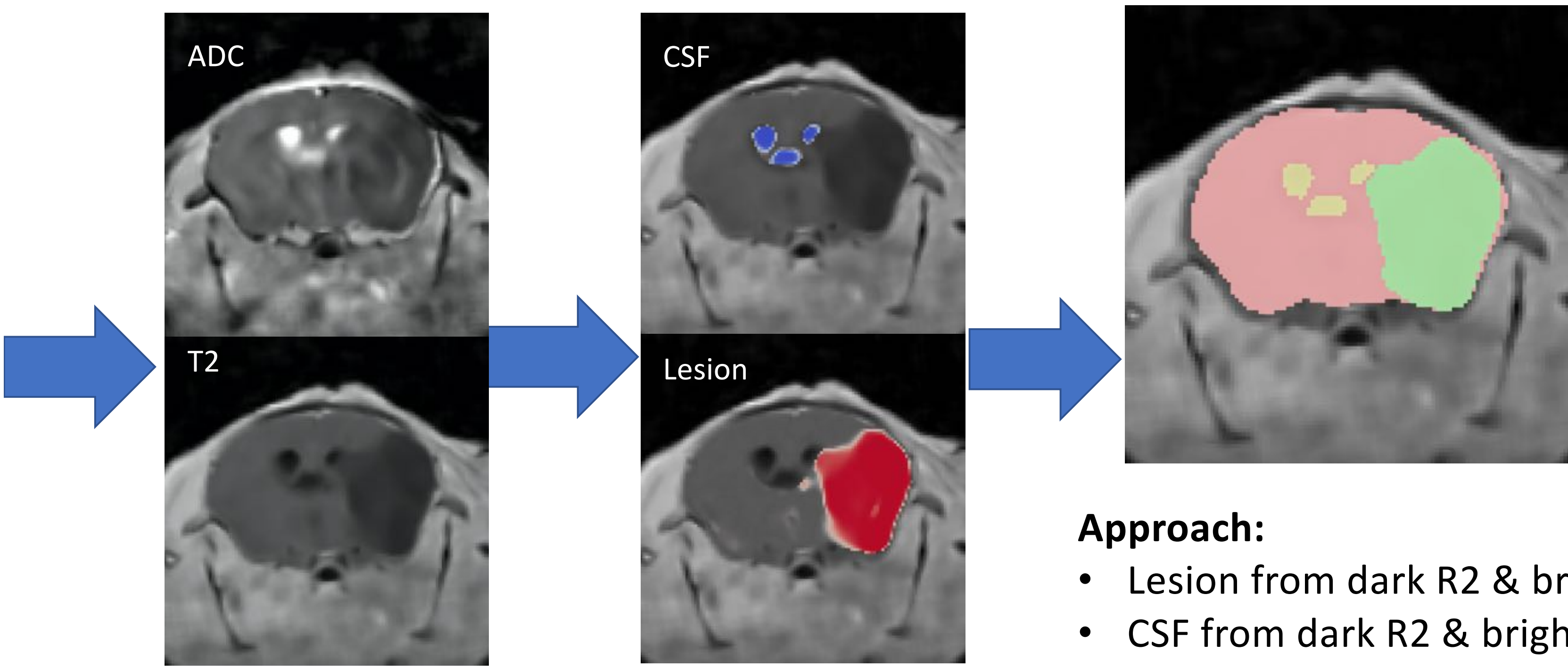


Challenge: There are some systematic inter-site differences in parameter maps

Approach: Use a statistical harmonization procedure to uniformly scale the image to standardize normal appearing tissue

Results: We can use common thresholds for lesion (T2 < 0.775) and CSF (ADC > 1.65)

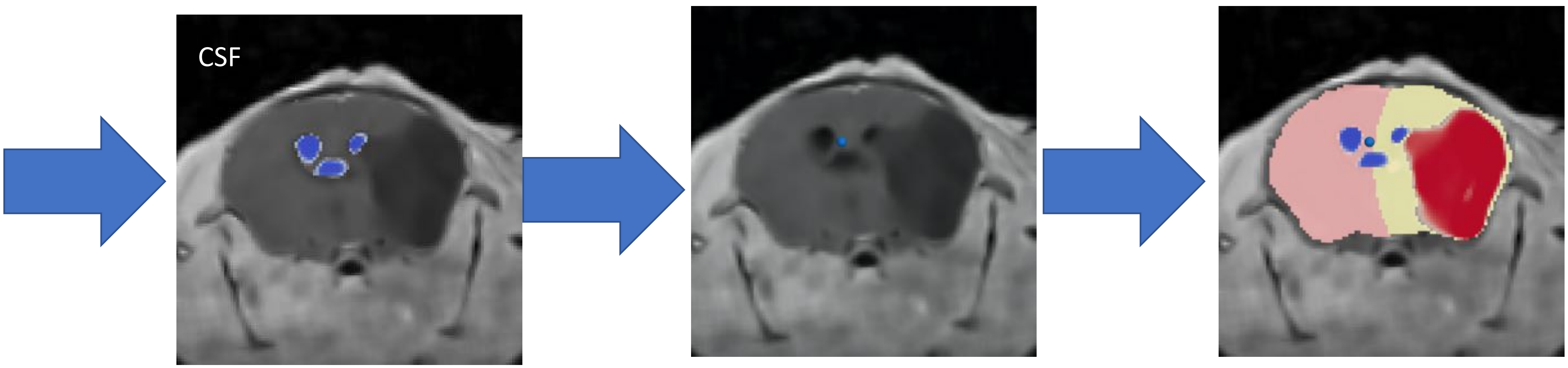
Lesion and CSF Segmentation



Approach:

- Lesion from dark R2 & bright ADC
- CSF from dark R2 & bright ADC
- Regularization to label voxels
- Rest is normal appearing tissue

Midline shift quantification

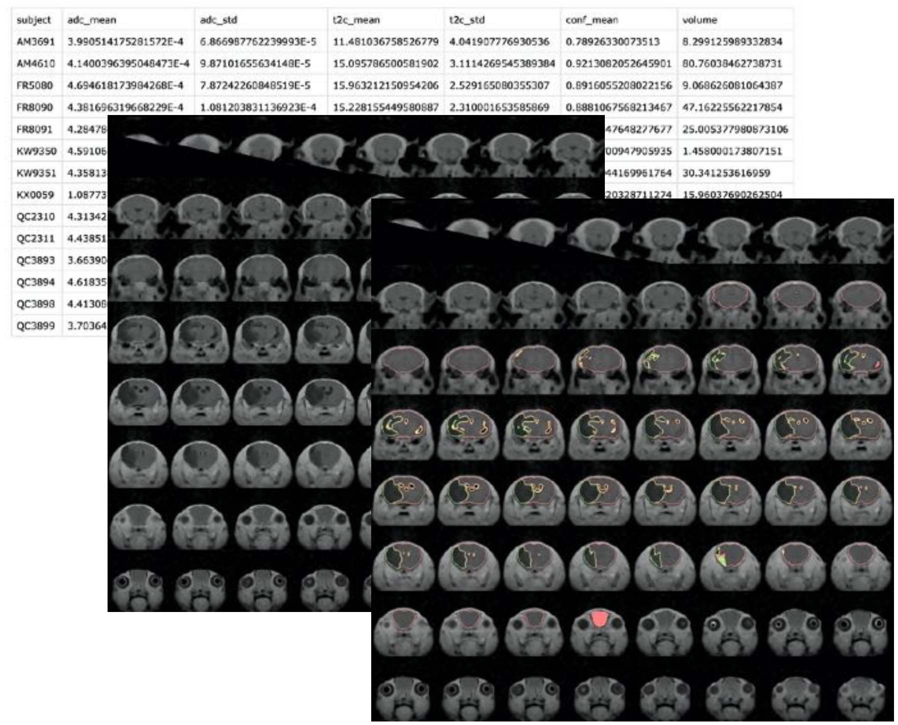


Approach:
- Select a thin coronal section of ventricles based on atlas
- Compute centroid and extremal left-right points of brain
- Measure absolute and relative measures of brain shift
- Segment left and right hemisphere atrophy (assuming a parabolic surface)

Analytics and Report Generation

Summary metrics:
- Image quality
- Lesion, CSF, and tissue* volume
- Total brain volume (sum of above)
- Mid-line shift indexes
- Per-hemisphere tissue* volumes
- Others are possible…

Visualizations:
- Mosaic plots of images
- Overlays of segmentations
- 3D models



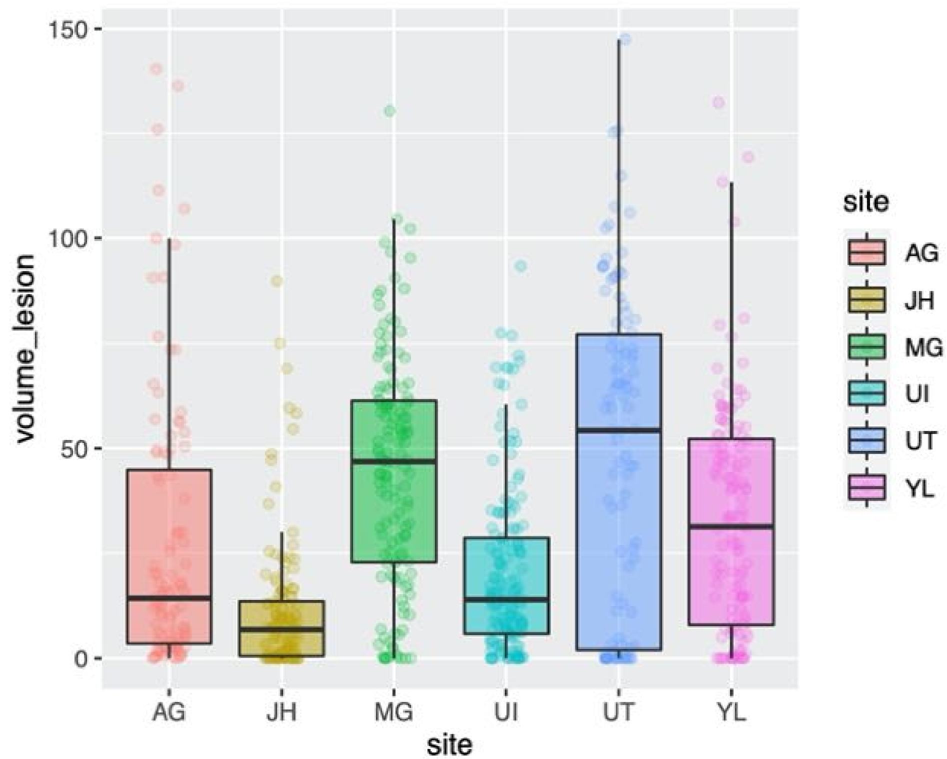
*by "tissue" we mean non-infarcted tissue that is normal-appearing

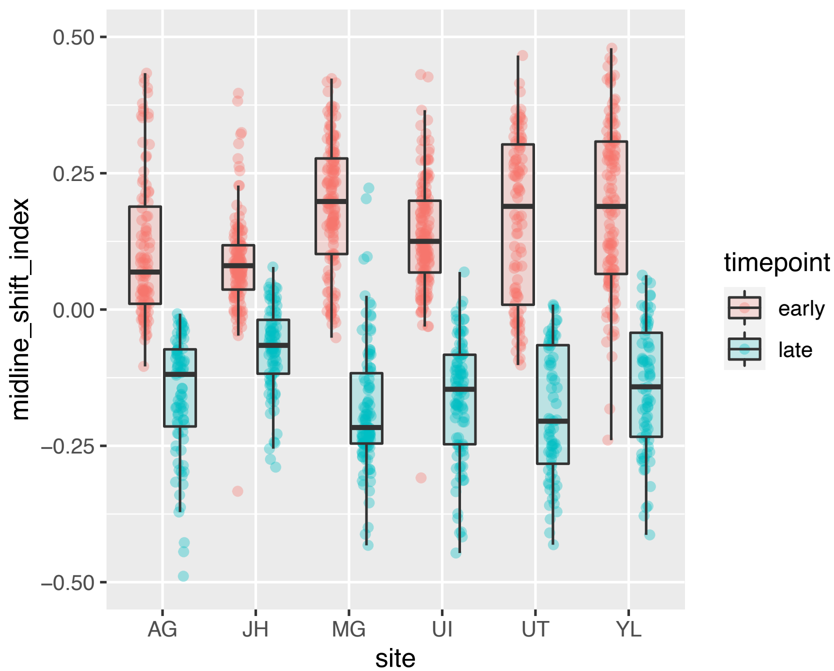
Summarizing the entire dataset

- 1309 scans uploaded to IDA
- 779 early timepoint, 530 late

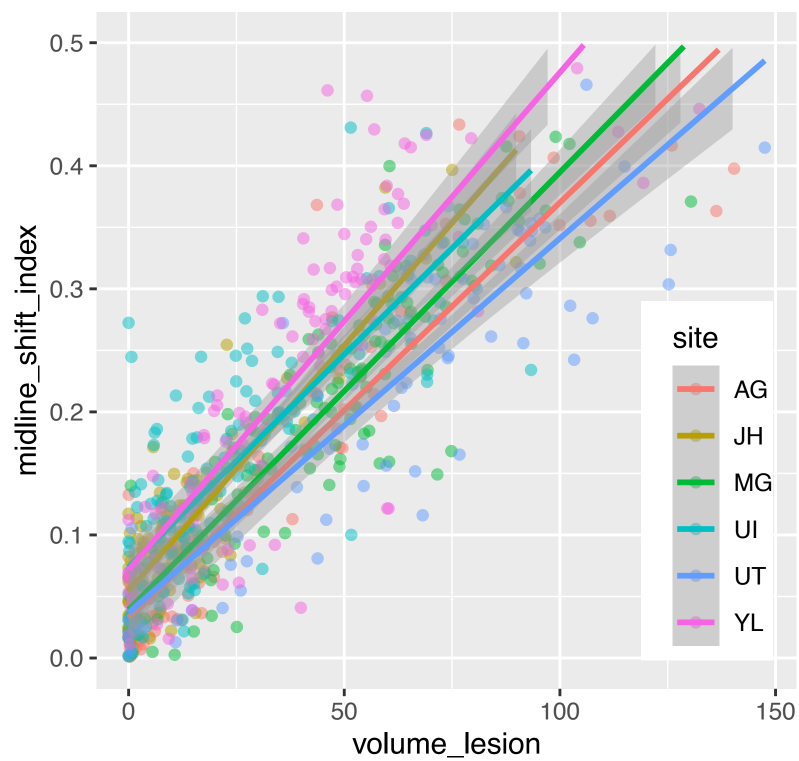
- 13 failed due to incomplete data
- 25 failed due to motion

site	variable	num	mean	sd	min	max	cv
AG	volume_lesion	104	27.45	33.14	0.00	140.39	1.21
JH	volume_lesion	137	10.86	15.66	0.00	89.85	1.44
MG	volume_lesion	138	44.21	27.68	0.00	130.40	0.63
UI	volume_lesion	162	20.05	20.15	0.00	93.31	1.00
UT	volume_lesion	103	47.58	39.10	0.00	147.51	0.82
YL	volume_lesion	128	32.92	27.34	0.00	132.32	0.83





site	timepoint	variable	num	mean	sd	min	max	cv
AG	early	midline_shift_index	104	0.11	0.13	-0.10	0.43	1.21
AG	late	midline_shift_index	84	-0.16	0.11	-0.49	-0.01	-0.71
JH	early	midline_shift_index	137	0.09	0.09	-0.33	0.40	1.01
JH	late	midline_shift_index	89	-0.07	0.08	-0.29	0.08	-1.07
MG	early	midline_shift_index	138	0.19	0.12	-0.05	0.42	0.61
MG	late	midline_shift_index	106	-0.18	0.11	-0.43	0.22	-0.63
UI	early	midline_shift_index	162	0.14	0.11	-0.31	0.68	0.80
UI	late	midline_shift_index	97	-0.16	0.11	-0.45	0.07	-0.67
UT	early	midline_shift_index	103	0.17	0.16	-0.10	0.50	0.94
UT	late	midline_shift_index	73	-0.19	0.12	-0.43	0.01	-0.65
YL	early	midline_shift_index	128	0.19	0.15	-0.24	0.48	0.80
YL	late	midline_shift_index	75	-0.14	0.12	-0.41	0.06	-0.82



timepoint	variable	num	mean	sd	min	max	cv
early	midline_shift_index	772	0.15	0.13	-0.33	0.68	0.89
late	midline_shift_index	524	-0.15	0.11	-0.49	0.22	-0.76