The Relationship between White Matter Structural Integrity and Language Performance in Individuals with Aphasia

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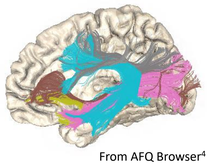
Introduction

White Matter Structural Integrity

- White matter (WM) may be damaged as a result of stroke lesions in individuals with post-stroke aphasia (i.e., language disorder)[1]
- WM structural integrity may be a useful predictor of language performance in individuals with aphasia[1 2]

Automated Fiber Quantification (AFQ)[3]

- Method for tractography and quantification of WM structural integrity along WM tracts binned into 100 nodes using diffusion tensor imaging (DTI) data, including bilateral:
  - Arcuate fasciculus (AF)
  - Inferior fronto-occipital fasciculus (IFOF)
  - Inferior longitudinal fasciculus (ILF)
  - Superior longitudinal fasciculus (SLF)
  - Uncinate fasciculus (UF) and
  - Corpus callosum (forceps major & minor)



From AFQ Browser[4]

- Fractional anisotropy (FA) values range from 0 [diffuse] to 1 [coherent]

Research Questions

In individuals with post-stroke aphasia:

1. For average WM integrity values (FA) in 10 tracts, are there inter-hemispheric differences between left-hemisphere tracts and right-hemisphere homologues?
2. For average WM integrity values (FA) across 12 tracts of interest, which tracts are associated with aphasia severity?
3. For pointwise WM integrity values (FA) in 12 tracts of interest, are there specific tract nodes associated with aphasia severity?

Methods

Participants (N=34 individuals with post-stroke aphasia)

Age (years) mean (sd)	Months Post Onset mean (sd)	Sex	WAB-R AQ mean (sd)
62 (11)	62 (86)	24 m, 10 f	62.7 (24.8)

Behavioral Assessment

Western Aphasia Battery – Revised (WAB-R)[5] to assess aphasia severity via Aphasia Quotient (AQ) (scores range from 0 [severe] to 100 [no aphasia])

Image Acquisition and Processing

MR imaging on Siemens 3T TIM Trio using 20 channel head+neck coil at Athinoula A. Martinos Center in Charlestown, MA

T1-weighted sagittal imaging (TR/TE = 2300/2.91ms, T1 = 900ms, flip angle = 90°, FOV = 256x256mm, slice thickness = 1mm^3, 176 sagittal slices)

High resolution whole-brain DTI (multiband of 3 sequence, TR/TE = 900/92ms, T1 = 900ms, flip angle = 90°, FOV = 230x230mm, slice thickness = 1.98x1.98x2mm voxels, 70 interleaved slices with 60 gradient and 10 *b*0 volumes, *b* value = 1500 s/mm^2)

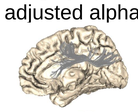
Raw diffusion data pre-processing[6]:
- denoising, eddy current correction, alignment of T1 to DWI, nonlinear distortion correction, rotating bvectors, diffusion tensor calculation

Post-processing with AFQ[3]:
- Deterministic tractography, fiber tract segmentation, refinement, and cleaning
- Question 1, 2a at default tractography parameters (min. tract length=50 mm; stopping criteria: FA<.2, angle>30º)
- Question 2b, 3 at lowered threshold in left hemisphere (min. tract length=20 mm; stopping criteria: FA<.1, angle>35º)
- Pointwise: FA at tract core in 100 nodes; Average: FA averaged across nodes

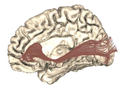
Results

1. Post-stroke inter-hemispheric differences

Wilcoxon signed-rank tests for left- vs. right-hemisphere average WM integrity[a] (FA) significantly lower in left hemisphere at Bonferroni-adjusted alpha-level of .01 (5 comparisons) for:



SLF Left FA: .395 (sd .077; N=20) vs. Right FA: .519 (sd .051; N=34) (p<.001 unadjusted)

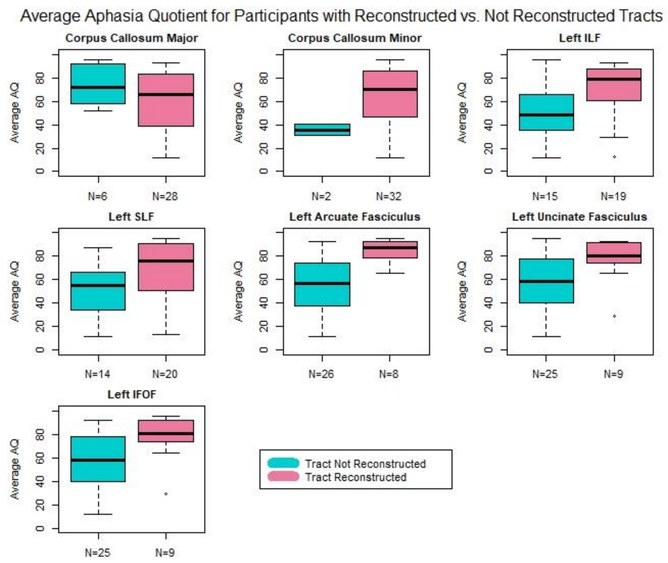


IFOF Left FA: .425 (sd .039; N=9) vs. Right FA: .478 (sd .049; N=34) (p=.004 unadjusted)

2a. Association between tract reconstruction and aphasia severity

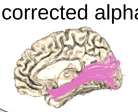
Spearman's rank-biserial correlations between presence of tract reconstruction[a] (for five left hemisphere tracts and corpus callosum forceps major and minor) and aphasia severity (AQ) significant at Bonferroni-corrected alpha-level of .007 (7 comparisons) for:

Left AF (r_s = .52 (p=.002[b] unadjusted))



2b. Association between average WM integrity and aphasia severity

Spearman's correlations between average WM integrity[c] (FA) and aphasia severity (AQ) in 12 tracts of interest significant at Bonferroni-corrected alpha-level of .004 (12 comparisons) for:



Left ILF (r_s = .65 (p<.001[b] unadjusted); N=29)

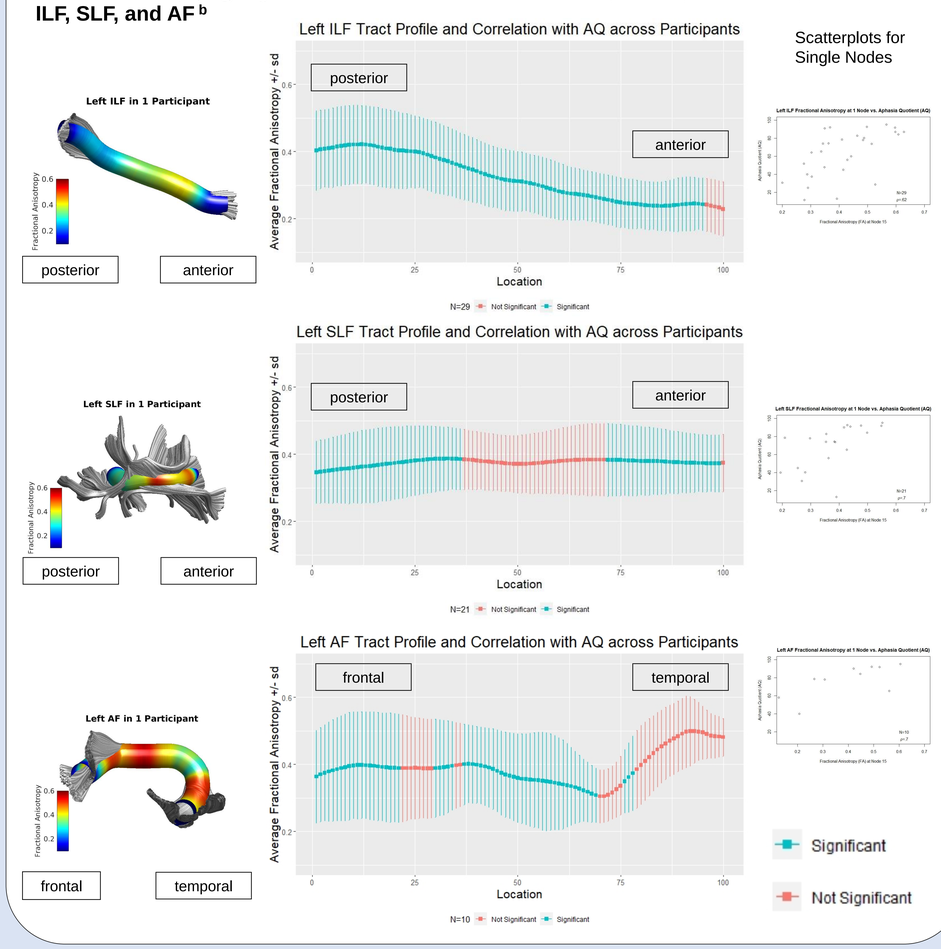
[a] at original AFQ threshold

[b] not significant after partial correlation accounting for lesion volume

[c] at lowered threshold in left-hemisphere tracts

3. Association between pointwise WM integrity and aphasia severity

Spearman's correlations between WM integrity[c] (FA) in 100 nodes for 12 tracts of interest and aphasia severity (AQ) significant after FDR correction for multiple comparisons for portions of **left ILF, SLF, and AF**[b]



Discussion

- Individuals with post-stroke aphasia show reduced left-hemisphere WM structural integrity
- Average and pointwise WM structural integrity metrics in left ILF, SLF, and AF correlate with aphasia severity prior to controlling for lesion volume
  - Pointwise metrics may give us information about specific portions of the tract more susceptible to damage or more important for certain functions[7]
- Limitations:
  - Potential difficulty with accurately delineating tracts due to crossing fibers
  - Challenge of statistical inferencing with varying amount of data across tracts due to lesions
- Future research will examine relationships between WM integrity and treatment outcomes

Acknowledgements

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References

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