Effects of leukoaraiosis on whole brain connectivity

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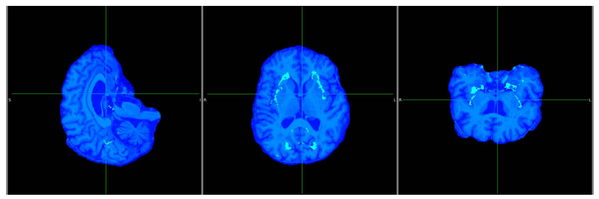
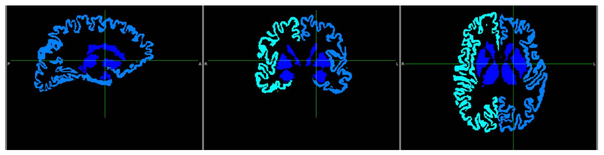
Introduction

Leukoaraiosis, a disease that affects white matter tracts in the brain, impacts nearly every aging individual. This research analyzed how localized leukoaraiosis could affect the brain as a whole by examining the brain as a network of nodes.

Since leukoaraiosis damages the connections between nodes, we hypothesised that leukoaraiosis would reduce the connectivity between areas of the brain as a whole. To test this hypothesis, we calculated several network metrics of nodes in the brain and compared them against leukoaraiosis volume.



Leukoaraiosis in a subject's brain (pictured in light blue)



Cortical and subcortical Regions of Interest (ROIs) in the brain

Methods

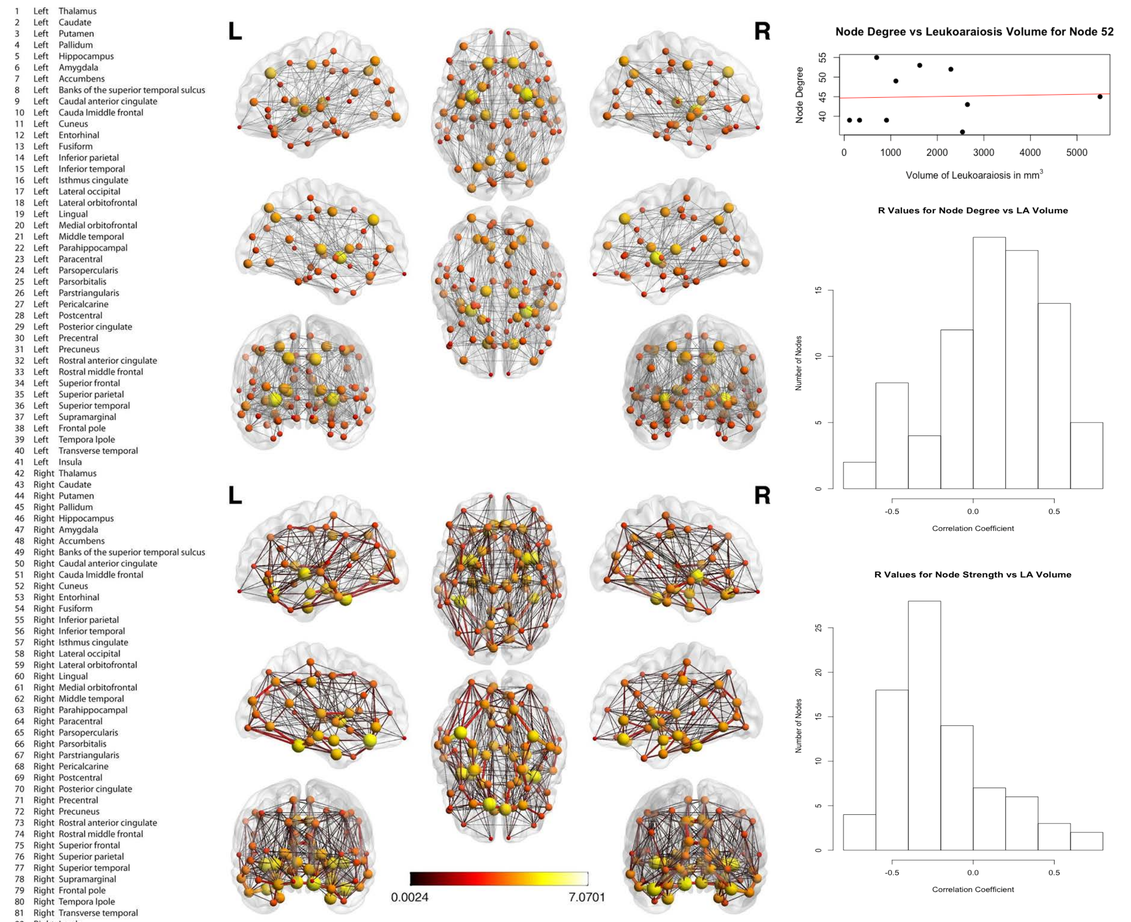
We started with a mask of leukoaraiosis and an MRI scan of ten elderly individuals. We then isolated certain regions of interest (ROIs) in each brain and calculated where the mask intersected with our ROIs using FSLMaths. Volume of the intersection was calculated using FSLStats.

To conduct network analysis of the brains, we used tractography tools created by the Mareci Lab. They allowed us to isolate the white matter tracts between regions of interest and calculate edge weights between each pair of nodes.

All statistical analysis and graph creation was done using R.

All the code used for this project can be accessed at www.github.com/jachan/la-project.

Results



Top right: Example of leukoaraiosis against node degree graph for node 52. Correlation coefficient of 0.08.
On the left: Atlas of the 82 regions, along with representative graphics of brain connectivity. Top graphic has edges weighted by node degree, bottom set has edges weighted by node strength
On the right: Histograms of how well leukoaraiosis volume correlates with node strength/node degree for the ROIs

For each of the brains, we calculated the volume of leukoaraiosis and created a matrix of edge weights. This allowed us to plot different network metrics against leukoaraiosis. The simplest metric used was mean edge weight. There was a correlation coefficient of -0.58 between mean edge weight and leukoaraiosis volume.

Another metric used was node degree. We plotted node degree versus leukoaraiosis volume for each of the eighty-two nodes within each brain. Then we performed a linear fit on the data for each node. The median correlation coefficient was 0.18.

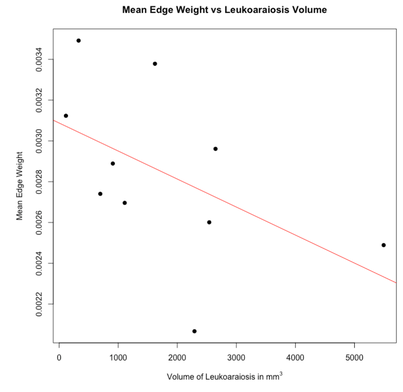
The final metric we examined was node strength, which was also plotted against leukoaraiosis volume for each of the eighty-two nodes within each brain. The median correlation coefficient was -0.27.

Conclusions

This study shows that there is a strong negative correlation between mean edge weight and leukoaraiosis volume in the ten patients analyzed. This is consistent with what we hypothesized. However, it would be expected that localized leukoaraiosis would lower edge weights in affected areas, and therefore decrease the mean edge weight of affected brains.

Node degree and node strength were measures of connectivity that offered a better look at how leukoaraiosis affected each node individually. While node degree did not seem to correlate well with leukoaraiosis volume in the nodes, node strength did: 23 of the nodes had a correlation coefficient of less than -0.37 and the distribution had a median value of -0.27. This reveals a problem with node degree: because it is a binary measure, it often includes connections between nodes that have little impact on the full connectivity of the brain.

Future studies could examine how neighboring nodes are affected by nodes with leukoaraiosis, or look at the anatomy of the brain and examine how cognition is affected by leukoaraiosis in specific areas. This project suggests that future research into the effects of leukoaraiosis are promising, but more trials are needed to determine whether the levels of correlation found in this study hold with a larger sample size.



Above: Mean edge weight graphed against leukoaraiosis volume for the ten patients studied. Correlation coefficient of -0.58.

Relevant Literature

- Behrens TE, Jbabdi S. MR diffusion tractography. Diffusion MRI 2009. p. 333–51.
- Colon-Perez LM, Spindler C, Goicochea S, Triplett W, Parekh M, et al. (2015) Dimensionless, Scale Invariant, Edge Weight Metric for the Study of Complex Structural Networks. PLoS ONE 10(7): e0131493.

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