A new method to evaluate the brain lesion in stroke assessing residual cross-sectional area of white matter tract atlas

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Introduction

Strokes have a disruptive impact on brain tissue, leading to various functional impairments. In case a stroke damages a white matter tract, it severely impairs its associated function. While the ideal approach to evaluate white matter damage is by comparing the white matter before and after the stroke using diffusion tensor imaging (DTI), it is often very difficult, due to unavailability of a pre-stroke DTI images and even missing DTI data for stroke patients. To address this, we have proposed a method using the overlap volume between the lesion and the white matter tract atlas as a surrogate measure of white matter damage, by assuming that the white matter tract atlas represents the undamaged state before a stroke [1]. However, this method does not provide an accurate assessment of the white matter damage, and/or associated symptom. It's because the residual cross-sectional area is more indicative of intact nerve fibers, and functionality rather than the overlap volume. Thus, we proposed a new method that analyzes the cross-sectional area of white matter tracts affected by lesions.

In **figure 1**, the brain image showed Johns Hopkins University (JHU) white matter (WM) atlas tracts and lesion (white part). Previous methods focused on volume where tracts and lesion were overlapped, such as the red oblique line part. But, Our new method focuses on cross-sectional area excluding overlapping parts, such as the red oblique line part.

Keywords: Stroke, cross-sectional area, white-matter atlas, lesion analysis

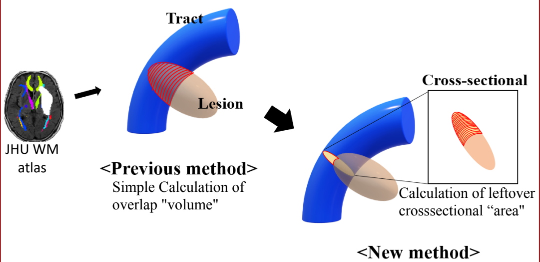

Fig. 1. Difference between our previous method and new method

Methods

A. Identifying Central curve

We first derived a central curve that follows a white matter tract delineated in the JHU atlas. The calculation of the curve involves several steps. First, we selected an arbitrary point P in the tract **(black dot in Figure 2)**, and constructed the various planes passing the point P. Second, among these planes, we identified the one with the smallest cross-sectional area, and calculated the centroid point of the cross-section **(red dot in Figure 2)**; we denoted it as C. We repeated this procedure along the major axis of the tract, obtaining a set of the central points, {C}, that forms the central curve.

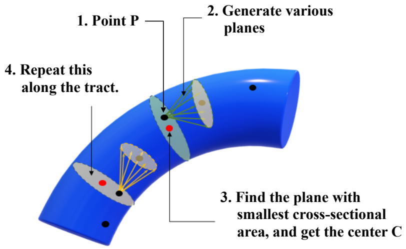

Fig. 2. Central curve construction, the black dots were the set of the points P. Various normal vectors were tested to find the smallest cross-sectional plane. The centroid of this minimal cross-section was the red point C. The set of points C forms a central curve.

B. Cross-sectional area

Once the central curve was obtained, for each point on the central curve, we constructed a plane whose normal vector is the curve's directional vector on the point. Then calculated the cross-sectional area of the white matter tract and intact fiber ratio(1).

$$\text{Intact Fiber Ratio} = \frac{CA_{leftover}}{CA_{JHU}} \qquad (1)$$

CA_{JHU} was the cross-section of the intact tract and $CA_{leftover}$ was the leftover cross-section area after subtracting the lesions from the tract. Since the remaining functionality of the tract may be proportional to the amount of tract remaining, the process was repeated to find the smallest intact fiber ratio, and we use it as a representative value for the tract.

Results

Figure 3 was the example of left superior longitudinal fasciculus (SLF), showing as blue. Figure 3A showed cross-sections along with the central lines of SLF, denoted as green.
In Figure 3B, The brain lesion was shown as crimson. In Figure 3C, the cross-section of the remaining part of the SLF after subtracting the lesion from each plane in Figure 3A. The affected plane was shown in crimson. The intact fiber ratio of two cross-sections were 85%, and 61.76%. Thus, the SLF's representative intact fiber ratio is **61.76%**.

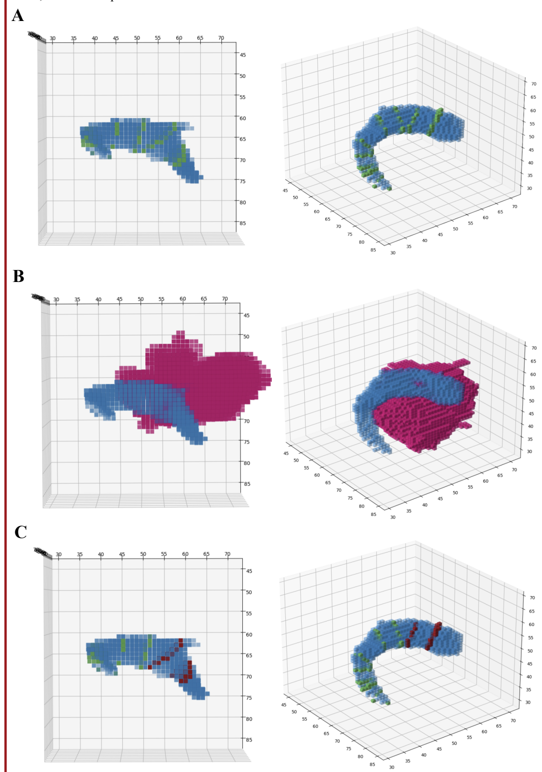

Fig. 3. 3D Visualization of lesions' influence on white matter tracts, the superior longitudinal Fasciculus (SLF). A. SLF, and its cross-sections. B. SLF and a lesion. C. SLF and affected cross-sections. The left column showed it in a transversal view, and the right column showed it in a 3D-view.

Discussion & Conclusion

We suggested a method to confirm the effect of white matter damage through cross-sectional area analysis. The cross-sectional area may indicate the amount of intact nerve fibers remaining: i.e. the functionality of the remaining white matter is more likely to be closely related to the remaining cross-sectional area than to the overlapped volume. This method is general and thus can be applied to any other white matter atlas.

Our method requires further refinement. 1) Currently, the cross-sectional area is calculated by counting the number of voxels, but a more precise method to compute cross-sectional area should be employed. 2) We need to divide the central curve more densely using spline interpolation, to ensure the representative intact fiber ratio of the tract more precise.

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Reference

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