Topographical evaluation of DTI corticospinal tractography and ischemic stroke utilizing spatial normalization

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Introduction

MR diffusion tensor imaging (DTI) can allow us to delineate in vivo neuronal fiber tracts non-invasively, which is known as tractography. In regard to small symptomatic cerebral infarction, some authors reported usefulness of DTI corticospinal tractography [1-3]. However, in their reports some cases showed hemiparesis even when a corticospinal tractogram was not engulfed by an infarct. One of the reasons is considered termination of tracking in infarction leading to underestimation of involvement. Corticospinal tractograms of volunteers are less likely to be terminated and are expected to identify a cause of hemiparesis if they are superimposed on images of stroke patients. For this purpose we attempted to utilize spatial normalization, and the aim of this study was to estimate feasibility of employing DTI tractography combined with spatial normalization when evaluating degree of corticospinal tract involvement within infarction in relation to motor functional recovery.

Methods

Volunteer study

Ten male healthy volunteers were enrolled. We used a 1.5-T imager (Signa Excite, GE Healthcare, Wis, USA) for DTI with a single-shot echo-planar sequence (TE/TR = 67/7000 ms, 30 MPG directions [4], b-values = 0 -1000 s/mm^2, FOV = 30 cm, 40 contiguous, 3-mm-thick slices, matrix = 128×128) as well as array spatial sensitivity encoding technique. After realignment, corticospinal tractography was created using dTV [5] with a two-regions-of-interest method. Voxels that trajectories penetrated were segmented out and transformed into the standard space using SPM2 [6] with the same parameters as fractional anisotropy (FA) images of each volunteer were transformed onto FA template that we developed. The whole ensemble of these tractograms was used as a normalized corticospinal tractogram [7].

Patient study

DTI data of 14 consecutive capsular or pericapsular, acute to early subacute stroke patients were retrospectively used. DTI was conducted on a 1.5-T imager (Signa Horizon, GE) with a single-shot spin-echo echo planar sequence (TE/TR = 67-96/5000-6000 ms, 13 MPG directions, b-values = 0-1000 s/mm^2, FOV = 24 cm, 30 contiguous, 5-mm-thick slices, matrix = 128×128). Isotropic diffusion-weighted images were spatially normalized similarly and infarction was segmented out by thresholding using MRIcro [8]. Muscle strength was measured with manual muscle testing scores on admission and at discharge.

Analysis

The normalized corticospinal tractogram was overlaid onto images of infarction that was segmented and normalized (Fig. 1). For each patient, we calculated (A) the median of the ratios of voxels within intersection of the corticospinal tractogram with infarction to the whole voxels within the corticospinal tractogram on axial images and recorded (B) the number of axial images where the corticospinal tractogram was engulfed in infarction. In relation to presence or absence of recovery of muscle strength, difference of degree of involvement was sought: (i) A, (ii) B, and (iii) 2×2 table analysis when cases were divided if A $\leq$ 30 % and B $\leq$ 30 slices, or not.

Results

The normalized corticospinal tractogram was engulfed in infarction in all patients (14/14) and this topographical feature clearly explained the cause of muscle weakness. Muscle strength recovered in 10 patients but not in 4 patients. Weakness persisted in patients in whom infarction involved the tract with larger axial or longitudinal extent (Fig. 2) and statistical significance was shown (p = 0.04) for (iii) by Fisher's exact test. No significant difference was found for (i) or (ii).

Conclusion

Topographical evaluation of corticospinal tract and infarction utilizing DTI tractography together with spatial normalization was found feasible as this could clearly visualize the cause of motor weakness. Our results also suggest that the larger axial or longitudinal involvement is present in patients with persistent weakness and highlight potential utility of DTI corticospinal tractography combined with spatial normalization to predict prognosis of motor recovery.

Reference

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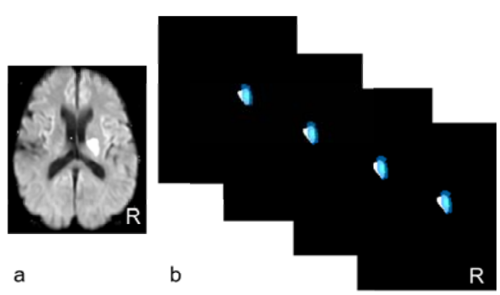

Figure 1. Normalized right capsular infarction (**a**) is segmented (**b**, white), and then the normalized corticospinal tractogram (**b**, translucent blue) is overlaid onto the infarction.

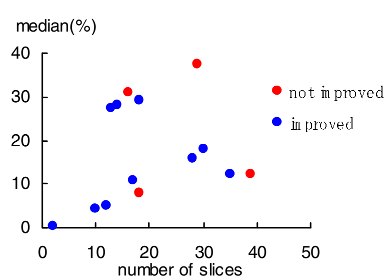

Figure 2. Scatter plot shows patients with persistent weakness have larger cross-sectional or longitudinal corticospinal tract involvement in infarction.