Morphological brain network of mild traumatic brain injury patients: a structural T1 study

Eunkyung Kim[1*], Han Gil Seo[1], Hyun Haeng Lee[1,5], Seung Hak Lee[1,2], Seung Hong Choi[3], Roh-Eul Yoo[3], Won-Sang Cho[4], Seo Jung Yun[1], Min-Gu Kang[1], Byung-Mo Oh[1†]

Seoul National University College of Medicine, Department of Rehabilitation Medicine[1], Incheon Workers Compensation Hospital, Department of Rehabilitation Medicine[2], Seoul National University College of Medicine, Department of Radiology[3], Seoul National University College of Medicine, Department of Neurosurgery[4], Konkuk University School of Medicine and Konkuk University Medical Center, Department of Rehabilitation Medicine[5]

Introduction

Morphological brain network represents mathematical correlation across brain regions using morphological features of brain such as cortical thickness and voxel intensity of gray matter. This approach has been successfully applied to the clinical research data such as schizophrenia and deaf adults. The aim of this study was investigating morphological brain network of mild traumatic brain injury (mTBI) patients using gray matter density of the structural T1 images, and comparing the network with the controls to examine the changes of morphological brain network after mTBI.

Methods

Twenty-two individuals with mTBI (53 ± 4.6 years) and thirty control subjects (56.1 ± 10.8 years) were included in this study. Table 1 summarized the characteristics of the individuals with mTBI. 3D T1 images were acquired through a 3T GE scanner. The raw image data was preprocessed by the SPM12 (Statistical Parametric Mapping) software. Gray matter density maps were obtained in each individual by the voxel-based morphometry (VBM) with DARTEL (Diffeomorphic Anatomical Registration Through Exponentiated Lie algebra) tool. After obtaining the maps, we generated the morphological network in each group, respectively. The number of nodes were 90 in this study, defined by the automated anatomical labeling (AAL) template excluding the cerebellum. The gray matter density of voxels within a node was averaged, and Spearman's correlation matrix (i.e., the morphological brain network) was constructed across the 90 nodes with age and total intracranial volume as nuisance variables. A nonparametric permutation test was performed to determine whether the morphological network of the two groups differed significantly ($P < 0.001$).

Results

Figure 1A-B showed the morphological brain network of control and mTBI groups. We thresholded the matrices and compared the positive correlation ones (Figure 1C-D) between the groups. The mTBI group showed the increased connectivity in between the left superior temporal and right fusiform areas, and in between the right parahippocampal and angular areas (Figure 2). There was no significantly decreased connectivity of mTBI group compared to the controls.

Conclusion

The increased connectivity was observed in between the brain regions where have responsible for the diverse symptoms of the mTBI, such as hallucination and memory. According to these findings, we may suggest that plastic changes occurred in mTBI group, due to their traumatic brain injury.

Table 1. Characteristics of patients I.

ID	Diagnose	Gender	Age	GCS (<24hr)	Loss of Consciousness	Posttraumatic Amnesia	Duration	RPCSQ	GOSE	GOAT	MMSE-K
P01	Mild	F	46	15	< 30 minutes	< 30 minutes	1 month 26 days	17	-	-	-
P02	Mild	F	53	15	(+) a few minutes	1 hour	6 months 21 days	37	6	-	26
P03	Mild	F	53	NA	(+) but no details available	(+) but no details available	29 months 3 days	-	-	93	27
P04	Mild	F	60	15	(+) but no details available	(+) a few minutes	5 months unknown days	39	6	100	29
P05	Mild	F	54	15	(+) but no details available	(+) but no details available	3 months 17 days	56	5	88	27
P06	Mild	F	56	NA	< 30 minutes	6 hours	46 months	-	-	-	-
P07	Mild	F	49	NA	5-10 minutes	3-5 minutes	1 month 16 days	-	-	98	22
P08	Mild	F	69	NA	-	(+) but no details available	1 month 20 days	-	-	-	29
P09	Mild	M	47	NA	-	-	4 months 10 days	21	7	-	-
P10	Mild	F	41	NA	-	-	1 month 4 day	45	5	85	-
P11	Mild	M	54	NA	(+) but no details available	(+) but no details available	1 month 6 days	30	5	98	30
P12	Mild	M	68	NA	-	-	6 months 12 days	42	6	89	-
P13	Mild	F	54	NA	(+) a few minutes	(+) but no details available	3 months 18 days	49	5	-	29
P14	Mild	F	56	NA	-	-	1 month 5 days	21	5	99	29
P15	Mild	M	36	NA	(+) but no details available	(+) but no details available	5 months 12 days	28	5	90	-
P16	Mild	F	50	NA	< 30 minutes	(+) but no details available	2 months 6 days	26	6	100	-
P17	Mild	M	45	NA	(+) but no details available	(-+)	2 months 15 days	46	5	80	27
P18	Mild	F	58	NA	(+) 1 minute	-	1 months 11 days	59	5	96	22
P19	Mild	F	31		-	-	26 days	-	-	-	28
P20	Mild	F	46	NA	unclear	> 30 minutes	1 month 27 days	-	-	-	30
P21	Mild	F	31	NA	(+) but no details available	(+) but no details available	1 month 15 days	34	5	100	30
P22	Mild	F	24	NA	(+) a few minutes	(+) a few minutes	25 days	36	6	93	28

Abbreviations: GCS, Glasgow Coma Scale; RPCSQ, Rivermead Post-Concussion Symptom Questionnaire; GOSE, Extended Glasgow Outcome Scale; GOAT, Galveston Orientation and Amnesia Test; MMSE-K, Korean version of the Mini-Mental State Examination; P, Patients; F, Female; M, Male; NA, not available. NA for GCS indicates "not available" because the patients visited outpatient clinic in post-acute phases.

Characteristics of mTBI group included in this study.
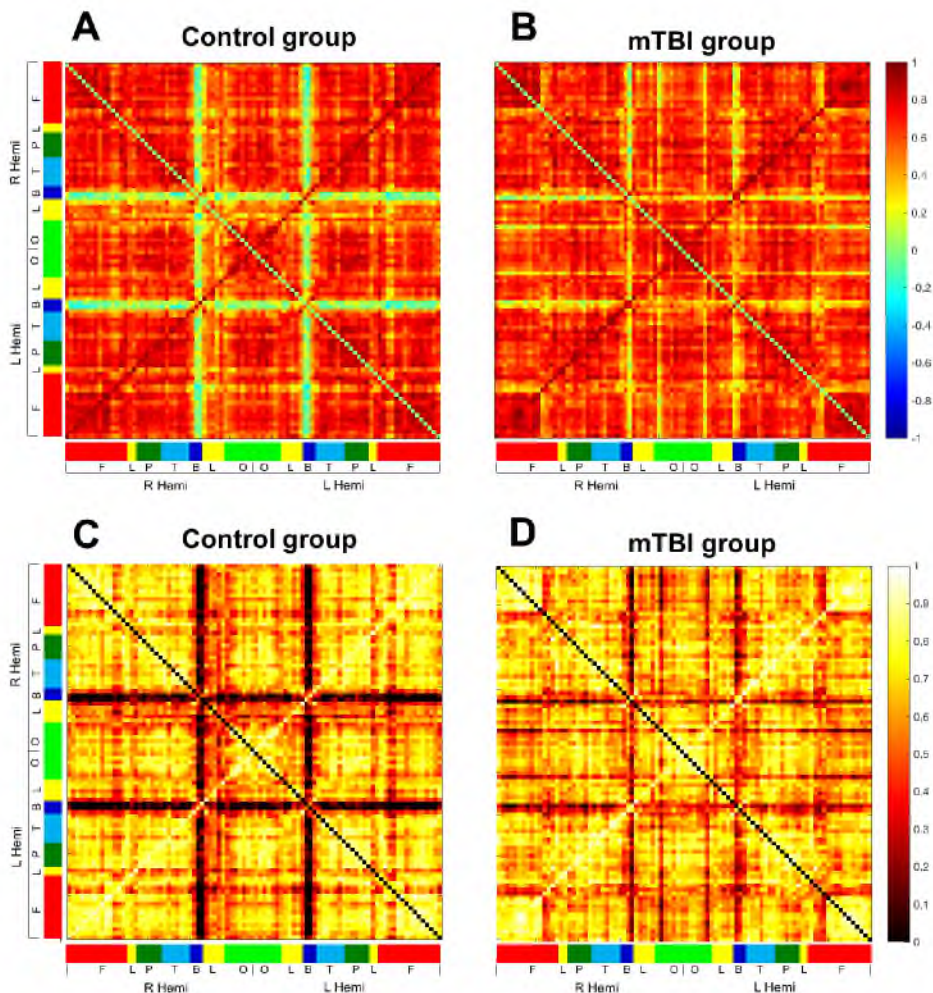
Morphological brain network of (A) control and (B)mTBI groups, and the positive one of the (C) control and (D) mTBI groups, respectively.
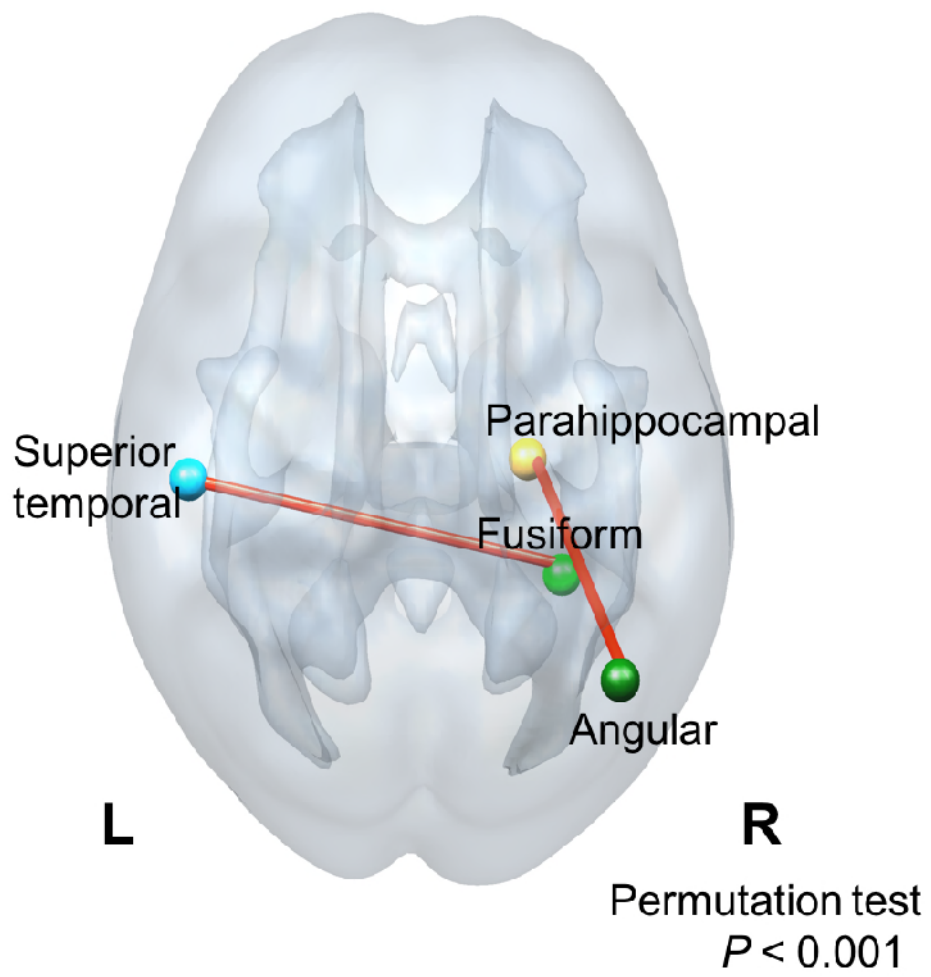
The significantly increased connectivity observed in the mTBI group.