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Structural brain changes of mild traumatic brain injury patients: a tensor-based morphometry study

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Introduction

Despite the negative findings of structural MR images in mild traumatic brain injury patients (mTBI) in clinics, there was clear evidence showing structural brain alterations in mTBI [1,2]. The aim of this study was to examine structural brain changes of mTBI compared to controls using a tensor-based morphometry (TBM) [3], capturing regional volume expansion and contraction. Since time post injury influence on brain changes significantly [4], we also tried to examine the relationship between time post injury and structural brain changes of mTBI.

Methods

Twenty-two patients with mTBI were included in this study (5M/17F, mean age: 53±4.6 years). Time post injury was from 25 days to 46 months (177.1±321.7 days). As a control group, thirty subjects were included (9M/21F, mean age: 56.1±10.8 years). 3D T1 images were acquired through a 3T GE scanner. TBM was applied to the groups using following framework by SPM12. First, we manually aligned the anterior and posterior commissures and segmented the images. DARTEL template was created using the segmented gray matter, white matter, and cerebrospinal fluid tissue maps. In this stage, flow field maps were acquired containing deformation information between subject space and template. The template is the inter-subject coregistered image, so we should normalize it to the MNI space. Deformation and jacobian determinant maps were estimated representing local shape changes from the individual T1 images to the MNI template image. Jacobian determinant value above, and below 1 indicated volume expansion and contraction, respectively. For statistical analysis, log transformed jacobian determinant maps were compared between the groups by a two-sample t-test with age and total intracranial volume as nuisance variables. Relationship between the structural brain changes and time post injury was also examined using the correlation analysis with age and total intracranial volume as nuisance variables. Statistical significance was all set at uncorrected $P<0.005$, with number of voxels per cluster>50.

Results

Compared to the controls, significant volume expansion of the patients was observed in the cerebral cortices, and significant volume contraction was observed in the cerebellum, midbrain, and middle cerebellar peduncles (Table 1 and Figure 1A and B, respectively). More complex results were found in between the structural brain changes and time post

injury of the patients (Table 2 and Figure 2). Volume of the frontal areas including precentral, and extra-nuclear were expanded while the volume of the parietal areas including postcentral, and superior temporal regions were contracted when time post injury was increased.

Conclusion

Structural brain changes observed in the mTBI patients may indicate plastic changes and vulnerability of the brain due to traumatic injury. Time post injury may be associated with the changes significantly. Future study should be needed to understand the meaning of the results.

Table 1. Volume enlargement and contraction observed in the mTBI patients compared to the controls (Uncorrected P < 0.005, cluster size > 50).

Contrast	cluster	Peak T	P value	MNI coordinates x	y	z	Region
Patients > Controls							
	504	4.02	0.000	-40	-33	63	Postcentral Gyrus
		2.94	0.003	-45	-30	52	Postcentral Gyrus/Inferior Parietal Lobule
	1469	3.67	0.000	56	-32	-22	Inferior Temporal Gyrus
		3.63	0.000	42	-24	-32	Fusiform Gyrus
		3.27	0.001	60	-38	-16	Middle Temporal Gyrus
	148	3.52	0.000	26	-12	69	Precentral Gyrus
	130	3.47	0.001	51	15	-16	Superior Temporal Gyrus
	56	3.27	0.001	-36	-12	-24	Fusiform Gyrus
	330	3.16	0.001	-32	12	58	Middle Frontal Gyrus
		3.06	0.002	-27	2	56	Sub-Gyral
	151	3.12	0.002	-44	-22	-32	Inferior Temporal Gyrus
	61	3.09	0.002	-26	-82	-14	Lingual Gyrus
Controls > Patients							
	305	3.61	0.000	2	-70	-40	Vermis_8
	935	3.29	0.001	0	-51	-26	Vermis_10
		3.25	0.001	4	-51	-42	Cerebellum_9
		2.78	0.004	-4	-42	-34	Vermis_10
	535	3.24	0.001	9	-28	-14	Midbrain
		3.21	0.001	14	-24	-32	Middle Cerebellar Peduncle
	172	3.23	0.001	34	-93	0	Infrerior Occipital Gyrus
		3.14	0.001	28	-94	14	Middle Occipital Gyrus
	364	3.09	0.002	-14	-27	-30	Middle Cerebellar Peduncle
		2.91	0.003	-8	-30	-15	Midbrain
	78	3.01	0.002	-51	-57	-32	Cerebellum_Crus1

Table 2. Volume enlargement and contraction associated with time post injury of the patients (Uncorrected P < 0.005, cluster size > 50).

Contrast	cluster	Peak T	P value	MNI coordinates x	y	z	Region
Volume enlargement with time post injury							
	148	4.78	0.000	60	-44	-20	Inferior Temporal Gyrus
	324	4.53	0.000	36	15	-4	Extra-Nuclear
	391	4.51	0.000	-45	30	32	Middle Frontal Gyrus
		4.47	0.000	-48	18	38	Middle Frontal Gyrus
	497	4.41	0.000	6	2	62	Medial Frontal Gyrus
	587	3.83	0.001	-30	4	48	Middle Frontal Gyrus
		3.80	0.001	-28	14	56	Middle Frontal Gyrus
		2.94	0.004	-42	-3	39	Precentral Gyrus
	79	3.53	0.001	33	-60	42	Angular Gyrus
	168	3.48	0.001	-32	15	-15	Extra-Nuclear
	52	3.28	0.002	40	-15	60	Precentral Gyrus
Volume contraction with time post injury							
	350	5.86	0.000	-60	-22	39	Postcentral Gyrus
	1203	5.14	0.000	46	-36	48	Inferior Parietal Lobule
		4.24	0.000	38	-48	63	Inferior Parietal Lobule
	198	4.84	0.000	-48	2	-4	Superior Temporal
	200	4.53	0.000	16	51	36	Superior Frontal Gyrus
	208	4.37	0.000	10	-72	-44	Cerebellum_8
	257	3.58	0.001	-54	-64	-6	Inferior Temporal Gyrus
		3.01	0.004	-62	-63	4	Middle Temporal Gyrus
	213	3.57	0.001	54	-16	10	Transverse Temporal Gyrus
		3.55	0.001	58	-27	18	Postcentral Gyrus
		3.27	0.002	45	-8	-3	Insula
	74	3.34	0.002	26	14	-42	Fusiform

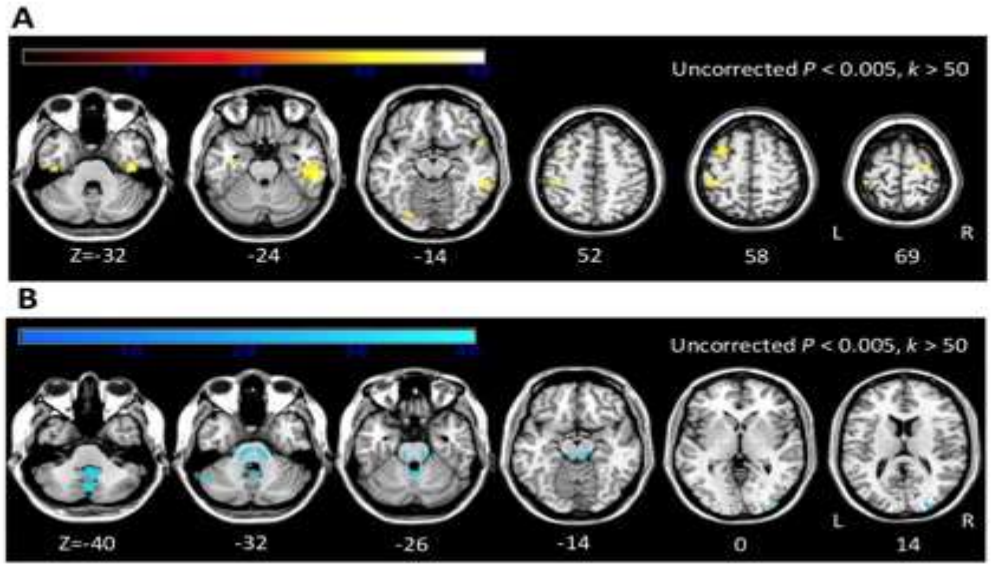

Fig 1. (A) Volume expansion and (B) contraction observed in the patients compared to the controls.

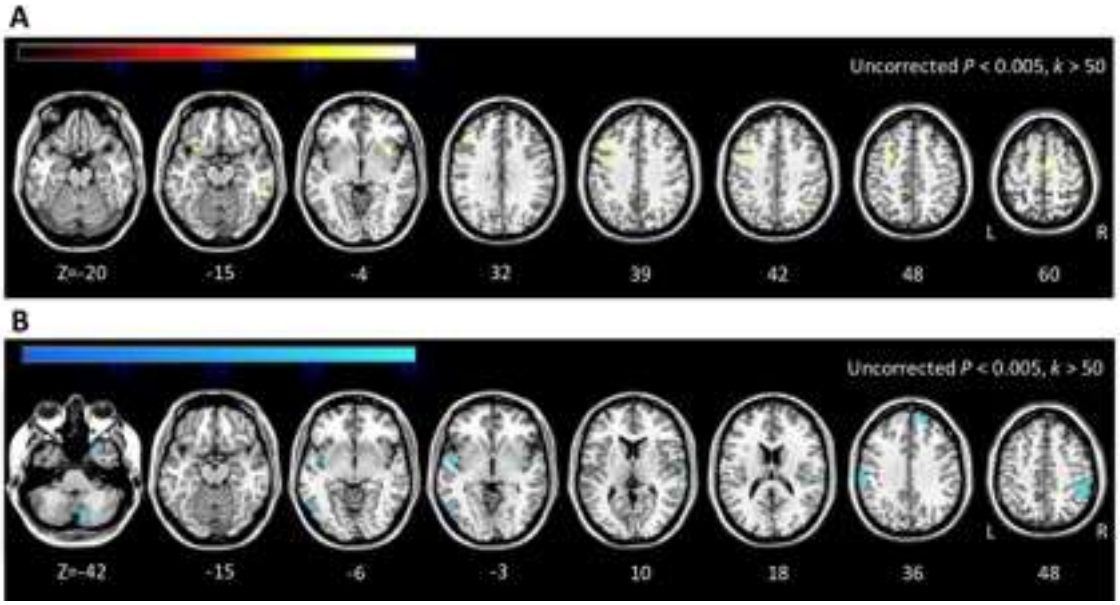

Fig 2. (A) Volume expansion and (B) contraction correlated with time post injury of the patients.