Dynamic Susceptibility Contrast Perfusion Imaging Revealed Asymmetric Cerebral Blood Flow in Chronic TBI Patients

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Introduction

Traumatic brain injury (TBI) is one of the leading causes of death and disability in young adults (1). TBI can cause secondary alterations in cerebral perfusion leading to hypoperfusion, ischemia, and cellular damage. Numerous studies have shown decreased perfusion following TBI at the acute stage (2,3). Previously, we demonstrated perfusion deficits in a group of mild TBI patients from a military population at the subacute stage using dynamic susceptibility contrast (DSC) imaging (4). Accurately measuring the structural and functional damage to the brain and tracking these changes over time in chronic TBI is of great importance as potential guides to rehabilitative efforts to influence these biological recovery processes. The project presented here attempted to characterize perfusion changes using DSC imaging in chronic TBI patients from a military population.

Methods

Study participants included 204 TBI patients and 31 controls. Patients were divided into three groups: mild, moderate and severe TBI based on their clinical diagnosis. The demographics of the participants are illustrated in Table 1. Images were acquired on a 3T GE 750 scanner (Discovery MR750; GE Healthcare, Milwaukee, WI) with a 32-channel phased array head coil (MR Instruments, Inc. Minnetonka, MI). Structural T1 images were acquired with the 3D BRAVO sequence: TR/TE = 6.7/2.5 ms, FA = 12°, voxel size = 0.5 × 0.5 × 0.6 cm^3. DSC images were acquired after 20 ml of Gd-DTPA administered at a rate of 5 ml/sec with the following parameters: TR/TE = 1590/22.3 ms, FA = 60°, voxel size = 2 × 2 × 4 cm^3, 70 dynamics, 40 slices. Arterial input function (AIF) was manually selected from the right and left middle cerebral arteries. In the calculation of regional cerebral blood flow (rCBF), model independent deconvolution was performed with AFNI (http://afni.nimh.nih.gov/afni) for manually selected AIF. Presented rCBF was normalized to the rCBF of the white matter. Freesurfer (http://freesurfer.net) segmentation was performed on the T1 images. Twelve ROIs (caudate, cerebellum, hippocampus, pallidum, putamen and thalamus, right and left respectively) were extracted from the Freesurfer segmentation. rCBF maps were aligned to the T1 images using *3dAllineate* in AFNI. Mean rCBF of each ROI was calculated accordingly. Right-left asymmetry (%) of the rCBF and brain volume was defined as the absolute value of the (right –left) /(right+left)* 200 (The absolute value was used because which side of the brain got damaged was not documented for this patient population.).

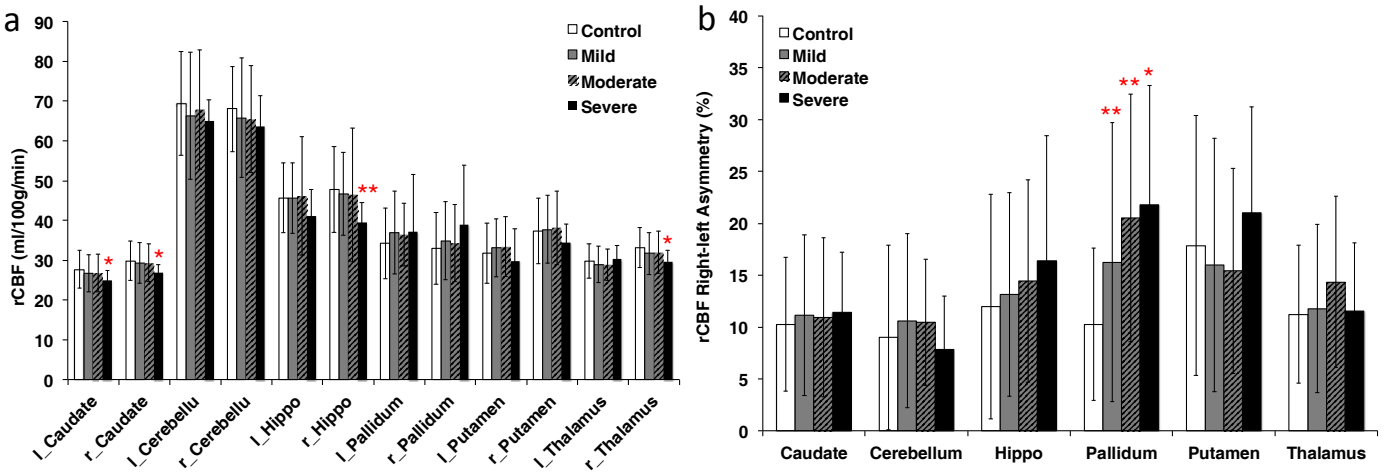
Table 1. Demographics of participants.

Injury Severity	Total Number	Female	Age (years)	Time since Injury (days)
Control	31	11	30.7 ± 8.4	n/a
Mild	167	8	34.5 ± 8.3	1347 ± 1408
Moderate	30	2	32.5 ± 7.6	704 ± 1314
Severe	7	0	32.7 ± 8.9	1874 ± 2665

Table 2. Right-left asymmetry of the brain volume (*p<0.05 vs. control).

Injury Severity	Caudate	Cerebellum	Hippo	Pallidum	Putamen	Thalamus
Control	14.9 ± 11.1	4.1 ± 3.0	6.2 ± 4.5	12.8 ± 9.5	7.5 ± 4.6	15.0 ± 7.6
Mild	15.8 ± 10.4	5.5 ± 3.7*	5.7 ± 5.8	14.2 ± 9.8	7.2 ± 5.1	16.7 ± 6.9
Moderate	14.8 ± 9.0	4.9 ± 3.8	8.5 ± 9.2	15.8 ± 10.5	7.7 ± 5.4	16.8 ± 7.7
Severe	27.1 ± 12.9*	6.4 ± 5.3	11.3 ± 7.1	16.6 ± 11.1	10.4± 4.5	21.6 ± 8.6

Figure 1. a. Mean rCBF of different groups (r_: right, l_: left). b. rCBF right-left asymmetry of different groups (* p< 0.05, ** p< 0.01 vs. control).



Results

Mild TBI and moderate TBI patients demonstrated unaltered rCBF in all twelve ROIs compared to the control group (Figure 1a). Severe TBI patients demonstrated reduced rCBF in the left caudate, right caudate, right hippocampus and right thalamus. Figure 1b illustrates that all three categories of chronic TBI patients demonstrated significantly increased right-left asymmetric rCBF in the pallidum (16.3 ± 13.5% for mild TBI, 20.5 ± 11.9 % for moderate TBI, 21.8 ± 11.5 % for severe TBI vs. 10.3 ± 7.3 for control), however the pallidum volume of the TBI patients demonstrated similar right-left asymmetry compared to the controls (Table 2).

Conclusion

Mild, moderate and severe TBI patients all demonstrated significantly increased right-left asymmetry in rCBF in the pallidum. The increased asymmetric rCBF does not correlate with changes in anatomical structure and could be a compensatory mechanism to the reduced rCBF typically seen at the acute and subacute stage.

References: 1.Report to Congress on mTBI, 2003. 2. Marion DW et al. J Neurosurg 1991;74:407-14, 3. Audenaert K et al. Med Sci Monit 2003;10:112-7 4. Liu W et al. NMR Biomed. 2013;26:651-63.