Greater activation of brain regions serving abstract reasoning abilities in alcohol dependents: An fMRI study

Deepika Bagga[1], Namita Singh[1], Shilpi Modi[1], Mohan Lal Garg[2], Debajyoti Bhattacharyya[3], Prabhjot Kaur[1], and Subash Khushu[1]

[1]NMR Research Centre, Institute of Nuclear Medicine and Allied Sciences (INMAS), Delhi, Delhi, India, [2]Department of Biophysics, Punjab University, Chandigarh, Punjab, India, [3]Base Hospital, Army Medical Corps, Delhi, Delhi, India

Introduction: Abstract reasoning is an element of executive functioning which is thought to involve both the ability to identify concepts (i.e. to recognize underlying category attributes so as to better understand them), and the ability to form concepts (i.e. to generate cognitive schemas to organize information [1]. Alcoholics display deficit in visuospatial abilities, perceptual-motor integration, abstract reasoning, and new learning during the first months of detoxification [2]. The aim of our study was to assess the deficit in abstract reasoning ability in alcoholics as compared to controls using fMRI.

Material and Methods: Ten male healthy subjects (mean age 33.6 ±5.58 (SD) yr) and ten male chronic alcoholics (mean age 39.6±5.23 (SD) yr) were chosen for the study. The alcoholics and controls were age, sex, IQ (performance IQ, verbal IQ assessed using PGI-BBD [3]), handedness and education matched. The alcoholic subjects were abstinent for more than 15 days but less than 1 month at the time of study. fMRI study was carried out using 3 Tesla whole-body MRI system (Magnetom Skyra, Siemens, Germany) with a 20 channel matrix head and neck coil. 36 oblique slices covering entire brain were acquired using gradient echo based interleaved EPI sequence with TR = 3000 ms, TE = 36 ms and field of view = 210 x 210 mm^2. Block paradigm (BABABABA….) with alternating phases of activation (A) and baseline (B) was chosen. 190 sequential image volumes (belonging to six cycles + one baseline for eliminating T_1 saturation effects and acclimatization of the patient to the gradient noise) were taken. The baseline phase (30 sec duration) involved a fixation cross, while the activation phase (60 sec duration) involved an abstract reasoning task comprising of a total of 42 questions (based on series, analogy and classification, of equal difficulty level, 7 questions per active phase). Each question was shown for 7 seconds. Stimuli were presented using fMRI hardware from NordicNeuroLab and the the subject's response was monitored with the help of Nordic response device system (http://www.nordicneurolab.com/Products and Solutions/Nordic fMRI solution/index.aspx). Pre-processing and post-processing were performed using SPM8 software. One-sample't' test for group analysis within task (uncorrected $p \leq 0.001$, extent threshold 'k' = 50 voxels) was performed for both controls and alcoholics. Two sample t test was performed for finding the difference in the activation pattern in alcoholics as compared to normal controls (uncorrected $p \leq 0.01$, extent threshold 'k'=50 voxels). Since this threshold might have led to false positive results, in those areas which passed this threshold a small volume correction (SVC) was further applied, setting the cut off value for significance at FWE corrected $p<0.05$ (at cluster level) and using a 8 mm radius. The anatomical representation of the clusters was related to cytoarchitectonic maps as implemented in the SPM Anatomy Toolbox [4].

Results and Discussion: There was no significant difference in the performance of controls and alcoholics for the abstract reasoning task (response accuracy of controls was 22.1(mean) ± 0.835 (SD) while that for chronic alcoholics was 21.5 (mean) ± 1.08 (SD)). 2 sample t-test revealed that alcoholics showed greater BOLD activations in the Right inferior temporal gyrus (RITG), Right Inferior Frontal Gyrus (RIFG), Right Putamen (RP), Right Superior Parietal Lobules (RSPL), Right Superior Frontal Gyrus (RSFG), Left Middle Frontal Gyrus (LMFG), Left Inferior Parietal Lobule (LIPL) as compared to controls (Figure 1). On the other hand, healthy controls recruited more of Th-visual (part of thalamus connected to visual cortex) as compared to alcoholics for performing the task.

Activations in RITG are attributed to higher levels of ventral stream of visual processing associated with representation of complex object features. RIFG and RSFG is attributed to executive functioning, choice making, attentional control and risk aversion while right putamen mediates various types of learning. RSPL is implicated in deductive reasoning while LIPL is involved in representation of complex objects and pictures [5]. Thus alcoholics showed greater BOLD activation in the areas responsible for reasoning and executive functions as compared to controls which could account for their compensatory mechanisms in order to maintain the same level of performance as controls. However, an enhanced activity in Th-visual in controls implies a greater activation of the ascending reticular activation system and better visual attention in controls as compared to alcoholics.

Conclusion: Thus, initial results suggest that the performance effectiveness of alcoholics was same as that of controls but there was a deficit in their performance efficiency which resulted in a greater recruitment of the neural network responsible for abstract reasoning as a compensatory mechanism for task performance. Our results give the first account of deficit in abstract reasoning ability of alcoholics using fMRI.

References:

1. Solomon M, Buaminger N, Rogers SJ. Abstract Reasoning and Friendship in High Functioning Preadolescents with Autism Spectrum Disorders. J Autism Dev Disord 2011; 41(1): 32–43.
2. Fein G, Bachman L, Fisher S and Davenport L. Cognitive impairments in abstinent alcoholics. West J Med. 1990; 152(5): 531–537.
3. Handbook Of P G I Battery Of Brain Dysfunction (PGI-BBD) 1990. Dwarka Pershad. ISBN : 81-85316-16-3.
4. Eickhoff SB, Stephan KE, Mohlberg H, Grefkes C, Fink GR, Amunts K and Zilles K. A new SPM toolbox for combining probabilistic cytoarchitectonic maps and functional imaging data. NeuroImage 2005; 25: 1325–1335.
5. Kroger JK, Nystrom LE, Cohen JD, Johnson-Laird PN. Distinct neural substrates for deductive and mathematical processing. Brain Res. 2008 Dec 3; 1243:86-103.

Table 1: Results of 2-sample-t-test comparing BOLD activations of controls and alcoholics

Location of peak voxel	Cluster size	T-value	MNI coordinates		
Alcoholics minus Controls (AmC)					
Right Inferior Temporal Gyrus	164	4.15	45	-61	-5
Right Inferior Frontal Gyrus	103	3.84	45	38	-11
Right Putamen	62	3.75	30	8	10
Right Superior Parietal Lobule (Area 7A)	61	5.63	18	-58	67
Right Superior Frontal Gyrus	56	3.58	24	56	19
Left Middle Frontal Gyrus	54	3.67	-33	53	25
Left Inferior Parietal Lobule (Area 2)	51	3.88	-24	-49	52
Controls minus Alcoholics (CmA)					
Visual thalamus	92	6.19	-24	-31	1

Figure 1: 3D rendered view showing results of 2-sample-t-test in (a) AmC and (b) CmA