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"Central Auditory Processing Disorder in Children"

Review

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Neuroimaging Techniques in Assessment of Auditory Processing Disorders: A Review

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ABSTRACT

There are many neuroimaging techniques that are being used to image the structure and/or function of the nervous system, either directly or indirectly. Also with the advent in technologies and better understanding of the anatomy and physiological aspects the imaging techniques are used for assessment and diagnosis of various disorders. The use of imaging techniques is also being recommended for an appropriate diagnosis of APD. Different neuroimaging techniques (magnetic resonance imaging (MRI), magnetoencephalography (MEG), positron emission tomography (PET), etc.) gives various information about auditory processing deficits in children with CAPD through the identification of abnormal brain activity in different brain areas. However, till date imaging techniques are used only in research mainly in developmental APD and the diagnosis of APD is majorly based on behavioural tests. The present review would throw a light on the various imaging techniques that can aid in the diagnosis of APD. With the better understanding of these techniques, neuroimaging can be used as an integral part in the diagnosis of APD along with the behavioural tests.

KEYWORDS: Magnetic resonance imaging (MRI); Techniques; Information.

ABBREVIATIONS: APD: Auditory Processing Disorder; MRI: Magnetic Resonance Imaging; MEG: Magnetoencephalography; PET: Positron Emission Tomography; EEG: Electroencephalography; CAPD: Central Auditory Processing Disorders; FLAIR: Fluid attenuation inversion recovery; BOLD: Blood oxygen level-dependent; HPDT: Hannover Phoneme Discrimination Test; DLT: Dichotic Listening Test; MST: Memory Span Test.

INTRODUCTION

There is growing interest towards studying the anatomical and physiological aspects of the nervous system in individuals with auditory processing disorder (APD). With the help of advancing technology various neuroimaging techniques have been used to image the structure and/or function of the nervous system, either directly or indirectly. The popular imaging techniques which helps to visualize brain and its function include, magnetic resonance imaging (MRI) (structural MRI (sMRI) and functional MRI (fMRI)), magnetoencephalography (MEG), positron emission tomography (PET) scan and electroencephalography (EEG).[1] Each technique gives a unique, though overlapping, vital information and the selection of the imaging technique to be utilized depends upon the information needed.

The use of imaging techniques is recommended for an appropriate diagnosis of APD. However, till date imaging techniques are used only in research especially in developmental APD.[2] In the current scenario, audiologist diagnose APD majorly with the help of different behavioral tests, without probing into neurological aspects of it.[3] There has been several efforts to develop and standardize different imaging techniques to use it as an additional tool to the behavioral and electrophysiological test battery of central auditory processing disorders (CAPD)

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and thus aid in the diagnosis of the same.

MAGNETIC RESONANCE IMAGING (MRI) IN APD

MRI is a medical imaging technique which uses high radio waves, magnetic fields and field gradients to image the body, either structurally (sMRI) or functionally (fMRI). sMRI using the fluid attenuation inversion recovery (FLAIR) technique is a good method to identify brain lesions. However, fMRI with blood oxygen level-dependent (BOLD) contrast is mostly used in researches to identify abnormalities in auditory processing pathways.[4] Hence, fMRI is suggested by the current researches for diagnosing developmental and secondary APD.

fMRI helps in localizing the neural processing centers and perception centers at the cortical level. A study by Bartel-Friedrich and colleagues[4] aimed at finding the areas responsible for processing auditory information with the help of fMRI in typically developing children. The tests used included Hannover phoneme discrimination test (HPDT) dichotic listening test (DLT) and auditory memory span test (MST). Depending on the processing required for each test, the activation occurred was documented and the findings were: activations in dorsal portion of superior temporal gyrus in both sides, Broca's area and left middle temporal gyrus are typical to HPDT. Activations in bilateral superior temporal gyrus and left inferior frontal gyrus (IFG) are seen in DPT. MST elicited bilateral activation of superior temporal gyrus and hippocampus (Figures 1, 2 and 3).

fMRI patterns to vocal sounds in children with APD showed failure in activation of voice selective areas of superior temporal sulcus. However, fMRI patterns to non-vocal sounds showed normal activation. This suggested an abnormal auditory processing presented for speech stimuli in individuals with APD.[5]

Pluta A et al[6] compared neural excitations in age matched typically developing children and children with APD using resting-state fMRI. It was found that the children with APD exhibited atypical activity in the resting state in the posterior cingulate gyrus, responsible for attention. However, differentiation of areas responsible for attention related to listening from the areas responsible for general attention is not possible using fMRI.

Even though fMRI probes into additional information about auditory processing which in turn helps in the diagnosis, one has to be cautious while using it due to different factors like anatomical and age factors. Children and adults vary in relative extent of different cortical areas. Also with the increase in age (11-13 years), relation between grey and white matter varies. In studies which deal with children, a suitable reference template has to be identified to serve as basis of spatial normalization.[4] If adult templates are used for children, it can mislead the activation in brain's spatial localizations.[7]

ELECTRO-ENCEPHALOGRAPHY (EEG) AND MAGNETOENCEPHALOGRAPHY (MEG) IN APD

Electroencephalography and MEG indicate the neural activity

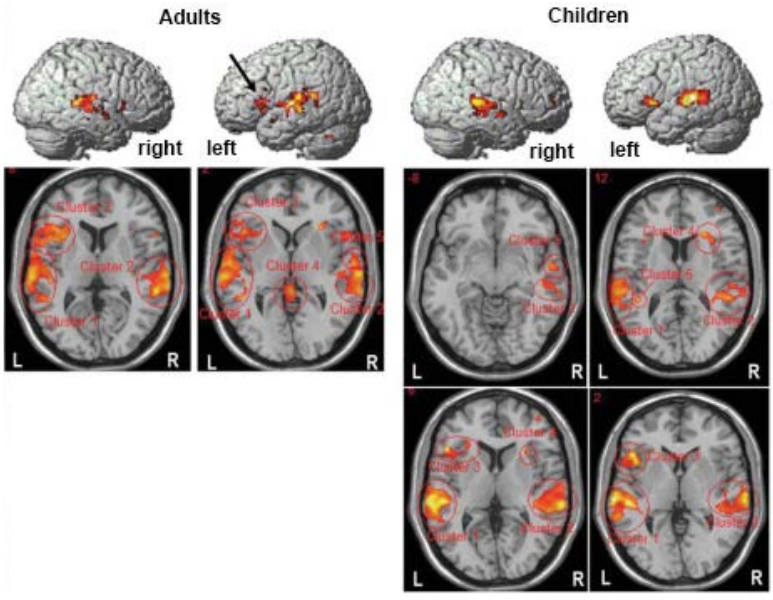

Figure 1: Clusters for the HPDT in adults (n=11) and in children (n=10) on selected axial T1-weighted images and the lateral view of the brain. Adults (left side): note BOLD responses in the STG (clusters 1 and 2) including the primary auditory cortex; in the IFG (cluster 3 and arrow, left lateral view) with Brodmann area 44 and branches extending to the insula. Children (right side): in the left hemisphere, the largest cluster present was located in the MTG, incorporating parts of the STG with the primary auditory cortex (cluster 1). The second cluster was found in the IFG and the left insula, activating parts of BA 44 and 45 (cluster 3). In the right hemisphere, note 2 clusters found in the STG (clusters 2 and 5).[4]

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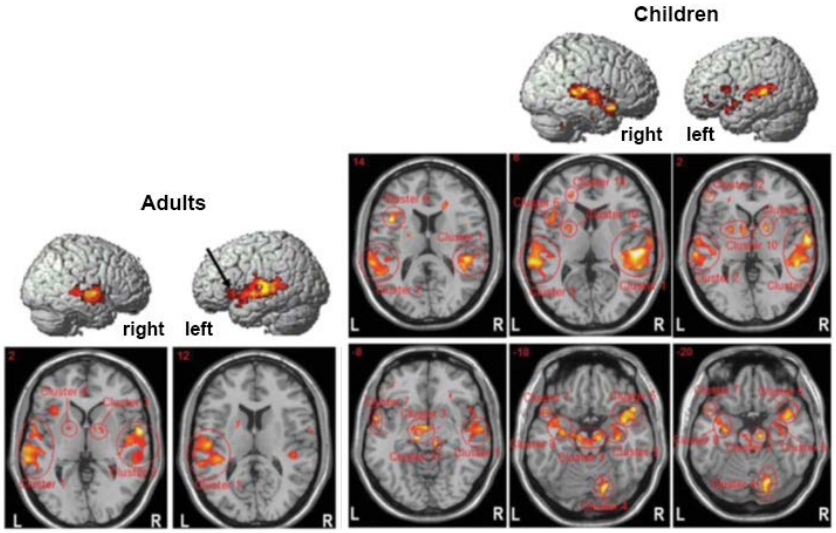

Figure 2: Clusters for the MST in adults (left) and in children (right) on selected axial T1-weighted images and the lateral view of the brain. Adults (left side): note large clusters present located in the STG, with extensions running to the MTG, the end of the temporal cortex, the insula (clusters 1 and 2) and the IFG. Children (right side): clusters present located in the temporal lobe, including the STG and MTG (clusters 1, 2, 5, and 7). Clusters were also found in the frontal lobe, each activating parts of the IFG, including BA 44 and 45 (clusters 6 and 12), and with extensions running to the insula (cluster 6). Also, activation of the limbic system (hippocampal area) of both hemispheres (clusters 8 and 9).[4]

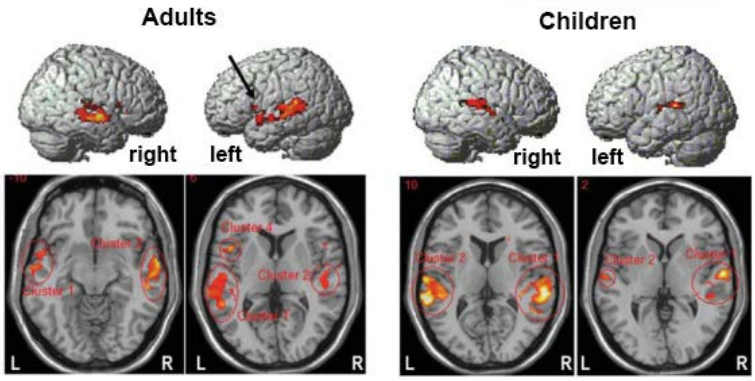

Figure 3: Clusters for the DLT in adults (n=11) and in children (n=6) on selected axial T1-weighted images and the lateral view of the brain. Result of second-level analysis. Adults (left side): in the left hemisphere, the largest of the clusters present was located in the STG, with extensions running to the end of the temporal cortex and the insula (clusters 1 and 4), one smaller cluster was detected in the IFG (arrow, left lateral view). In the right hemisphere, the cluster was located in the MTG and STG (cluster 2). Children (right side): 2 clusters were found (clusters 1 and 2), one in the left STG, the other in the right STG.[4]

through the electric and magnetic fields, respectively. These techniques helps to assess the cortical neural networks while the perception of auditory stimulus. The combination of EEG and MEG gives more precise information on source localization. Since, these techniques have a good temporal resolution they are more widely used for connectivity analysis to assess the auditory processing.

MEG studies showed 20 ms delay in response of brain to the auditory stimuli which resulted in auditory processing abnormalities in children.[8] Hence, it is clear that the temporal processing of children with APD will be affected. This can be clearly evidenced in the behavioral difficulties they face in understanding speech for speech perception (Figure 4).

Roberts et al[9] used MEG technique to compare the neural response for pure tones of different frequencies, between typically developing children and children with autism spectrum disorder (ASD). The recording was done using a 275-channel whole-cortex MEG system. They reported a delayed response in children with ASD. They concluded that such a delay could be due to the auditory processing deficit seen in children with ASD. In yet another study, a 306 channel system was used to record MEG in normal young adults. In order to identify the cortical areas that are responsible for language processing and speech perception, mismatch negativity (MMN) for phrase structures was done during the MEG recording. They reported a strong activation in the superior temporal sulcus and primary auditory cortex, more in the left than in the right hemisphere. Thus, the author's suggested that these areas especially in the left hemisphere are responsible to process the changes in language structure. They also reported a reduction in the MMN

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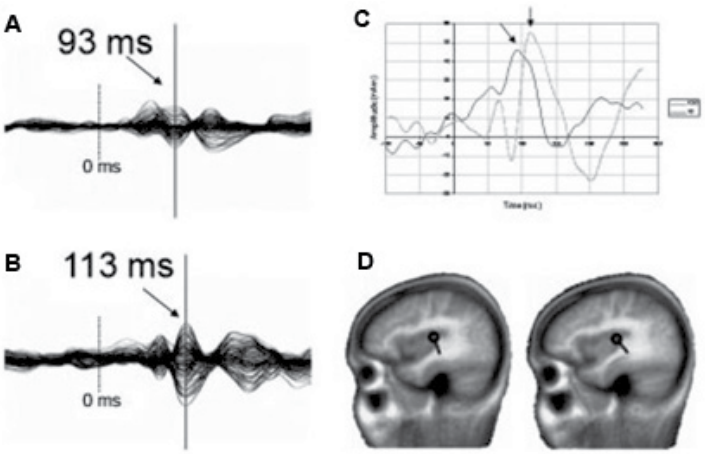

Figure 4: MEG analysis (**A**) M100 STG sensor waveforms for a typically developing (right-hemisphere) and (**B**) age-matched ASD participant. Note similarity in the waveform morphology, but a ~20 msec temporal shift in participant with ASD. Stimulus onset is indicated by a verticle dashed line (0 msec). (**C**) Right-hemisphere source waveforms derived from BESA standard source model applied to the sensor data shown in (A) and (B). (**D**) Sagittal brain image showing the difference in STG dipole oriented for peak M100 in both subjects.

signals recorded from children with dyslexia (which is usually associated with APD).

Gavin WJ et al[10] compared children with APD to typically developing children using EEG and ERP. To record the ERPs clicks and tones of various frequencies and intensities were used as the auditory stimulus. A significant difference in cortical processing was reported between 2 groups. Hence, concluded that the auditory neural functioning differed significantly between typically developing children and children with APD (Figure 5).

Over all, EEG and MEG techniques provide us with umpteen amount of information that can aid in the diagnosis of APD. However, its poor spatial resolution poses certain limitations in its applicability in the diagnosis of APD. More research has to be done in this field so that the results would aid in the diagnosis of APD.

PET SCANS IN APD

PET scans help to identify areas with highest and lowest activity with the help of radioactive tracer. Presently, it is likely to be used in APD researches, and also can be used when fMRI cannot be done especially for cochlear implantees with incompatible materials.[11] Children with APD showed reduced activation in speech related regions in the left side as evidenced in PET scans.[12] Kim and colleagues[12] did F-FDG PET scan in a young adult who had a complaint of difficulty in understanding speech since childhood. They observed that there was a significant

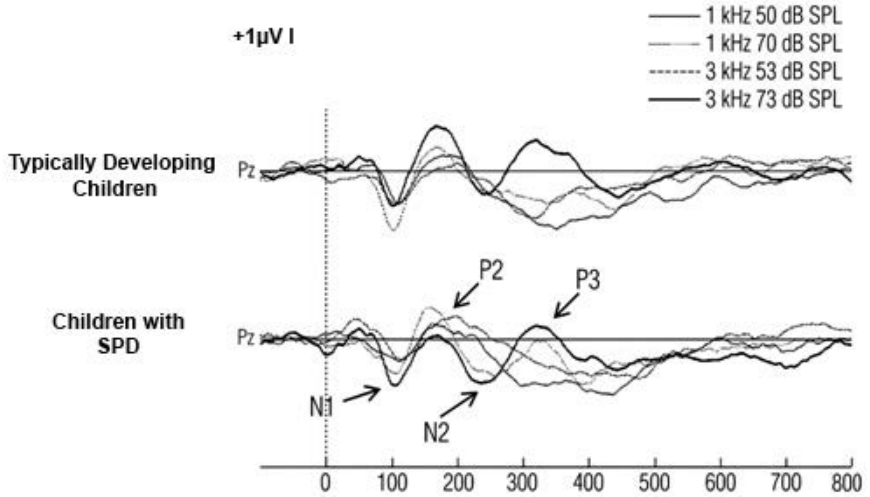

Figure 5: Averaged event related potentials to auditory stimulus recorded from the Pz electrode site from typically developing children (top) and children with SPD (bottom). The major peaks are labelled (N1, P2, N2, P3).[10]

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hypo-metabolism in the auditory cortex, that is, the precuneus and the Heschl's Gyrus, and a hyper metabolism at the right caudate and the superior frontal sulci of both the hemispheres.

CONCLUSION

The different neuroimaging studies throws light into auditory processing deficits in children with CAPD through the identification of abnormal brain activity in different brain areas. Thereby, it is clear that imaging techniques play a role in diagnosis of APD. Hence it provides an additional evidence based diagnosis, when used along with the client history, audiometry and electrophysiological tests. Also, the use of neuroimaging techniques provides evidence of the cortical neural mechanisms that underlies the CAPD and the type of compensation that occurs as a result of APD.

However to date, there are no imaging studies used for diagnosis of APD in children. Also, to understand how the neuroimaging techniques assist in diagnosis of APD requires one to have basic understanding of how typical brain processes to any kind of auditory stimuli. More of evidence based research needs to be conducted in this field to apply neuroimaging techniques into routine test battery of APD.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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