fMRI in Hearing Impaired Children Under Sedation

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Introduction - We have examined several groups of children using auditory stimulation with fMRI to determine whether brain activation of cortical regions associated with auditory function and language processing can be detected reliably in children with severe to profound hearing impairment (HI) who must be sedated for the fMRI procedure. Our preliminary findings suggest that BOLD activation can be detected reliably in hearing impaired children using a 1.5T MRI scanner in children sedated with sodium pentobarbital or chloral hydrate. However, the Talairach reference frame fails to provide a good coordinate system for coregistration of pediatric brain images for children under five years of age.

Materials and Methods - Nine (n=9) hearing impaired patients ranging in age from 1 to 16 years of age have participated in an fMRI study of auditory and language stimulation. Children under 10 kg are sedated with chloral hydrate (75-100 mg/kg). Children larger than 10 kg but unable to participate in the fMRI procedure voluntarily are sedated with Nembutal (3-5 mg/kg). Patients are sedated as part of the clinical imaging protocol and the fMRI scans are collected under an IRB approved research protocol, added on at the end of the clinical routine. Hearing levels for all subjects were obtained from clinical audiology testing. All subjects had bilateral hearing levels ranging from 65-100 dB.

Age matched normal hearing control subjects (n=14) were recruited for the auditory fMRI study from patients referred for MRI to the department of pediatric radiology. Auditory stimulation with tones and language stimulation with short stories read in a female voice is performed during the fMRI scans. Activation maps for each subject are computed using a pixel-wise, generalized linear model (GLM) with fixed effect. Composite activation maps for each task and group are computed in the Talairach reference frame.

fMRI was performed on a 1.5 Tesla MRI scanner using EPI-BOLD imaging methods with TR/TE=3000/50 msec. 32 slices were acquired axially, covering the entire brain with the following resolution parameters: matrix=64 x 64, FOV = 25.6 x 25.6, Slice thickness = 5 mm. Auditory stimulation was performed using a block-periodic fMRI paradigm consisting of a series 5 cycles of random, modulated tones in the frequency range of 100-4000 Hz for a 30 second interval followed by a 30 second interval of silence. Language stimulation was also performed using a block-periodic paradigm consisting of 5 cycles of 30 second short stories interleaved with 30 seconds of silence. Anatomical images were obtained at the same imaging session using a 3D T1 weighted gradient echo acquisition. These images allow for identification of the anterior and posterior commissures so that the image data can be transformed to the Talairach reference frame for composite mapping. Sound levels of the MRI compatible audio system were set to amplitudes of 20 dB (SPL) above the hearing level of each subject to insure auditory stimulation.

Results and Discussion

Based on the GLM normalized Z-score threshold: $Z > 2$, two sided $p<0.05$, Cluster size = 9, we examined brain activation in right and left hemisphere ROIs based in auditory cortex. Cortical activation was detected using fMRI during auditory stimulation tasks in the subjects as follows:

Group: Activation for	Stories	Tones
14 normal sedated children:		
5 chloral hydrate:	2/5	2/5
9 pentobarbital:	5/8	5/9
9 hearing impaired children:		
5 non-sedated*:	4/5	4/5
3 chloral hydrate:	2/3	3/3
1 pentobarbital:	1/1	1/1

Many subjects also demonstrated brain activation of Wernicke's Area during the language stimulation paradigm. Composite activation maps of the hearing impaired subjects performing the auditory and language stimulation tasks compared favorably with composite maps of age matched normal hearing children performing the same task. HI children showed activation in primary auditory cortex and Wernicke's Area, but with lower intensity than the normal hearing control subjects.

Conclusions - Positive activation during fMRI auditory and language mapping in severe to profound hearing impaired children demonstrates that it is feasible to use fMRI as a means of evaluating central auditory processes in these children. Our consistent finding of activation in auditory and language areas of HI children suggests that fMRI might be useful in evaluating central auditory function in children with HI. This constitutes an important first step in developing an fMRI protocol for pre-implant evaluation in pediatric cochlear implant candidates. Future work will extend these findings to correlate with the outcome of cochlear implantation.

The lower rate of activation to auditory stimulation in normal hearing younger children sedated with chloral hydrate is somewhat surprising given that this sedative is know to have less of a cortical depressive effect on the brain than sodium pentobarbital (a barbiturate with known cortical depression effects). This finding warrants further investigation. Finally, it appears from the composite maps of the youngest group of participants, those sedated with chloral hydrate, that transformation into the Talairach reference frame may not be an appropriate approach to composite mapping in these subjects.