Functional MRI of Unilateral Vocal Cord Paralysis before and after Thyroplasty: Comparison to healthy subjects

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Introduction

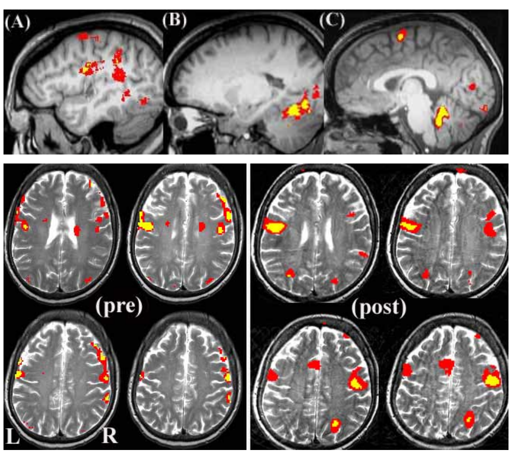
Previous studies have shown that patients treated with partial glossectomies for squamous cell carcinoma of the tongue adapt by utilizing the remaining portions of the tongue body to propel the bolus in swallowing (1). Subsequent BOLD (blood oxygen-level dependent) fMRI studies of patients 2 to 9 months following partial glossectomy demonstrated increased activity in the primary sensory cortex and in the parietal cortex. The goal of this study is to utilize fMRI techniques to identify central mechanisms of adaptation to alterations in vocal cord morphology and voice and swallowing function in patients with unilateral vocal cord paralysis (UVCP) who will be undergoing thyroplasty for the purpose of voice rehabilitation.

Subjects and Functional Tasks

A UVCP patient participated in voice evaluation and fMRI prior to surgical rehabilitation and one month following surgery. Six healthy volunteers, with no previous history of neurological illness, served as controls and had a single session of fMRI. Four fMRI paradigms, consisting of three voice production tasks and a finger tapping task, were used. Specifically, the subject generated the "uh" vowel sound for a maximum duration of 4 sec in an active state (repetition=10) with minimal mouth movement, and the task followed a rest state of 16 sec. The "uh" voice production task was performed using three different intonations consisting of high, comfortable, and low pitches. The finger tapping task, was used to provide a baseline to indicate scanner stability for the longitudinal study of the patient. Prior to fMRI scanning, these functional paradigms were practiced outside of the scanner until subjects could execute the task successfully. In addition, all subjects underwent standardized voice evaluation serving as a secondary endpoint. The evaluation included a battery of acoustic and aerodynamic tests as part of a standard voice assessment protocol.

Method and Data Analysis

T1-weighted images for 26 axial slices were acquired for the anatomical reference images. Functional images were acquired with a gradient echo EPI sequence (TR=2000 ms; TE=30 ms; 128×128 matrix; 240 mm FOV; 4.5 mm in thickness) with 3T GE scanner. 3D T1-weighted images were acquired with a spoiled gradient-recalled acquisition in a steady state sequence. The slices were acquired parallel to the AC-PC line. Image analysis was performed with AFNI (2). The reconstructed fMRI data was aligned using a 3D rigid-body registration method. Spatial smoothing, using a gaussian filter of 4mm, and temporal filtering, reducing high frequency noise were applied. A deconvolution analysis was applied to the signal time series to generate statistical maps and to derive the hemodynamic impulse response function on a voxel-wise basis. The inherent difference in the time scales of BOLD and voice induced signal changes has been used to minimize voice-correlated motion artifacts by discarding the first few images after voice production (3). Additionally, to reduce false positive activity due to large venous structures, voxels were set to zero where the standard deviation of the acquired time series exceeded 6-8 percent of the mean signal intensity. Anatomical and functional images were converted to standard Talairach atlas space with 1mm^3 voxels. For healthy control group analysis, voxel-wise t-tests were conducted, comparing the experimental task to the baseline with generated t-value activation maps at $p<0.001$. Functional activities from the fMRI studies before and after surgical treatment were detected and compared to healthy controls. Voice evaluation as a behavioral output was also performed.



Results

Controls (Figures A, B, C): Statistical maps (p<0.001) obtained from group analysis show significant activations in the following areas: *Comfortable Pitch*: bilateral cerebellum; left hemisphere only: precentral gyrus, superior temporal gyrus, inferior parietal lobe, medial and middle frontal gyri, cingulate gyrus, and insula. *High Pitch*: bilateral precentral gyri, inferior frontal gyri, inferior parietal lobe, middle temporal gyri; left hemisphere only: medial frontal gyri. *Low Pitch*: bilateral precentral gyri, inferior frontal gyri, superior temporal gyri; left hemisphere only: insula; right hemisphere only: cerebellum.

Patient (pre vs post): Prior to surgical intervention *(pre)*, significant activations were evident in bilateral postcentral gyri in all voice production tasks. In addition, greater degrees of activation when compared to control subjects were noted in bilateral precentral gyri, medial frontal gyri, inferior frontal gyri, left insula, and cerebellum. One month after surgery *(post)*, acoustic and aerodynamic measures showed significant improvement and correlated well with fMRI results, which showed similar areas and comparable volumes of activation compared to healthy controls.

Discussion

Prior to surgical intervention, the subject with UVCP demonstrated significant, increased areas of activation in many of the same cortical regions evident in control subjects, with additional activation in somatosensory areas, possibly indicating central mechanisms of adaptation to/compensation for peripheral changes at the level of the larynx. One month post-surgery, areas and degree of activation were noted to be comparable to controls. fMRI data positively correlated with quantitative improvements in acoustic and aerodynamic vocal parameters, showing a return to vocal functioning within normal limits. These findings have the potential to provide valuable information about alterations in cortical sensorimotor organization in response to UVCP and developing methods for assessing and providing treatment for disability associated with voice pathology.

References

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