Brain activation during Tongue Motor and Swallowing tasks:A Functional MRI Study in healthy Volunteers and Patients with Tongue Cancer

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Introduction

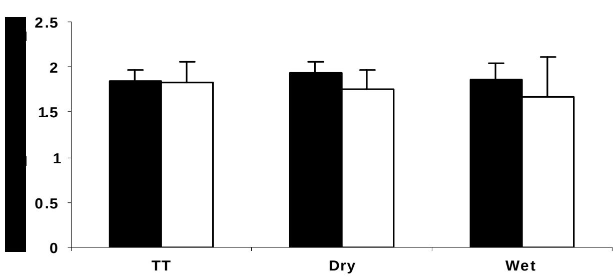
The central nervous system (CNS) response, including cortical reorganization and plasticity, to peripheral injury is poorly understood. Given the precise regulation required for deglutition, peripheral injury to the structures associated with swallowing are likely to elicit a substantive CNS response. Ultimately, rehabilitation strategies which target not only the peripheral deficit, but also the adaptation of the CNS to maximize peripheral function are likely to improve outcomes in this challenging patient population. In this regard, the regulatory response to altered tongue anatomy during swallowing has been previously investigated via functional MRI (fMRI) (1). However, functional tasks including tongue motor, dry, and bolus swallows have not been utilized in this population. In the current study, using fMRI, we seek to provide preliminary data regarding cortical adaptation during three functional tasks to determine the functional task most beneficial to optimize therapeutic strategies and which is the most sensitive to use for future pre and post surgical studies. We hypothesize that tongue motor tasks will be less sensitive than dry or bolus swallowing tasks in patients than in healthy controls.

Subjects and Functional Tasks

The patient population includes nine healthy control subjects (five males and four females) and fourteen tongue cancer patients (nine males and five females). Three fMRI paradigms were applied: 1) Tongue tapping (TT) (press tongue on roof of mouth as fast as possible during “on” period), 2) Dry swallow (Dry) (swallow saliva as many times as possible during “on” period), and 3) Bolus swallow (Wet) (slowly infused 3 ml of water into oral cavity during “on” period and subject swallowed 3-4 times). The paradigm was presented as a block design, consisting of 62 images, with 4 intervals (3 images) of paradigm execution alternating with 5 intervals (10 images) of rest. Stimuli was presented by giving subject verbal instructions through headphones. Prior to scans, investigators instructed and confirmed patient’s ability to perform the tasks.

Method and Data Analysis

The functional studies were performed on a 1.5T GE using echo planner imaging. Functional images were acquired with TR=4000 ms; TE=40 ms; 90° flip angle; 128×128 matrix; 240 mm FOV; 4.5 mm thickness. 26-28 oblique axial slices were acquired parallel to the AC-PC line. 2D and 3D T1 weighted anatomical images were acquired with a spin echo and a spoiled GRASS sequence to overlay functional activity. Image processing and analysis were performed with AFNI software (2). Reconstructed fMRI data were aligned using a 3D rigid-body registration. Motion parameters generated during slice registration were used as regressors to reduce motion-correlated activation. Images were then de-trended of low-frequency drifts. Spatial smoothing using a 4 mm Gaussian filter and temporal filtering was used to reduce high frequency components in the time series. Statistical activation maps were generated based on the blood oxygenation-level dependent (BOLD) signal percentage change. To reduce additional false positive activity from large venous structures or random signal fluctuations, voxels in which the standard deviation of the acquired time series exceeded 6~8 % of the mean signal intensity were set to zero. From the data for each task, ten voxels revealing the greatest activation within the tongue movement associated region, were selected, averaged together, and used to generate corresponding BOLD signal percent change maps. Statistical significance between average signal change values were assessed using t-tests.



Results and Discussion

Individual subject analysis indicated that significant precentral gyrus activity associated with tongue movement was observed during the functional tasks in all subjects. The figure shows histogram of BOLD signal percentage changes obtained from three functional tasks in healthy controls (black) and patients (white). In controls, averaged values were TT: 1.8% (SD=0.1), Dry: 1.9% (SD=0.1), and Wet: 1.8% (SD=0.1). For patients, averaged values were TT: 1.8% (SD=0.2), Dry: 1.7% (SD=0.2), and Wet: 1.6% (SD=0.4). There is good agreement with previous study (3) showing that healthy controls have greater activity in the precentral gyrus with dry swallow than with wet swallow. Statistically significant differences were found between controls and patients using dry swallowing ($p<0.006$). A trend showing statistical differences was found using bolus swallowing ($p<0.08$). No statistical significance was found using tongue tapping ($p<0.3$). The implications of these findings are evolving and will contribute to our increased insight into the role of the CNS and ultimately direct rehabilitation strategies for patients with swallowing disorders.

1. Mosier KM, et al., Annals of Otology, Rhinology & Laryngology 2005; 114(9): 681-687, 2. Cox RW., Comput Biomed Res 1996; 29(3): 162-73, 3. Mosier, KM, et al., Laryngoscope 1999; 109: 1417-23.