A fMRI Study of Correlation Between Acupoints and Brain Cortical Sites Involved in Language Functions

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In this study, cortical sites implicated in language functions were identified in 24 volunteers using a standard functional MRI (fMRI) protocol and a word generation paradigm. Significant activation was seen in Brodmann's areas (BAs) 9/46, 47 and 37. In the same cohort without using the word generation paradigm, bipolar electrical stimulation of acupoints (SJ8 or DU15), which are relevant to language disorders according to ancient Oriental literature, produced significant activation in the BAs 9/46, 37and 18. Similar stimulation over the adjacent non-acupoints failed to activate the brain. Our results indicate that some cortical sites implicated in language functions can be activated by stimulation over specific peripheral acupoints. Ability of acupuncture over SJ8 or DU15 in selective activation of functional brain sites for language may provide a central mechanism responsible for the benefit of acupuncture in language disorders.

Introduction

In recent years, acupuncture has become widely accepted by patients and aroused interest in the scientific community. In the Western literature, accumulating data supports the therapeutic benefit of acupuncture in many medical disorders. Nevertheless, it remains mysterious how acupuncture really works.

Under physiological condition, increased neuronal activity will be matched by vasodilatation. The latter will, in turn, increase the regional oxygen saturation within the venous blood. MRI can measure such tiny changes in the regional blood oxygenation using the blood oxygenation level dependent (BOLD) effects. As physiological maneuvers are used to increase neuronal activity over specific brain regions, functional MRI (fMRI) study provides a non-invasive method of functional brain mapping. Wu and colleagues (1999) used fMRI to study the central nervous system pathway for acupuncture-induced analgesia. More recently, acupuncture-stimulated activation of visual (Cho et al., 1998) and auditory (Cho et al., 2000) cortices has been observed using fMRI.

According to ancient Oriental literature, acupoints known as SJ8 and DU15 are treatment points for language disorders. The purpose of this study was to correlate the fMRI cortical sites activated by a language paradigm with that obtained by electrical stimulation of the SJ8 or DU15 acupoints.

Methods

Informed written consent form was obtained in 24 healthy Mandarin-speaking Chinese male volunteers aged between 19 and 26 (median age of 22) years. Their handedness was determined by their responses to an inventory devised by Snyder and Harris [1993]. Using a 5-point scale to score each task with 1 for exclusive use of left hand and 5 for exclusive use of right hand, the lowest sum of scores of 9 indicates strongest left-handedness while the highest sum of scores of 45 indicates strongest right-handedness.

All MRI studies were done in a 1.5 T Siemens MRI scanner at the MRI Center of Chang Guang Memorial Hospital, Taiwan. The subject was first familiarized with the experimental procedures and the environmental conditions to minimize anxiety and enhance task performance. Next, the subject lied supine on the scanning table and was supported by a body-length, vinyl-upholstered, dense foam pad. The subject was then fit with plastic ear-canal molds with the head immobilized by a tightly fitting, thermally molded, plastic facial mask extending from the hairline to chin.

The fMRI study employed a block design of ABAB for mapping cortical sites activated by a word generation paradigm with A representing rest and B representing the task. Each resting or stimulation period lasted 30 s. The word generation task consisted of comprehending the meaning of single Chinese characters shown through the goggle and using the single Chinese characters to make up as many meaningful two-character Chinese words as possible. Mapping of language sites was repeated after insertion of the acupuncture needles without electrical stimulation. Four needles were inserted: 2 over the acupoints SJ8 on both arms and 2 over the non-acupoints at 1 cm lateral to the acupoints SJ8 on both arms. Four needles were inserted 2 over the acupoints DU15 about 1 cm directly above the midpoint of the posterior hairline and 2 over the non-acupoints at 1 cm lateral to the acupoints DU15 on both side of the head. Bipolar electrical stimulation of the acupoints or the non-acupoints at 2 Hz was made with the positive electrode over the left side and negative electrode over the right side. Intensity of the electrical stimulation was set at the mid level between the barely perceptible level and the maximally tolerable level. A block design of RARBRBRARARB was used for mapping cortical sites activated by electrical stimulation of the acupoints or the non-acupoints with R representing rest, A representing stimulation over the non-acupoints (i.e. control acupuncture task) and B representing stimulation over the acupoints (i.e. active acupuncture task). Each period lasted 45 s.

Matlab and cluster analysis technique were used to process the image data with corrections for head motion and global MRI signal shift. Skull stripping of the 3D MRI T_1-weighted images was done using Alice software. Processed images were then spatially normalized to the Talairach brain atlas using the Convex Hull algorithm.

fMRI images were divided into groups according to the period of data collection: resting state, language task, control acupuncture task with stimulation of non-acupoints, and active acupuncture task with stimulation of acupoints. Images from the first 8-sec of each condition were excluded from further functional data processing to minimize the transit effects of hemodynamic responses. Activation maps were obtained by comparing the data acquired during the task state with those acquired during resting state, using a paired student's t-test. Activation maps were also spatially normalized into Talairach space using the Convex Hull algorithm and overlaid on the corresponding T_1 images. Using a threshold t value of 3.106 ($p < 0.01$), activation maps of the 12 subjects were combined into an overall map. For each condition, Talairach coordinates of the center-of-mass and volume (mm^3) of the activation clusters were determined based on the averaged activation maps. Anatomical labeling of lobes and gyri and designation of BAs were automatically applied using a 3-D electronic brain atlas.

Results

All 24 subjects were strongly right handed with scores higher than 40 on the handedness inventory devised by Snyder and Harris [1993]. BAs 9/46, 47 and 37 over both left and right hemispheres showed significant, positively activated pixels in response to the word generation task (Fig. 1A). Insertion of acupuncture needles without electrical stimulation did not affect the activation map due to the word generation task (Fig. 1B). BA 9/46 of the left hemisphere showed significant, positively activated pixels in response to electrical stimulation of the SJ8 acupoints (Fig. 1C). Comparing the activation map of acupoint stimulation with that of the non-acupoint stimulation showed significant, positively activated pixels in left middle frontal gyrus (BA 9/46), left middle occipital gyrus (BA 18) and right temporal fusiform gyrus (BA 37) (Fig. 1D). Activated pixels were rarely seen during non-acupoint stimulation (Fig. 1E).

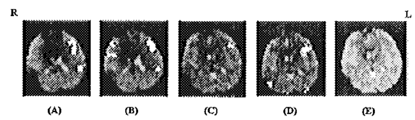

Fig. 1. Overall activation map of the 12 subjects during each of the following tasks: A, word generation task; B, word genration task with acupuncture needle inserted into acupoints and non-acupoints with no electrical stimulation; C, bipolar acupoint stimulation; D, bipolar acupoint stimulation minus non-acupoint stimulatoin; and E, non-acupoint stimulation. Significant, positively activated pixels are displayed lighter than backgroung. Statistical ignificance was set at $P < 0.01$. Brain regions significantly activated during each task are discussed in the text.

Discussion

Our results indicate that language areas (BAs 9/46, 18, 37) on both hemispheres were activated during the language task or during stimulation of acupoints relevant to language disorders according to ancient Oriental literature. The left frontal regions (BAs 9/46) were much more strongly activated (Fig. 1) than the right frontal regions, demonstrating left hemispheric dominance in right handed people. The left frontal region (BA 9) is involved in semantic processing of words (Poldrack et al., 1999). Activations in the left middle occipital gyrus (BA 18) are probably involved in the processing of the visual properties of words (Tan et al., 2000). The basal temporal fusiform gyrus (BA 37) is involved in word recognition (Brunswick et al., 1999) and is an association region that integrates converging inputs from many brain regions (Buchel et al., 1998).

Conclusion

This present study demonstrates some correlation between cortical sites activated by a language task and those sites activated by electrical stimulation of acupoints implicated in language disorders. Such an ability to activate relevant cortical sites may underlie the benefit of acupuncture in various diseases such as language disorders.

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