Introduction

The most common use of fMRI is for the presurgical mapping within the Rolandic tumor surgery (1). Compared with the motor fMRI studies, there are a few visual fMRI studies in patients with tumor in or near the visual cortex. The visual fMRI is used in clinical areas including visual pathway imaging, evaluation of cortical activation in patients with visual field defect or optic neuritis, amblyopia, evaluation of chiasma anomalies and presurgical mapping in patients who are candidates for brain surgery (2). These studies generally give information about the course of the disease, treatment of choice and plan of the surgery. However, there is a question that merits consideration: because of it is based on the activation created by vision, should we correct the refractive errors to achieve the accurate results, in visual fMRI studies. On review of the literature, we found only two studies that evaluated the effects of refractive errors on fMRI of visual cortex. In this study, we aimed to evaluate the requirement of correction of refractive errors and the effect of induced myopia on visual fMRI.

Material and Methods

The institutional ethics committee approved the study protocol and the written informed consent form was obtained from all patients before procedure. A prospective study including 13 patients with refractive error (group 1) and 30 emetropic volunteers (group 2). Group 2 was also subgrouped as 20-32 years old (young) and over 45 years old (old) to analyse accommodation effect. fMRI data were acquired with a block design paradigm with 3 Tesla MR system. In both groups, images initially were acquired in normal refractive state. fMRI was performed again in both groups during refractive error. Activation areas on visual cortex were calculated as square centimeter. Total activated areas on visual cortex was compared between normal refractive state and induced/uncorrected refractive error.

Results:

In group 1, activation areas of visual cortex during uncorrected refractive error revealed significantly decrease compared with activation areas during corrected refractive error (p=0.001). In group 2, induced myopia resulted significant decrease in activation areas compared with normal refractive state. Decrease in activation areas were significant both in 2 and 4 diopters (D) of myopia compared with normal refractive state (p=0.003, p<0.001 respectively). Both in young and old subgroup, activation areas were significantly decreased during induced myopia. We revealed no difference between young and old subgroups.

Conclusion:

The refractive errors have a clear effect on fMRI of visual cortex. Thus, to achieve accurate results they should be corrected in patients that included in the visual fMRI study.

Keywords: Refractive errors, Functional magnetic resonance imaging, Visual cortex
(TR: 2460 ms TE: 15 ms Ti: 400 FOV:200x200 Matrix: 264x210 Flip Angle: 90) and ecoplanar imaging (TR: 3000 ms TE: 35 ms FOV:230x230 Matrix: 96x96 Flip Angle: 90 ) sequences in axial plane were acquired for each patient. The fMRI task was a block design paradigm consisted of 5 alternating 30 s periods of rest and stimulation. The rear projection system and mirror was used in this study. Visual stimuli were shown via a liquid-crystal display (LCD) projector on a rear-projection screen. We used a picture composed of Bosphorus bridge and Eiffel tower. The patients were asked to look at the screen but not to get fixed at a point. The screen was viewed via an angled surface mirror attached to the head coil. In group 1, images were initially acquired with MR compatible eyeglasses and then without eyeglasses. In group 2, images were initially acquired without any eyeglasses and then with induced myopia via +2D lenses in 15 volunteers and +4D lenses in the other 15 volunteers. By this way in group 1 and group 2, images were initially acquired in normal refractive state and then with refractive error. After image acquisition, activated areas on visual cortex was calculated as square centimeter in another workstation (Release 2,5,3,0 2007-12-03, Philips Medical System). Cluster size was set to 4, threshold was set to between 3 and 5 according to patient. In both groups activated areas on visual cortex were calculated during normal vision initially and then with refractive error. During normal vision, activated areas in group 1 (with their glasses/lenses) were compared with group 2 (without lenses) to make sure that refractive errors are truly corrected. Then activated areas on visual cortex during refraction error were compared with the activated areas during normal vision by drawing region of interest (ROI) manually. The variables were investigated using visual and analytical methods to determine whether or not they are normally distributed. Since the measurements of activated areas in group 1 and group 2 were not normally distributed, nonparametric tests were conducted to compare these parameters. The Wilcoxon test was used to compare the change between activated areas during normal refractive state and activated areas during induced/uncorrected refractive error. The Mann-Whitney U test was used to compare the percentage of decrease of activated areas between induced 2D and induced 4D myopia. A p-value of less than 0.05 was considered to show a statistically significant result.

Results

Comparing group 1 and group 2 revealed no statistically significant difference of total activated areas on visual cortex during normal vision (p=0.539) that showed all refractive errors are corrected truly. In group 1, age and refraction degree independent results showed significant decrease of activation areas in refractive error compared with normal vision (p=0.001). Total activated areas decreased %54,35±30,03 in refractive error compared with the normal vision (Table 2). In group 2, induced-myopia resulted decrease of activation areas compared with normal refractive state. Decrease in activation areas was significant both in 2D and 4D myopia compared with normal refractive state (p for 2D=0.001 p for 4D=0.001). Separately evaluation of younger and older subgroups revealed statistically significant decrease of activation areas. In younger subgroup percentage of decrease of activated areas in induced 2D and 4D myopia are %45,77±19,45 (p=0.005) and %81,09±22,63 (p=0.005) respectively (Table 3). Examples are shown in figs. 1 and 2. In older subgroup percentage of decrease of activated areas in induced 2D and 4D myopia are %66,73±12,92 (p=0.043) and %89,67±14,51 (p=0.043) respectively (Table 4). Examples are shown in figs 3 and 4. In group 2, there was a significant decrease of activation in 4D myopia compared with the 2D myopia (p for young group=0.002, p for old group=0.032). We revealed no significant difference between young and old subgroup.

Table 1. Demographic characteristics of group 1 and group 2

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
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<tbody>
<tr>
<td></td>
<td>Younger subgroup</td>
<td>Older subgroup</td>
</tr>
<tr>
<td>Number of patients</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Gender (male/female)</td>
<td>10/3</td>
<td>12/8</td>
</tr>
<tr>
<td>Age (years)</td>
<td>23-61 (36.46±13.43)</td>
<td>20-31 (26.2±3.83)</td>
</tr>
<tr>
<td>Refractive error degree</td>
<td>1.5-4.5 (2.57±0.97)</td>
<td>48-60 (51.7±4.27)</td>
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Table 2. Visual fMRI of group 1. Activated areas of visual cortex of patients during corrected refractive error and during refractive error.

<table>
<thead>
<tr>
<th>Number of patients (n=13)</th>
<th>Activated area during normal refraction (corrected refractive error) (cm²)</th>
<th>Activated area during refractive error (cm²)</th>
<th>Decrease of activation (%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.64±8.42</td>
<td>8.50±7.15</td>
<td>54.35±30.03</td>
<td>0.001</td>
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Figure 1: BOLD images of an emetropic volunteer in younger subgroup. Upper images obtained during normal refraction and lower images obtained during induced 2D myopia. Images show the decrease of activation during myopia compared with the normal refraction.

Table 3. Visual fMRI of younger subgroup of group 2. Activated areas of visual cortex of younger emetropic subgroup during normal refraction and induced myopia.

<table>
<thead>
<tr>
<th>Induced 2D myopia (n=10)</th>
<th>Activated area during normal refraction (cm²)</th>
<th>Activated area during induced myopia (cm²)</th>
<th>Decrease of activated area (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.67±9.29</td>
<td>10.43±4.25</td>
<td>45.77±19.45</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Induced 4D myopia (n=10)</td>
<td>30.98±23.42</td>
<td>5.64±7.04</td>
<td>81.09±22.63</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Figure 2: BOLD images of an emetropic volunteer in older subgroup. Upper images obtained during normal refraction and lower images obtained during induced 2D myopia. Images show the decrease of activation during myopia compared with the normal refraction.
Myopia is a global public health concern and is the most common eye disorder in the world (3). Ganesan reported that myopia may be graded as; mild myopia (spherical equivalent from -0.50 DS to -3.0 DS) moderate myopia (spherical equivalent from 3.0 DS to -5.00 DS) and high myopia (spherical equivalent less than -5.00 DS) (4). In our study we induced mild and moderate myopia by using +2D and +4D lenses. Accommodation is the ability of the lens to increase the refractive power. Presbyopia which
is the loss of accommodative ability due to decrease in lens elasticity, is the most common disease that affects the accommodation (5). The amplitude of accommodation decreases by age and around the age of 40 years symptoms may manifest (6). Thus we subgrouped the group 2 as young and old to analyze presbyopia and accommodation effect. Presurgical fMRI provides convenience in radical but function-preserving surgery (7). The most common use of fMRI for presurgical mapping is the motor fMRI in the rolandic tumor surgery (1). Compared with the motor fMRI studies, there are a few visual fMRI studies in patients with tumor in or near the visual cortex. There are visual fMRI studies that demonstrate the changes in visual cortex in different diseases (8-12). But on review of the literature, we found only two study that focus on the effect of refractive errors on visual fMRI. Elbel GK et al. (13) found that induced myopia caused a reduction of the blood oxygenation level dependent response more than >20%. Mirjazani et al. (14) studied the effects of induced myopia by 1D, 3D and 5D lenses. They reported a decrease in activated areas during induced myopia compared with the normal vision respectively %27.2, %13 and %38. They found no significant differences between 1D, 3D and 5D myopia. But they reported that induced 1D myopia changed the fMRI results significantly (14). In our study induced myopia resulted with statistically significant decrease in activation areas within the induced 2D and 4D myopia. The percentage of decrease was greater in 4D than 2D. These results showed that mild and moderate myopia have a significant effect on fMRI of visual cortex. Also an increase in the degree of the myopia results with more decrease of activation areas. We did not find any significant difference between younger and older subgroups in group 2.

In group 1 total activated areas significantly decreased during refractive error compared with the normal vision. Because of the limited number of the patients we did not subgroup the group 1 as younger and older. But individual evaluation revealed that percentage of decrease of activation areas was greater in older patients than in the younger patients with same refractive error degree. For example in a younger patient with -2,25 D myopia, fMRI data revealed %21,6 decrease in activation areas and in an older patient with -2D myopia fMRI data revealed %85,05 decrease in activation areas. We think that this is related to the accommodation effect.

There are two main limitations of our study. First and the major limitation of our study is the small number of patients in group 1. Since the MRI compatible eyeglasses that we used to correct refractive errors was not able to correct astigmatism which usually accompanies with myopia and hypermetropia, we excluded the patients with astigmatism. Second, the duration of the procedure was approximately 10 minutes. It may have been difficult for the patients to keep on looking at the picture, especially at the second period (looking with uncorrected/ induced refractive error). Although the patients claimed that they kept looking at the screen it was difficult to check it.

In conclusion, refractive errors have a clear effect on fMRI of visual cortex. Thus, the refractive errors should be corrected or the patients should be selected from emetropic patients where that visual fMRI study is planned.

References


