Functional MR Imaging of Cerebral Motor Cortex: Comparison between Conventional Gradient Echo and EPI Techniques*

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Purpose : To evaluate the differences of functional imaging patterns between conventional spoiled gradient echo (SPGR) and echo planar imaging (EPI) methods in cerebral motor cortex activation.

Materials and Methods : Functional MR imaging of cerebral motor cortex activation was examined on a 1.5T MR unit with SPGR (TR/TE/flip angle=50ms/40ms/30°, FOV=300mm, matrix size=256×256, slice thickness=5mm) and an interleaved single shot gradient echo EPI (TR/TE/flip angle=3000ms/40ms/90°, FOV=300mm, matrix size=128×128, slice thickness=5mm) techniques in five male healthy volunteers. A total of 160 images in one slice and 960 images in 6 slices were obtained with SPGR and EPI, respectively. A right finger movement was accomplished with a paradigm of an 8 activation/ 8 rest periods. The cross-correlation was used for a statistical mapping algorithm. We evaluated any differences of the time series and the signal intensity changes between the rest and activation periods obtained with two techniques. Also, the locations and areas of the activation sites were compared between two techniques.

Results : The activation sites in the motor cortex were accurately localized with both methods. In the signal intensity changes between the rest and activation periods at the activation regions, no significant differences were found between EPI and SPGR. Signal to noise ratio (SNR) of the time series data was higher in EPI than in SPGR by two folds. Also, larger pixels were distributed over small p-values at the activation sites in EPI.

Conclusions : Good quality functional MR imaging of the cerebral motor cortex activation could be obtained with both SPGR and EPI. However, EPI is preferable because it provides more precise information on hemodynamics related to neural activities than SPGR due to high sensitivity.

Index words : Functional imaging ; EPI ; SPGR ; Motor task

Introduction

Small difference of signal intensities between the activation and rest states by BOLD effect caused functional neuroimages to be prone to the degradation by noises (1—4). Many measurement techniques and statistical methods have been presented for the reliable and meaningful functional neuroimages (5—9). An optimized, robust and reliable

JKSMRM 1 : 109—113(1997)
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* 이 논문은 보건복지부 G7 의료공학기술개발 연구비(HMP-95-G-1-03)의 보조로 이루어졌음
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scan method and map algorithms have, however, been not known yet. Of a variety of statistical methods, cross-correlation method has been known as a reliable tool for obtaining functional map images in the fMRI study using block design. When using the cross-correlation method, the signal to noise ratio (SNR) of time series of signal intensities with a given paradigm will be important for the evaluation of the activation sites and their hemodynamic information. Therefore, high SNR in functional MR raw data may be an important requirement for analyzing brain function more precisely. Currently, either conventional gradient echo or EPI sequences has been used as a tool of functional MR studies and their results were satisfactory, but there were few reports on comparative analysis of the patterns of functional MR images with two methods (10). Our study comparatively investigated the patterns of time series and the signal intensity changes between the rest and activation periods in functional MR study of the cerebral motor cortex with SPGR and EPI techniques. Also, the locations and areas of the activation sites were compared between the two methods.

Materials and Methods

Five healthy and righted-handed men were investigated using interleaved single shot gradient

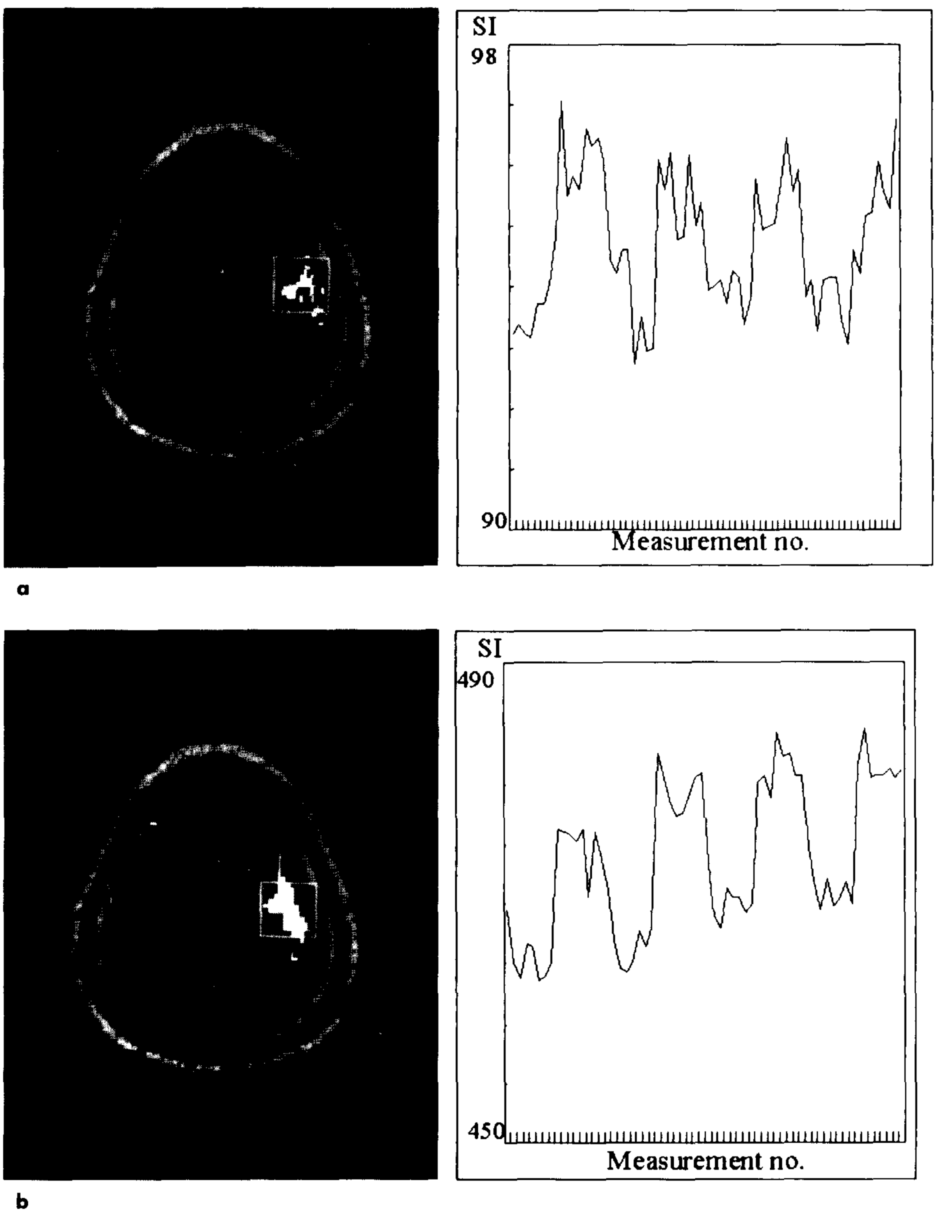

Fig. 1. Activation map images of the right finger movement and the time series of signal intensities at the activation regions with a box ; SPGR (**a**) vs. EPI (**b**). Cross-correlation method was used for a statistical analysis and the pixels with p value below 0.05 are shown.

Table 1. The Average SNRs of the Time Series Data in SPGR and EPI.

Subjects	SPGR	EPI
1	23.0	67.7
2	19.8	32.3
3	28.7	50.2
4	30.8	46.8
5	4.3	34.9
Total	21.3±13.5	46.4±20.2

Note. The SNRs were significantly higher in EPI than in SPGR (p〈0.0001).

echo EPI and SPGR sequences on a 1.5T scanner (GE Signa Horizon) with a quadrature head coil. Six slices were acquired using gradient echo EPI sequence (30cm FOV, 128×128 matrix, TR/TE/α =3000ms/40ms/90°, 5mm slice thickness). In SPGR (30cm FOV, 256×256 matrix, TR/TE/α=50ms/40ms/30°, 5mm slice thickness), one slice containing motor cortex area was scanned of six slices obtained by using EPI sequence. T1-weighted spin echo images were obtained for precise localization of the activation regions and the overlay of functional MR images. Motor task used periodic paradigm of 8 rests/8 activations (right finger movement) in both techniques. In EPI, imaging time was 8 minutes with alternating rest (30 sec) and activation (30 sec) periods, whereas in SPGR imaging time was 30 minutes with alternating rest (130 sec) and activation (130 sec) periods. Finger movement consisted of the alternative stretching and grasping of all right fingers simultaneously at a rate of 1/sec. In EPI and SPGR, a total of 960 and 160 images (10 images/1 rest or 1 activation period/1 slice) were acquired, respectively. All reconstructed images were transferred to an off-line workstation for analysis. In EPI, the first three functional images from each period were excluded from quantitative and statistical analyses in order to achieve steady state conditions in the pretask baseline period and to avoid the transient hemodynamic response delay in task-related activation at the start and end of finger movement. Functional MR images were determined by the cross-correlation method using the reference waveform that matches the paradigm. In one slice selected in SPGR and EPI, we measured SNRs of time series data, the locations and areas of the activation sites, and the signal intensity changes between the rest and activation periods in SPGR and EPI. The SNR was measured as an average of each period's one.

Table 2. The Distribution of the Activation Areas with p-value on Five Volunteers' Functional MR Images : SPGR vs. EPI

unit : mm²

Subject	Sequence	P value: 5e-2 ~ 5e-3	5e-3 ~ 5e-4	5e-4 ~ 5e-5	5e-5 ~ 5e-6	5e-6 〉	Total
1	SPGR	6.9	2.7	4.1	0.0	0.0	13.7
	EPI	8.9	2.8	5.5	1.4	6.2	24.8
2	SPGR	5.5	2.7	6.9	4.1	9.6	28.8
	EPI	5.5	2.8	2.8	4.1	11.7	26.9
3	SPGR	1.4	4.1	0.0	0.0	6.9	12.4
	EPI	1.4	2.8	4.8	4.8	6.9	20.7
4	SPGR	1.4	2.7	0.0	0.0	2.7	6.9
	EPI	4.1	1.4	1.4	1.4	12.4	20.7
5	SPGR	5.5	1.4	0.0	0.0	1.4	8.2
	EPI	3.4	3.4	1.4	0.0	5.5	13.7

Results

EPI and SPGR techniques provided similar activation regions located at premotor cortex and the surrounding central sulcus (Fig. 1). However, EPI technique showed higher SNR than SPGR in time series data at motor cortex area by a factor of two. The SNRs in five volunteers were summarized in Table 1. Activation areas in EPI than in SPGR were significantly larger (Table 2. 21.4±5.1 and 14±8.7mm² in EPI and SPGR, respectively, paired student t-test, p〈0.05). Also, Table 2 shows that larger pixels in EPI than in SPGR were distributed over small p-values at the activation sites. In the signal intensities changes between the rest and activation periods at the activation regions, no significant differences were found between EPI and SPGR (1.64±0.34 and 1.56±0.54% in EPI and SPGR, respectively).

Discussion

Because MRI techniques used in the functional MR study were based on a BOLD effect with very small changes (5−10%) in cerebral blood oxygenation (1), the SNR of MR raw data was of very importance for a functional map. In our study, the SNR of time series data at cortical motor areas was higher in EPI than in SPGR. Therefore, these results suggest that more detailed information on hemodynamics in functional MR study can be obtained by using EPI than SPGR. Time series data may be degraded by a variety of sources such as random noise, systematic noise due to MR characteristics, subjects' motion and physiological noises due to cardiac and respiratory pulsations (2—4). High performance in MR system components has made their noises to be ignored. Thus physiological noises may be a major source for determining SNR of time series data. In SPGR, time resolution available was about 8—11 sec, which MR raw data to be easily affected by subjects' motion and physiological motion such as CSF pulsation. These motion-induced noises reduce SNR in time series of SPGR. But in EPI a better temporal resolution overcomes the motion-related artifacts, which increases the SNR in time series data. Therefore, in EPI higher SNR of functional MR raw data may cause the activation areas to be larger than in SPGR at functional MR images by the cross-correlation method and p-values of the activation pixels to be shifted to smaller. More detailed information on hemodynamics in functional MR study can be obtained by using EPI than SPGR because of increased sensitivity in EPI.

Better spatial resolution and no geometric distortion in SPGR may provide advantages in spatial information of the activation sites over EPI (11, 12). But, our study shows that EPI and SPGR techniques made no significant difference in the localization of the motor cortex and the signal intensities changes between the rest and activation periods, which suggests the usefulness of two methods for localizing the activation sites in a functional MR study.

In conclusion, although both SPGR and EPI are useful in fMRI study, EPI method is preferable due to higher SNR and short imaging time.

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대한자기공명의과학회지 1:109-113(1997)

뇌 운동피질의 기능적 영상: 고식적 Gradient Echo기법과 EPI 기법간의 비교

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목 적: 고식적인 spoiled gradient echo (SPGR) 기법과 EPI 기법간의 뇌의 운동피질에 대한 기능적 영상의 차이를 평가하고자 하였다.

대상 및 방법: 5명의 정상 성인을 대상으로 1.5T 자기공명영상기기에서 SPGR기법(TR / TE / flip angle=50ms / 40ms / 30°, FOV=300mm, matrix size=256×256, 단면 두께=5 mm)과 EPI 기법 (TR / TE / flip angle=3000ms / 40ms / 90°, FOV=300mm, matrix size=128×128, 단면 두께=5mm)을 사용하여 MR 데이터를 얻었다. EPI 기법의 경우, 총 6개의 단면에 대해 총 960개의 영상을 얻었고 SPGR 기법 경우, 위 6개의 단면 중 운동중추영역이 포함된 한 단면에 대해 총 160개의 영상을 얻었다. 사용된 paradigm은 각각 8번의 휴지 기간과 활성 기간으로 구성되었고 활성기간동안에 시행된 작업은 오른손 손가락의 쥠과 펼침 운동이었다. 뇌의 활성영역을 국소화 하기 위해 사용된 통계적인 처리방법은 cross-correlation 방법이었다. 두 기법의 활성화 영상에 대해 활성 영역에서의 휴지 기간과 활성 기간간의 신호 크기의 변화와 연속적인 MR 데이터의 신호 대 잡음비의 측정, 그리고 활성 영역의 위치와 그 범위를 비교 분석하였다.

결 과: 두 기법 모두에서 운동중추영역인 전운동피질이 잘 관찰되었다. 휴지 기간과 활성 기간간의 신호 크기의 변화는 두 기법간의 유의한 차이가 없었다. 그러나, 연속적인 MR 데이터의 신호 대 잡음비에 있어서는 EPI 기법이 SPGR 기법보다 약 2배 높았다. 또한, 활성 영역에 있어서 EPI 기법이 SPGR 기법보다 낮은 쪽으로의 p 값의 분포를 보여 주었다.

결 론: 본 연구는 운동중추영역에 대한 뇌의 기능적 영상을 얻는 데에 있어서 두 기법 모두 유용함을 보여주었다. 그러나, EPI 기법에서 얻을 수 있는 높은 신호 감도 특성에 의해 EPI 기법이 SPGR 기법보다 뇌의 기능적영역에 대한 더 정확한 정보를 제공하는 장점을 지닌다.

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