Clinical Application of Functional MRI

Kyoung-Min Lee, M.D., Ph.D.

Department of Neurology, Program for Cognitive Science, Neuroscience Institute, Seoul National University

(functional magnetic reso-
nance imaging, fMRI) 1992 Ogawa
[1]

,
(positron emission tomogra-
phy, PET)
, (intrinsic contrast agent)
,

.
,

,
.

fMRI
,
,
. ,

.

1. fMRI

1)

fMRI

MRI
. ,
MR (perfusion MRI) , ,

(blood oxygenation level depen-
dent, BOLD) MR .
,
. , BOLD

[2]

Turbo ASL, FAIR arterial spin labeling
fMRI
, [3,4] ,
,
, MRI
fMRI
BOLD .

.

(oxyhemoglobin) ,
(deoxyhemoglobin)
.

$T2*$. ,

$T2*$.
MR
BOLD [5]
fMRI

BOLD (

* Address for correspondence
Kyoung-Min Lee, M.D., Ph.D.
Department of Neurology,
Seoul National University Hospital,
Yongon-dong 28, Chongno-gu, Seoul, 110-744, Korea
Tel : +82-2-760-2985   Fax : +82-2-3672-7553
E-mail : kminlee@snu.ac.kr

, volume element=voxel) .

. Blocked design

(echoplanar imaging, EPI) spiral
sequence imaging (efficiency)
[6,7] single trial design .[11] single trial
design

. EPI fMRI ,
2~5% , blocked design
, 3
(repetition time) . [10]

, fMRI
BOLD T2* 2) fMRI
, fMRI
.

BOLD

. ,

. ,
4~6
, ,
(undershooting) .[8]
(hemodynamic .
response function, HRF) . BOLD UCLA AIR package
HRF ,[12]
, fMRI Talairach coordinate .[13]
. , fMRI
HRF fMRI , smoothing ,
. ,
HRF , 3
BOLD
. . ,
fMRI , 16 ,
.[9] ,

BOLD .
. fMRI
blocked ,
design . .
, ,
, 20~30 ,
, .
. 5 fMRI
(cognitive 1) MR (realignment),
subtraction) . , single 2) (spatial normalization),
event design blocked design 3) MR (statistical
.[10] inference) .
BOLD fMRI

MRI , ,
BOLD

fMRI   ,

        . fMRI   fMRI

2~ 5%   mm

        (   )   ,   BOLD

                                                                            .[14]   .

                                                                fMRI

                                                                                                .

                    .

            ,

                                                                    .

            .

                                                                        .

                                                                                ,

        .   ,

                                .   .[17]

Talairach   Tournoux   ,   ,

                                                                                        .   ,

            .[13]

    fMRI   fMRI

        MR   .[18]   ,

                                .

                MR   ,

    (statistical parametric map)   .

                        ,   , t-   .

                                                                    fMRI

            .[15]   ,

                                                                                        .   ,

                                .   .

                        SPM99   Gaussian   ,

random field theory   ,

                                        .[16]

    2. fMRI   .   , fMRI   MRI   ,   ,

            fMRI

                            ,   ,

                    .   .

                .

                                                                            .   ,

        ,   .

    fMRI   ,

                    ,   .

                                                                                        , fixed effect

        .   ,   , random effect

,   ,   8   .[19]

                                    fMRI   ,

                    .   MRI   .

, (premotor area) .

(post-central gyrus) ,
,
,
. .

fMRI ,
,
. , fMRI . Yetkin
28 fMRI
. fMRI ,
fMRI 100% fMRI
20 mm , 87% 10 mm
. [20]
. ,
fMRI , ,
fMRI , ,
. , fMRI
fMRI
, 8~ 30%
. [20-22] , ,
fMRI ,
. .

fMRI 25
, 1 cm 12 6
, 1~ 2 cm 6 2
. , fMRI . [22] 2
cm 7
, . [22] MRI
. ,
fMRI
- . , ,

3. fMRI
1) . [21]
fMRI ,
, PET 2)
. fMRI
fMRI ,
. , . ,
fMRI
, , ,
,
. fMRI
. ,
-
. [22-25]
. (localiza-

tion)   (lateralization)
                                        Wada
                              ,
                    ,
            .
              ,   fMRI
          .   fMRI   Wada
                        ,
            Wada
                                    .
                        fMRI
            ,
                                        .
Thulborn

                                    .[26] Cao

                    ,
                            .[27]

            fMRI
                            .   ,

                                ,   ,
            ,   ,
                        .   ,

                        .   ,

                    .   ,
                            .   ,

                    .   ,
                                    ,
                            .
            ,
                                    ,

        , fMRI

                    .

REFERENCES

1. Ogawa S, Tank DW, Menon R, Ellermann JM, Kim SG, Merkle H, Ugurbil K. Intrinsic signal changes accompany- ing sensory stimulation: functional brain mapping with magnetic resonance imaging. *Proc Natl Acad Sci USA* 1992;89:5951-5.

2. Wong EC, Buxton RB, Frank LR. Quantitative perfusion imaging using arterial spin labeling. *Neuroimaging Clin N Am* 1999;9:333-42.

3. Wong EC, Luh WM, Liu TT. Turbo ASL: arterial spin labeling with higher SNR and temporal resolution. *Magn Reson Med* 2000;44:511-5.

4. Zaini MR, Strother SC, Anderson JR, Liow JS, Kjems U, Tegeler C, Kim SG. Comparison of matched BOLD and FAIR 4.0T-fMRI with [15O]water PET brain volumes. *Med Phys* 1999;26:1559-67.

5. Zarahn E. Spatial localization and resolution of BOLD fMRI. *Curr Opin Neurobiol* 2001;11:209-12.

6. Stehling MK, Turner R, Mansfield P. Echo-planar imag- ing: Magnetic resonance imaging in a fraction of a second. *Science* 1991;254:43-50.

7. Glover GH. Simple analytic spiral K-space algorithm. *Magn Reson Med* 1999;42:412-5.

8. Glover, G.H. Deconvolution of impulse response in event- related BOLD fMRI. *NeuroImage* 1999;9:416-429.

9. Hathout GM, Gopi RK, Bandettini P, Gambhir SS. The lag of cerebral hemodynamics with rapidly alternating periodic stimulation: modeling for functional MRI. *Magn Reson Imaging* 1999;17:9-20.

10. D'Esposito M, Zarahn E, Aguirre GK. Event-related func- tional MRI: implications for cognitive psychology. Psychol Bull. 1999;125:155-64.

11. Liu TT, Frank LR, Wong EC, Buxton RB. Detection power, estimation efficiency, and predictability in event- related fMRI. *Neuroimage* 2001;13:759-73.

12. Woods RP, Grafton ST, Holmes CJ, Cherry SR, Mazziotta JC. Automated image registration: I. General methods and intrasubject, intramodality validation. *J Comput Assist Tomogr* 1998;22:139-52.

13. Talairach J, Tournoux P. *Co-planar stereotaxic atlas of the human brain*. Stuttgart, Germany: Thieme Verlag, 1988.

14. Hajnal JV, Saeed N, Soar EJ, Oatridge A, Young IR, Bydder GM. A registration and interpolation procedure for subvoxel matching of serially acquired MR images. *J Comput Assist Tomogr* 1995;19:289-96.

15. Poline JB, Holmes A, Worsley K, Friston KJ. Making sta- tistical inferences. In: Frackowiak RSJ, Friston KJ, Frith CD, Dolan RJ, Mazziotta JC. *Human Brain Function*. New York: Academic Press. 1997.

16. Worsley KJ. An overview and some new developments in the statistical analysis of PET and fMRI data. *Human Brain Mapping* 1997;5:254-258.

17. Lee KM, Lee SH, Kim CY, Kim NY, Chang KH, Roh JK. Technical improvement of functional MRI for clinical application. *J Korean Neurol Assoc* 1999;17:222-227.

18. Sunaert S, Van Hecke P, Marchal G, Orban GA. Attention

to speed of motion, speed discrimination, and task difficulty: an fMRI study. *Neuroimage* 2000;11:612-23.

19. Friston KJ, Holmes AP, Worsley KJ. How many subjects constitute a study? *Neuroimage* 1999;10:1-5.

20. Yetkin FZ, Mueller WM, Morris GL, McAuliffe TL, Ulmer JL, Cox RW, Daniels DL, Haughton VM. Functional MR activation correlated with intraoperative cortical mapping. *AJNR Am J Neuroradiol* 1997;18:1311-5.

21. Atlas SW, Howard II, Robert S, Maldjian J, Alsop D, Detre JA, et al. Functional Magnetic Resonance Imaging of Regional Brain Activity in Patients with Intracerebral Gliomas: Findings and Implications for Clinical Management. *Neurosurgery* 1996;38:329.

22. Haughton VM, Turski PA, Meyerand B, Wendt G, Moritz CH, Ulmer J. The clinical applications of functional MR imaging. *Neuroimaging Clin N Am* 1999;9:285-93.

23. Yetkin FZ, Mueller WM, Morris GL, McAuliffe TL, Ulmer JL, Cox RW, et al. Functional MR activation correlated with intraoperative cortical mapping. *AJNR* 1997;18:1311-5.

24. Desmond JE, Sum JM, Wagner AD, Demb JB, Shear PK, Glover GH, Gabrieli JD, Morrell MJ. Functional MRI measurement of language lateralization in Wada-tested patients. *Brain* 1995;118:1411-9.

25. Binder JR, Swanson SJ, Hammeke TA, Morris GL, Mueller WM, Fischer M, et al. Determination of language dominance using functional MRI: a comparison with the Wada test. *Neurology* 1996;46:978-84.

26. Thulborn KR, Carpenter PA, Just MA. Plasticity of language-related brain function during recovery from stroke. *Stroke* 1999;30:749-54.

27. Cao Y, Vikingstad EM, George KP, Johnson AF, Welch KM. Cortical language activation in stroke patients recovering from aphasia with functional MRI. *Stroke*. 1999;30:2331-40.