CHAPTER A6
Clinical fMRI

INTRODUCTION

Clinical functional MRI (fMRI), in the context of this chapter, refers specifically to the use of blood oxygenation level dependent (BOLD) contrast to detect localized hemodynamic responses due to specific regional neuronal activity elicited by defined cognitive tasks to which the patient is exposed in a controlled manner. The method was first demonstrated in humans in the early 1990s in a research setting (Bandettini et al., 1992; Kwong et al., 1992; Ogawa et al., 1992), but has rapidly found clinical applications (Lee et al., 1999; Thulborn, 1999). At clinical field strengths of 1.5 T, the signal change is small (1% to 3%) thereby requiring the use of image averaging during the cognitive task. Thus, the stimulus paradigm has a block design, consisting of repetitive cycles of at least two different stimulus conditions. These two conditions differ by the cognitive function being examined. Both the baseline and the active conditions may last from 20 to 60 sec and as many as 10 cycles may be used. Images are acquired continuously across all cycles. This block design allows the signal averaging that is essential to detect the small signal changes induced by the paradigm at 1.5 T, although these changes can be increased at higher field strengths (Gati et al., 1997; Thulborn 1999). The alternative approach of event-related design is being developed in a research setting (Rosen et al., 1998; Richter, 1999), but the lower signal-to-noise performance does not suit the short duration of acquisition times that are important in clinical applications (Marquart et al., 2000). An interesting approach, in which no paradigm is apparently required to demonstrate connectivity between different regions of the brain, may have clinical applications but will not be discussed further until clinical applications (*UNIT A6.1*) are reported from multiple sites (Biswal et al., 1995).

The statistical processing of such data to derive the activation map can take many forms, and no general agreement as to a common method has been reached within the research community. Generally, for imaging data of adequate quality from a cooperative subject, the processing method will have little impact on the clinical information sought in presurgical planning. The available software packages have been reviewed elsewhere (Gold et al., 1998). Some of this software is public domain, is supported with excellent documentation, and continues to evolve (Friston et al., 1991; Cox 1996; Eddy et al., 1996; Strupp, 1996). It is generally sufficient to use a simple Student *t* test to detect differences in MR signal intensity between the two conditions. This information is presented as a color scale, representing statistical significance, displayed over the original images or superimposed over a high-resolution anatomic image coregistered to the original functional images during acquisition.

Imaging is usually performed with a fast imaging sequence to maximize signal averaging of as many images as possible in the shortest time. This is important for patient comfort and to minimize task fatigue. Echo-planar imaging is the most common strategy, and is supplied by most scanner manufacturers (Cohen and Weisskoff, 1991). Other methods are also available including spiral imaging (Glover et al., 1996) and turboflash (Frahm et al., 1992). Although the mechanism of the MR signal difference is a complex function of localized changes in blood flow, blood volume, hematocrit, and hemoglobin oxygen binding (Cohen, 1997; Buxton et al., 1998), the phenomenon depends on the changes in magnetic susceptibility arising from changes in the tissue content of paramagnetic

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deoxyhemoglobin and diamagnetic oxyhemoglobin (Thulborn et al., 1982; Ogawa et al., 1990). This is the basis for the improved sensitivity of fMRI at higher magnetic field, and predicts the success of the newer very high field scanners (3.0 T) appearing on the clinical market (Thulborn, 1999).

The interpretation of the small signal differences detected by fMRI requires that there are no systematic changes in scanner performance over time. Routine quality assurance (*UNIT A6.2*) avoids frustration for the technologist resulting from wasted scanner time, as well as for the patient who must repeat a study if the first did not provide beneficial clinical information. Some simple system performance parameters should be monitored routinely.

The clinical questions of fMRI are largely driven by the need to localize various functions. This means that the host of research paradigms (*UNIT A6.3*) being used to investigate many aspects of human cognition can be reduced to a simple, robust and informative subset of tasks to map eloquent cortex.

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Keith R. Thulborn