CHAPTER 5

Imaging the Basal Ganglia

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A. Introduction

The rapid implementation of new techniques for imaging the central nervous system is one of the most impressive developments to have taken place in clinical neuroscience in the last decade. Not only have these techniques revolutionized the clinical management of patients with neurological disorders, but in many situations they have advanced our understanding of the pathophysiology of diseases which affect the brain.

Traditional concepts of imaging have focussed on the depiction of the anatomical detail of the brain. The development and widespread implementation in the 1970s of X-ray computed tomography (CT) as a structural imaging modality was the initial milestone in the establishment of the new science of "neuroimaging". More recently, the development of magnetic resonance imaging (MRI) has provided a further advance in our ability to depict anatomical detail.

By applying tomographic principles to radionuclide imaging methods, it has become possible to study cerebral physiology in human subjects with techniques such as positron emission tomography (PET). Although techniques for functional imaging have not yet seen widespread use in clinical patient management, they have provided new information concerning brain function in health and disease and show promise for providing yet further information in the future.

This chapter is divided into two major sections. The first part deals with structural imaging techniques and reviews the abnormalities which have been demonstrated in various movement disorders with these methods. The second section deals with functional imaging and discusses briefly the principles of methodology which are required to understand the associated potentials and difficulties. This section also discusses the application of these methods to the study of disorders of the basal ganglia.
B. Structural Imaging Techniques

I. Methodology

1. X-Ray Computed Tomography (CT)

This technique has seen widespread application in clinical neurosciences in the last decade and the results are well known. Current CT technology permits high quality images with a spatial resolution approaching 0.5 mm to be obtained and reconstructed in about 20 seconds per slice. With CT, it is usually possible to obtain reasonable distinction between the grey matter of the basal ganglia and the adjacent white matter and cerebrospinal fluid. Images correspond primarily to a map of electron density of the tissue being studied. The main limitations are the predilection for artifacts in tissues adjacent to bone, and the relative difficulty in discriminating minor differences in tissue density.

2. Magnetic Resonance Imaging

This technology has developed rapidly in recent years. Magnetic resonance imaging (MRI) is superior to CT in the depiction of structural detail, in particular with regard to the differentiation of grey matter from white matter. Other relative advantages include the fact that MRI does not involve ionizing radiation, and that direct multiplanar imaging, e.g. transverse, coronal, or sagittal, may be performed independently of patient positioning.

The technique itself is based on the magnetic properties of hydrogen nuclei (protons), their response to externally applied magnetic fields, and on the excitation of protons within such a field by a radiofrequency (RF) pulse. When the RF pulse is terminated, the protons lose energy by emitting an RF signal, the intensity and temporal decay pattern of which is related to the chemical milieu of the protons. This signal is recorded by the imaging device and is dependent upon the imaging parameters as well as tissue properties such as mobile proton density and $T_1$ and $T_2$ relaxation times. The theory underlying the MRI technique and details concerning the methodology itself have been summarized in recent reviews (Norman and Brant-Zawadzki 1985; Oldendorf 1985).

II. Parkinson’s Disease

The major pathological abnormality in Parkinson’s disease is the loss of dopaminergic neurons from the substantia nigra. An early claim (Bydder et al. 1982) that the substantia nigra could be visualized and appeared to be atrophied has not been confirmed. High field strength (1.5 T) MRI studies have been reported to show reduced signal intensity in the putamen and lateral substantia nigra on $T_2$ weighted images (Drayer et al. 1986), and this has been suggested to represent increased iron deposition in these regions.