
Preface

Bioimaging is in the forefront of medicine for the diagnosis and treatment of neurodegenerative disease. Conventional magnetic resonance imaging (MRI) uses interactive external magnetic fields and resonant frequencies of protons from water molecules. However, newer sequences, such as magnetization-prepared rapid acquisition gradient echo (MPRAGE), are able to seek higher levels of anatomic resolution by allowing more rapid temporal imaging. Magnetic resonance spectroscopy (MRS) images metabolic changes, enabling underlying pathophysiologic dysfunction in neurodegeneration to be deciphered. Neurochemicals visible with proton ^1H MRS include *N*-acetyl aspartate (NAA), creatine/phosphocreatine (Cr), and choline (Cho); NAA is considered to act as an in vivo marker for neuronal loss and/or neuronal dysfunction. By extending imaging to the study of elements such as iron—elevated in several neurodegenerative diseases—laser microprobe studies have become extremely useful, followed by X-ray absorption fine-structure experiments.

Positron emission tomography (PET) and single-photon emission tomography (SPECT) have become important tools in the differential diagnosis of neurodegenerative diseases by allowing imaging of metabolism and cerebral blood flow. PET studies of cerebral glucose metabolism use the glucose analog [^{18}F] fluorodeoxyglucose analog ([^{18}F]FDG) and radioactive water (H_2^{15}O) and SPECT tracers use $^{99\text{m}}\text{Tc}$ -hexamethylpropylene amine oxime, ($^{99\text{m}}\text{Tc}$ -HMPAO), and $^{99\text{m}}\text{Tc}$ -ethylcysteinate dimer ($^{99\text{m}}\text{Tc}$ -ECD). Moreover, direct imaging of the nigrostriatal pathway with 6-[^{18}F]-fluoro-1-3,4-dihydroxyphenylalanine (FDOPA) in combination with PET technology, may be more effective at differentiating neurodegenerative diseases than PET or SPECT alone. Radioactive cocaine and the tropane analogs directly measure dopamine (DA) transporter binding sites and $^{99\text{m}}\text{Tc}$ -TRODAT-1 is a new tracer that could move imaging of the DA neuronal circuitry from the research environment to the clinic. [^{123}I] altropane SPECT may equal and further advance FDOPA PET.

Surgical treatments of neurodegenerative diseases are gaining attention as craniotomies become more routine, and as patients opt for surgery because they experience intractable responses to pharmacotherapy for neurodegeneration. These treatments fall into three categories: lesion ablation, deep brain stimulation (DBS), and restorative therapies such as nerve growth factor infusion or DA cell transplantation along the nigrostriatal pathway, particularly in Parkinson's disease. Also, electron micrographics image amyloid β aggregation in Alzheimer's disease (AD) and MRI (gadolinium enhanced) has been successfully exploited to image neuroinflammation in AD. MR-based volumetric imaging

helps to predict the progression of AD via mild cognitive impairment (MCI) studies.

Novel neuroimaging technologies, such as neuromolecular imaging (NMI) with a series of newly developed BRODERICK PROBE[®] sensors, directly image neurotransmitters, precursors, and metabolites in vivo, in real time and within seconds, at separate and selective waveform potentials. NMI, which uses an electrochemical basis for detection, enables the differentiation of neurodegenerative diseases in patients who present with mesial versus neocortical temporal lobe epilepsy. In fact, NMI has some remarkable similarities to MRI insofar as there is technological dependence on electron and proton transfer, respectively, and further dependence is seen in both NMI and MRI on tissue composition such as lipids. NMI has already been joined with electrophysiological (EEG) and electromyographic (EMG) studies to enhance detection capabilities; the integration of NMI with MRI, PET, and SPECT can be envisioned as the next advance.

The tracer molecule, [^{11}C] α -methyl-L-tryptophan (AMT) is already used with PET to study serotonin (5-HT) deficiencies, presumably attributable to kynurenine enhancement in neocortical epilepsy patients. Moreover, AMT PET, in addition to FDG PET, provides reliable diagnosis for pediatric epilepsy syndromes such as West's syndrome. Important in children with cortical dysplasia (CD), FDG PET delineates areas of altered glucose, which can be missed by MRI. The new tracer, [^{11}C] flumazenil used with PET (FMZ PET), has found utility in the detection of epileptic foci in CD patients with partial epilepsies, and yet normal structural imaging is observed. Another new 5-HT $_{1A}$ tracer for PET imaging in abnormal dysplastic tissue is a carboxamide compound called [^{18}F]FCWAY.

Diagnosis of neocortical epilepsy has been significantly advanced by IOS or intrinsic optical signal imaging. IOS has its basis in the light absorption properties of electrophysiologically active neural tissue, activity caused by focal alterations in blood flow, oxygenation of hemoglobin, and scattering of light. IOS can map interictal spikes, onsets and offsets, and horizontal propagation lines. Thus, IOS is useful for diagnosing "spreading epileptiform depression." As with NMI, IOS holds promise for intraoperative cortical mapping wherein ictal and interictal margins can be more clearly defined. As does intraoperative MRI (iMRI) with neuronavigation, these technologies provide what is called "guided neurosurgery." Correlative imaging of general inhalational anesthetics such as nitrous oxide (N_2O) during intraoperative surgery is made possible by NMI technologies with nano- and microsenors.

NMI and MRI also enable the differential detection of white matter versus gray matter in discrete neuroanatomic substrates in brain, detection which is critical to both the epilepsies and the leukodystrophies. Although NMI is in its early stage in this arena, the immediate and distinct waveforms that distinguish white from gray matter are impressive. Moreover, the early finding of a leukodystrophy by MRI, particularly relevant for metachromatic leukodystrophy (MLD), Krabbe's disease (KD), and X-linked adrenoleukodystrophy (ALD), allows clinicians therapeutic interventions before overt symptoms are exhibited. Imaging technologies, pathologies, clinical features, and treatments for these and other leukodystrophies, including peroxisomal disorders and leukodystrophies with macrocrania (Canavan's disease and Alexander's disease), are presented here in precise detail. The van der Knaap syndrome is a recently described leukodystrophy in vacuolating megalencephalic leukoencephalopathy (VMI). This vanishing white matter disease highlights the potential of MRS imaging, which was used in its identification.

Bioimaging in Neurodegeneration provides extensive detail on pediatric mitochondrial disease, including imaging, pathologies, clinical features, and treatment or lack of treatment. It is extremely important to note that in pediatric mitochondrial cytopathies, a frequent finding on MRI is abnormal myelination, and infants with

leukoencephalopathies, especially leukodystrophies, should be evaluated for mitochondrial cytopathy. Infarct-like, often transient lesions not confined to vascular territories are the imaging hallmark of mitochondrial myopathy, encephalopathy, lactic acidosis, and stroke-like episodes (MELAS). [³¹P] MRS, which can measure transient changes in nonoxidative adenosine triphosphate (ATP) synthesis, and [¹H] MRS, which can measure lactate, are included in the mitochondrial imaging technologies.

Thus, *Bioimaging in Neurodegeneration* fulfills the current need to bring together neurodegeneration with bio- and neuroimaging technologies that actually enable diagnosis and treatment. Professionals in neurology, psychiatry, pharmacology, radiology, and surgery are among many who will greatly benefit. Neurodegenerative disease is divided into four areas, i.e., Parkinson's disease, Alzheimer's disease, the epilepsies, and the leukodystrophies. Chapter authors were selected for their formidable expertise in each field of medicine, their expertise in imaging technologies, and their scholarly contributions to medicine and science. Our appreciation is extended to them, and their staffs, for their fine research. We thank the editors and staff at Humana Press for their excellent assistance and support.

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