Evaluation of cerebral structural, functional, and metabolic abnormalities with combined PET/MRI analysis

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Comprehensive evaluation of cerebral structural, metabolic, vascular and functional abnormalities can be achieved by combined analysis of advanced MRI and PET images, an approach we use in a variety of neurological disorders, including epilepsy, brain tumors and neuro-developmental disorders. MRI and PET images are co-registered, and PET abnormalities are evaluated in both MRI-positive and MRI-negative brain regions, along with a variety of quantifiable MRI variables.

1. Molecular imaging with PET allows detection of epileptic foci. While FDG-PET is used clinically to detect epileptic cortex with abnormal glucose uptake, other PET tracers can evaluate associated neuroinflammatory changes in patients with drug-resistant epilepsy. In developmental epileptogenic tubers and cortical dysplasia, that express inflammatory markers, alpha-methyl-L-tryptophan PET can reveal increased interictal uptake. In addition, PET imaging of activated microglia is useful to evaluate epilepsies of autoimmune etiology. Imaging epilepsy-associated inflammation can assist pre-surgical evaluation and may also identify and monitor patients amenable for therapy with drugs targeting underlying immune mechanisms.

2. Enhanced detection of infiltrative brain tumors can be achieved with combined analysis of advanced MRI with perfusion and diffusion abnormalities together with amino acid PET. While high-perfusion tumors may indicate a phenotype responsive to antiangiogenic treatment, amino acid PET has the ability to identify glioma-infiltrated brain regions extending beyond the contrast-enhancing tumor mass in low-perfusion areas. In such non-enhancing tumor-infiltrated regions, increased amino acid uptake is associated with high cellularity as estimated by diffusion imaging. These studies allow a comprehensive assessment of the extent and severity of tumor involvement before targeted therapy (surgery or radiation) and can also identify responders to novel antiangiogenic and immune therapy of brain tumors.

3. In children with early brain damage, combined PET/MRI analysis allows evaluation of structural/functional relationships and correlate these with clinical outcome. In our longitudinal studies of children with Sturge-Weber syndrome, MRI and PET studies not only demonstrated progressive brain atrophy, calcification, and associated progression of hypometabolism, but also uncovered early vascular and neuronal compensatory mechanisms leading to reorganized cognitive functions.

Combined PET/MRI analysis allows enhanced detection of metabolic and functional correlates of macroscopic and microscopic brain lesions and also provides new insights in underlying pathophysiology. Clinical applications of neuroimaging should rely on an integrated, quantitative evaluation of brain abnormalities on multimodal imaging in a wide range of neurological disorders.