Clinical PET/MR Imaging in Dementia and Neuro-Oncology

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KEYWORDS

• PET/MR imaging • Dementia • Brain tumor • Glioma • Alzheimer disease

KEY POINTS

- PET/MR imaging using [18F]-fluorodeoxyglucose (FDG) is a practical clinical tool in the evaluation of dementia and allows for a fast, condensed, and well-accepted high-quality imaging protocol with interpretation effectively supported by statistical tools.
- In neuro-oncology, PET/MR imaging using [18F]-fluoro-ethyl-tyrosine (FET) is a practical clinical tool that can be adapted to different clinical demands depending on the clinical question.
- The clinical value of the multiparametric imaging capabilities of PET/MR imaging needs to be established.

INTRODUCTION

Commercially available integrated PET/MR imaging has recently been introduced in clinical nuclear medicine. Although it has been the cause of considerable excitement, the exact role and benefits of this technique have not been firmly defined. Given the key role that MR imaging has in the diagnostic evaluation of diseases of the brain, this application is an obvious clinical target to consider. The strength of MR imaging is the ability to perform detailed regional tissue characterization in high resolution and with superior soft tissue contrast. This is achieved through a time-consuming multisequence approach. Thus, as opposed to whole-body PET/MR imaging, in which MR imaging acquisition time is expended on screening body areas that may not be afflicted with disease using only a limited number of the most basic MR imaging sequences, acquisition time in PET/MR imaging of the brain is much more efficiently used for characterizing the organ of interest. Ideally, the PET and MR imaging acquisitions are performed simultaneously to minimize total scanner time that may adversely affect image quality because of head movements. The patient groups that will have access to clinical PET/MR imaging are determined by local demands and procedures, prevalence of disease, the proven efficacy and availability of MR imaging sequences, PET radiotracers, work flow, and reimbursement. At our unit, dementia and brain tumors are the 2 primary indications for PET/MR imaging of the brain, constituting 75% and 25% of indications, respectively (**Fig. 1**).

There are a number of recent reviews presenting a broad perspective of possible PET/MR imaging applications for brain PET/MR imaging.[1–5] These are not repeated in this review. It is possible to perform very lengthy MR imaging acquisitions that may be considered experimental without established clinical value for the patient. Instead, we present the experiences and diagnostic

The authors have nothing to disclose.
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PET Clin 11 (2016) 441–452
http://dx.doi.org/10.1016/j.cpet.2016.05.003
1556-8598/16/$ – see front matter

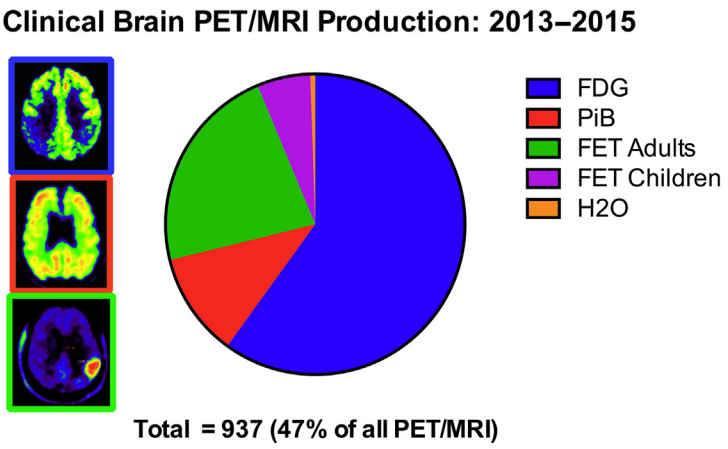

Fig. 1. Distribution of clinical PET/MR imaging brain studies. Pie plot showing the distribution of clinical PET/MR imaging brain studies over a 3-year period divided by PET radiotracer. Brain studies constitute approximately 50% of all scans performed, and is dominated by patients referred for neurodegeneration (3/4, FDG or PiB) and neuro-oncology (1/4, FET).

strategies used from the realities of a single institution based on immediate clinical value.

PET/MR IMAGING IN DEMENTIA

The dementias are dominated by neurodegenerative disease and cerebrovascular disease (CVD). Most neurodegenerative diseases are histologically characterized by the progressive accumulation of protein structures of low solubility in brain tissue, and the progressive destruction of neural tissue. The most common neurodegenerative disease is Alzheimer disease (AD), which accounts for approximately 50% of all patients with dementia, whereas CVD is the cause of 30% of dementia cases, vascular cognitive disorder (VCD),[6] where half of these cases also have AD pathology (mixed dementia). Other causes are Lewy body dementia (DLB) and fronto-temporal lobar degeneration (FTLD), each with their own distinctive pathology.

Brain Imaging in Dementia

Accurate and early diagnosis is central to the management of patients suffering from neurodegenerative disease. Both PET and MR imaging are established clinical tools that to a large extent give independent and complementary clinically valuable information. The functions that a series of MR imaging sequences should be able to contain to support PET interpretation and to exclude or identify clinically relevant pathologic conditions are listed in **Box 1**. A standard MR imaging clinical dementia protocol will usually consist of variations of the 4 sequences in **Box 2**. Initially, a Dixon water-fat-separation (DWFS) sequence is usually performed and/or the ultrashort echo time (UTE) sequences that some use for attenuation correction (AC). Thus, a relatively lean less than 20-minute MR imaging session composed of the essential sequences contributes most value to the routine clinical evaluation of the patient with general dementia. Two optional sequences to consider are diffusion-weighted imaging (DWI) and three-dimensional (3D) postcontrast T1-weighted magnetization-prepared rapid gradient echo (T1-MPRAGE) in the complicated patient (see **Box 2**). In our setting, the more unusual clinical presentation will lead to the relevant MR imaging sequences performed before PET. Thus, DWI or 3D postcontrast T1-MPRAGE is performed by request only or post hoc in a separate MR imaging session for this

Box 1
Most important uses of MR imaging in clinical PET/MR imaging of dementia

- Exclude structural lesions that may be treated neurosurgically: subdural hematoma, brain tumor (meningioma, metastasis, glioma), arteriovenous malformation, normal-pressure hydrocephalus.
- Exclude generalized or local edema; for example, secondary to infection/inflammation (encephalitis, Creutzfeldt-Jakob disease).
- Identify cerebrovascular pathology: vascular white matter lesions, territorial infarcts, lacunar infarcts, (micro) hemorrhages.
- Identify other structural lesions or abnormalities of importance: regional cortical and central atrophy,[a] hippocampal atrophy, trauma, developmental disorders (heterotopia).
- Facilitate integration of the above in the evaluation of the local and distant functional effects of structural change.

[a] This includes a widening of the perivascular Virchow-Robin spaces.