can improve the quality of the PET images, depending on the properties of the used radiopharmaceutical. Further details on FDG and amino acid tracer patient preparation, image acquisition, reconstruction, semi-quantitative parameters, interpretation, reporting, and pitfalls are presented elsewhere [39]. A wide range of PET attenuation correction techniques in neuro PET/MRI has been suggested. The reported impairment of PET quantification by AC-artifacts in brain PET/MRI is, except for close proximity to bony structures or air cavities as low as known from PET/CT, on the order of up to 4%. Depending on the proximity to bony structures or air cavities, this may lead to systematic differences in the activity distribution and calculated semi-quantitative tumor metrics [79], which should carefully be considered during PET image interpretation [28, 80].

The MRI sequences required may depend on whether the patient has recently had extensive imaging, in which case an abbreviated protocol, possibly even only sequences for MRAC, might be acquired. Ellingson et al. [81] have proposed consensus guidelines for MRI of brain tumors for clinical trials, to assure reproducibility and inter-trial comparisons. They suggest 5 key sequences (3D T1 pre, Ax T2 FLAIR, Ax DWI, Ax T2 post-contrast, and 3D T1 post-contrast) as minimum standards [82]. To acquire all these sequences, an imaging duration of about 30 min is required. Examples of pediatric neurooncology PET/MRI protocols can be found in the literature [77, 78, 82, 83].

A number of advanced functional MRI techniques that may be useful in neurooncology in a multiparametric setting that are available for measurement of tumor perfusion by arterial spin labeling (ASL), tumor biochemistry by MRI spectroscopic imaging (MRSI), and tumor angiogenesis by relative cerebral blood volume (rCBV) using dynamic susceptibility contrast (DSC) or dynamic contrast enhancement (DCE) have been reviewed recently [84, 85]. Also, dedicated fMRI techniques can be performed for evaluation of feasibility of surgical resection in one setting together with PET-imaging.

Table 1 Most commonly used PET tracers for brain tumors

Tracer	Pathologies
2-deoxy-2-[^{18}F]fluoro-D-glucose (FDG)	First choice: • CNS lymphoma Alternative use: • Glioma • MTS
O-(2-[^{18}F]fluoroethyl)-L-tyrosine (FET) L-[methyl-^{11}C]methionine (MET) 3,4-dihydroxy-6-[^{18}F]fluoro-L-phenylalanine (FDOPA)	First choice: • Glioma
[^{68} Ga]DOTA-conjugated peptides	First choice: • Meningioma

An additive diagnostic advantage of combining advanced MRI techniques to standard PET and MRI has been suggested in smaller patient series [86], but has not been consistently documented. The challenges are the lack of standardization and availability of MRI techniques, both for acquisition and post-processing, and the limited tissue coverage because of susceptibility to patient movement and artifacts on postsurgical MRI [87, 88].

Other useful advanced MRI techniques for multiparametric use in neurooncology PET/MRI have recently been reviewed and published in a position paper by the European Cooperation in Science Technology (COST) Glioma MRI Imaging 2.0 (GliMR) initiative.

Head and neck

For head and neck tumors, mainly FDG is indicated as radiotracer. Exceptions apply to neuroendocrine tumors, paraganglioma, and medullary thyroid carcinoma (DOTA-conjugated somatostatin receptor targeting peptides, DOPA) [89–91], extracranial meningiomas (DOTA-conjugated somatostatin receptor targeting peptides) [92], differentiated thyroid cancer (I124), and parathyroid neoplasia (choline-based radiotracers) [93]. However, the use of non-FDG radiotracers in these indications is partly off-label in the USA and in Europe.

PET/MRI can contain a dedicated MRI protocol tailored to the head and neck region. PET/MRI can be used for the staging of head and neck carcinomas greater than clinical stage T2 / N2a. Also, lower neck tumor location (e.g., in the hypopharynx) and the presence of lower neck level (III, IV) nodal metastases should prompt whole-body staging (which can be done with PET/MR), owing to the higher risk of distant metastases in these patients [94]. Furthermore, in a study conducted by Chan et al. [95], PET/MRI outperformed MRI and PET/CT in T and N staging while providing similar performance for M staging. Whole-body imaging should cover the area from the skull vertex to the upper thighs and is usually accomplished with an axial T1-weighted Dixon-type sequence, which takes approximately 3 min. With the lung being the most common site for distant metastatic disease, the acquisition of specific lung MRI sequences is recommended [96–98].

PET/MRI is useful for detecting residual disease in patients after non-surgical therapy, with optimal diagnostic reassurance at 12 weeks after therapy [99, 100]. Recurrent disease after different kinds of therapy can reliably detected with PET/MRI, as shown by Queiroz et al. [101].

PET/MRI for head and neck cancers can be safely performed without the use of gadolinium-based contrast agents. As shown by Kuhn et al. [102], this is still as accurate as contrast-enhanced PET/CT imaging, provided fat-suppressed T2-weighted pulse sequences are used in the head