PET–MR Imaging in Head and Neck

Yueh Z. Lee, MD, PhD[a,*], Joana Ramalho, MD[a,b], Brice Kessler, MD[c]

KEYWORDS

• PET–MR imaging • Head and neck cancer • Diffusion-weighted imaging • Treatment planning • Squamous cell carcinoma

KEY POINTS

- Hybrid PET–MR imaging offers high sensitivity and specificity for head and neck cancers, enabled by the functional imaging of PET and soft tissue discrimination by MR imaging.
- Whole-body imaging enabled by PET–MR imaging offers the ability to evaluate the primary tumor, local nodal, and distant metastases.
- Advanced MR imaging techniques, such as diffusion-weighted imaging and permeability imaging, can also add value to head and neck imaging.

INTRODUCTION

Head and neck cancers are a complex set of neoplasms that involve the nasal-oral-digestive tract, extending from the nose to the mediastinum, with a worldwide incidence of approximately 6.8%.[1] There is significant geographic variability in causative agents including genetic susceptibility, cultural risk factors, smoking, alcohol, and infectious agents but ultimately there is significant morbidity and mortality from these cancers. The anatomic region in which these cancers occur is complex with multiple small structures that push the limits of conventional imaging resolution. Distant metastases are also common in these cancers, including metastases to the bone and lungs. Secondary cancers also occur at a high rate in survivors, reported as 3% to 7%.[1]

Ultrasound, computed tomography (CT), MR imaging, and PET are commonly used imaging modalities for the evaluation of head and neck cancers, but each of these modalities has significant specific weaknesses. One of the strongest clinical indications for PET–MR imaging is likely the evaluation of cancers in this region, because of the limitations of the other modalities and importance of high-quality imaging on patient outcome. Furthermore, because of frequent distant metastases the whole-body approach of hybrid PET–MR imaging may be an advantage over conventional modalities.

A few factors point to the potential benefit of PET–MR imaging over conventional PET-CT or MR imaging for head and neck cancers. First, effective head and neck imaging requires high resolution and functional information. Second, staging of cancers in this region requires local and distant evaluation, for which PET–MR imaging offers distinct advantages. Finally, surgical and radiotherapy treatment planning is complex given the anatomy and structures at risk, and dual-modality approaches that include functional information may offer substantial benefits. **Fig. 1** shows a patient with a primary tonsillar cancer and local nodal metastases imaged with PET–MR imaging.

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[a] Department of Radiology, The University of North Carolina at Chapel Hill, 101 Manning Drive, CB#7510, Chapel Hill, NC 27599-7510, USA; [b] Department of Neuroradiology, Centro Hospitalar de Lisboa Central, Rua Jose Antonio serrano, Lisbon 1150-199, Portugal; [c] Department of Neurosurgery, The University of North Carolina at Chapel Hill, 101 Manning Drive, CB#7060, Chapel Hill, NC 27599-7060, USA
* Corresponding author.
E-mail address: Yueh_Lee@med.unc.edu

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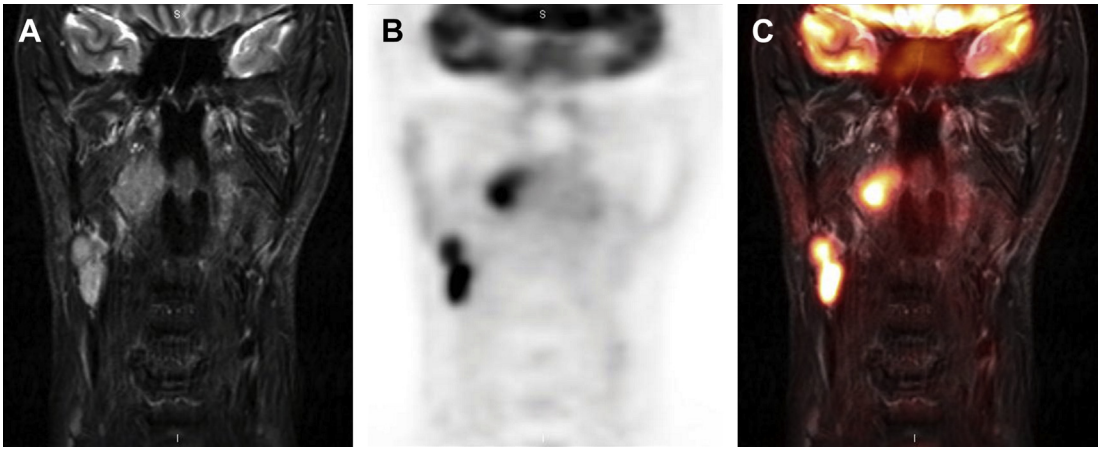

Fig. 1. Staging coronal short tau inversion recovery (STIR) MR imaging (*A*), PET (*B*), and PET–MR imaging (*C*) of a 61-year-old man presenting with primary tonsillar cancer and local nodal metastases shows the high fluorodeoxyglucose (FDG) uptake within the primary lesions and nodal metastases. The nodes are pathologic in size with avid FDG uptake. High normal FDG uptake is also noted in the brain.

Squamous cell carcinoma is the most important tumor entity of this area (also, **Fig. 1**). In recent years, PET-CT has broadly been applied for this indication and has been shown to be more accurate than CT alone for tumor detection and precise anatomic localization.[2]

Previously, the most reliable data on the diagnostic performance of combined PET–MR imaging comes from studies using retrospective fusion of MR imaging and PET datasets. When compared with MR imaging and PET separately, the fused PET–MR imaging images have offered higher sensitivity and specificity to the presence of malignancy.[3] Huang and colleagues[4] investigated the diagnostic value of fluorodeoxyglucose (FDG) PET coregistered to anatomic MR imaging compared with PET-CT, CT, and MR imaging in advanced buccal squamous cell carcinoma. The authors found that fused PET–MR imaging images have the highest sensitivity and specificity of the four approaches. Furthermore, tumor size as measured by PET–MR imaging had a higher correlation coefficient ($r^2 = 0.96$) with pathologic tumor size than CT ($r^2 = 0.55$), MR imaging ($r^2 = 0.58$), or PET-CT ($r^2 = 0.74$).[4]

The first report on integrated PET–MR imaging on patients with head and neck cancer showed that PET images obtained with the PET–MR imaging system exhibited better-detailed resolution and greater image contrast in comparison with those from the PET-CT system.[5] The authors concluded that simultaneous PET–MR imaging of the head and upper neck area is feasible, and within a reasonable imaging time. These initial results are particularly important for demonstrating feasibility, because the interfaces between bone, air, and soft tissues in nasopharynx, oropharynx, and hypopharynx are considered major challenges for PET–MR imaging. Practically, however, many of these interfaces are evaluated by direct observation through endoscopy, and it not necessarily anticipated that PET–MR imaging would be responsible for the evaluation of a mucosal surface. It is worth noting that all modalities have somewhat limited sensitivity to the detection of head and neck cancers, particularly these small mucosal based lesions. Patients with head and neck cancers may present with nonhealing ulcers, difficulty swallowing, or neck masses representing primary or metastatic disease.

Accurate staging is essential for the treatment planning and prognostication in head and neck cancers, and staging is based on the tumor-metastasis-nodal system.[6] PET-CT has been shown to offer additional diagnostic information that more appropriately stages patients in several studies.[7] The early fusion work laid the ground work for the simultaneous imaging modality, but limitations to fusion remain because of differences in patient positioning. PET-MR offers different benefits for each staging component (**Box 1**).[3,8]

T-STAGING

T-staging is mainly based on morphology and size of the tumor, including local osseous invasion. This staging level predicts the ability to surgically resect the primary lesion. MR imaging is known to be more accurate than CT alone for T-staging, with CT requiring PET to perform more accurate staging.[9] Even within the PET-CT literature, there is some debate over the necessity of iodinated contrast-enhanced CT imaging with the use of