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CLINICAL PERSPECTIVES OF PET/MRI – A REVIEW ARTICLE

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ABSTRACT

Hybrid PET/MRI is a recently developed technique that is gaining a growing interest from the medical community owing to its potential clinical applications. It leverages the high soft-tissue contrast and the functional sequences of MR with the molecular information of PET in one single, hybrid imaging technology. Studies on indirect PET/MRI have already generated interesting preliminary data to pave the ground for potential applications of PET/MRI. These initial data convey that PET/MRI is promising in neuroncology and head & neck cancer applications as well as neoplasms in the abdomen and pelvis. The pediatric and young adult oncology population requiring frequent follow-up studies as well as pregnant woman might benefit from PET/MRI due to its lower ionizing radiation dose. PET/MRI couples the MR strengths of superior soft-tissue contrast compared to CT and sophisticated sequences to characterize the microenvironment of the neoplasm with PET's molecular and metabolic information of tumor biology.

KEYWORDS: Cancer MRI, PET, Soft-tissue.

INTRODUCTION

Radiological techniques started to contribute relatively late in clinical neurology after the original discovery of x – rays in 1895 by Roentgen. The application of conventional skull x-ray techniques improved the diagnosis and treatment of skull traumas. But first the development of pneumoencephalography for the study of the soft tissues and ventricles in the brain and myelography after injection of air or inert gas into the CSF space started a new stage of development. These techniques were slowly substituted after late fiftees by the introduction of contrast media (aortocervical and later selective angiographies and water insoluble and later water soluble opaque contrastmedia for myelography.[1]

A new and revolutionary stage of the imaging techniques in neuroradiology and neurology started, when Hounsfield and Cormack developed CT (computerized tomography) and received a Nobel price in 1972. CT uses ionizing radiation, but it has no other major risks and is relatively comfortable for the patient. Until the development of spiral- techniques and 3D modelling the CT slices have been limited primarily to transaxial views. In CT images are generated by passing an x–ray beam through the skull or other object and measuring its degree of attenuation. The ability to attenuate x – rays of different tissues differs and can be measured numerically as a tissue density number for each voxel. These numbers can be converted to gray scale values and presented visually as pixels. A large number of reconstruction and filtering techniques are nowadays available to improve the quality of the pictures and thus also the diagnostics. The use of CT contrast media further improves the differential diagnostics. MRI is rapidly substituting CT as the best structural neuroimaging technique. MRI has also potential for the study of the biochemistry and physiology of the nervous system. In fact the principles of MRI are older than those of CT. The MR phenomenon was demonstrated already in 1946 by Bloch and Purcell. However the first clinical applications in radiology appeared in the seventies. In MRI the object is placed in a high field strength magnetic field. This concentrates the magnetic moment of individual protons and the net magnetic moment is then tipped by sending radio-frequency signals that excite the tissue. After this the protons relax again and return to their original position. Different relaxation times as well as proton density are measured and can be further manipulated by using various pulse sequences. Several quantum leaps have been made during eightees and ninetees in MRI techniques.Bradley WG and Bydder GM, 1997. The possibility to vary the components of the MR signal and the type of image generated improve the clinical applicability of MRI considerably especially for identifying pathological tissue. Thus the tissue resolution of MRI is far superior to the CT except for bone.[2.3]

The concept of hybrid imaging holds a promising value in modern-day medical care, overcoming the existing boundaries between morphological, functional and molecular information in current diagnostic imaging.[4] Positron emission tomography/computed tomography (PET/CT) has gained widespread use in oncologic imaging by combining the metabolic information of positron emission tomography with the anatomic detail of computed tomography.[5-7] The establishment and success of PET/CT in clinical practice stimulated the need and research of further hybrid medical technologies including PET/MRI to overcome inherent limitations, mostly in soft tissue resolution. Initially, PET and magnetic resonance data were fused retrospectively with software, mainly in the brain.[8,9] Recently, the first PET/MRI scanners for use in humans were introduced in the clinical arena.

PET and MR are the methods of choice for neuroimaging, allowing to combine the metabolic information provided by PET imaging, with the various morphological and functional parameters measured by MR. In this respect, MR has clear advantages compared to CT and mainly to the nonYcontrast-enhanced CT, which is usually coupled to PET when a routine PET/CT investigation is realized. There are already preliminary reports describing the potential clinical applications of hybrid PET/MR in brain imaging based on studies realized on a brain-dedicated prototype of hybrid PET/MR. However, dedicated brain systems usually have limited availability, mainly confined to research centers. New whole-body PET/MR hybrid scanners that are currently available will presumably have a wider diffusion over the next few years, being able to perform both brain and whole-body imaging.

The technologies of MRI and PET have advanced rapidly. Development of novel imaging sequences or “contrast” agents that are sensitive to imaging of amyloid-beta peptide or tau pathology could change the landscape for diagnosis of prevalent cases by imaging. Specific molecular markers for MRI or PET imaging would be invaluable for predicting incident cases and in therapeutic trials. Ongoing collaboration between clinicians and neuroimaging practitioners is the key to moving closer to our ultimate goal in dementia research: to reduce the burden of dementia on individuals and on society.

Clinical applications

Many authors regard PET/CT as the reference standard that sets the benchmark for PET/MRI and thus investigation is to some extent focused on applications where MRI has significant advantages over CT. In this context, promising applications include liver, prostate, or head-and-neck imaging, which take advantage of the excellent soft tissue contrast provided by MRI.

In addition to anatomical images, MRI provides functional and quantitative data like diffusion-weighted imaging, spectroscopy, blood oxygenation level-dependent imaging in functional MRI, T1/T2 mapping and dynamic contrast-enhanced imaging. Consequently, valuable applications of PET/MRI might emerge in the field of multiparametric and quantitative imaging. Nique features like real parallel PET and MRI acquisition that enable certain imaging protocols like integrated functional MRI and dynamic PET after presentation of a stimulus or cardiac stress PET/MRI. In combination with the ionizing radiation-free nature of MRI, parallel acquisition also allows for the continuous acquisition of anatomical images that can be used for motion correction of PET data. Thus, the quality of PET images in applications like cardiac, lung, or bowel imaging can be increased while respiratory and/or electrocardiography-gating can be potentially omitted.

Pediatric patients and pregnant women

For pediatric oncology applications PET/MRI has potential to reduce overall radiation exposure to the patient. In tumors with need for repetitive follow up studies PET/CT can lead to a significant radiation burden. If with PET/MR the radiation dose from CT omitted, the actual radiation exposure is limited to the radiation dose from the PET component only which is substantially minor in comparison to the radiation dose from CT.[10] Not only pediatric patients but also the pregnant population may benefit from PET/MRI. For certain cancers during pregnancy an imaging modality including PET can be crucial for further treatment decisions. As MRI is not associated with any radiation burden a PET/MRI exam should be preferred vs. PET/CT.

Neurologic and head & neck applications

The strongest evidence for a clinical indication of PET/MRI exists in the head & neck cancer population. Due to frequent distant metastases the whole body approach of the novel hybrid imaging technology is of significant advantage for distant metastases staging. For local staging the high spatial and contrast resolution of MRI can delineate the tumor extent and lymph node involvement from surrounding normal tissue in the complex head and neck anatomical region. This may lead to a superior primary tumor staging and regional lymph node staging (N-staging). Furthermore PET/MRI can be useful for radiation therapy and presurgical treatment planning in head and neck cancer patients.

Chest

Lung cancer is one of the common clinically established indications for 2-deoxy-2[F-18]fluoro-D-glucose-PET. Diagnosis, staging, and restaging of lung cancer are among the most extensively studied applications of FDG-PET.[11, 12] With the exception of bronchioloalveolar cell cancer and carcinoid, lung neoplasms are generally very FDG-avid. The integration of CT and PET information has improved correlation of functional and morphologic characteristics. The staging of nodal and distant metastatic sites is the major strength of combined PET/CT.[13, 14] However, T-staging can be difficult, especially in cases of well-differentiated tumors, infiltration of the surrounding tissue, and post obstructive pulmonary parenchyma changes. A recent study could show comparable results between PET/CT and PET/MRI in terms of pulmonary nodule detection when using a 3-dimensional Dixon-based dual-echo gradient-echo sequence.

Abdomen and pelvis

Abdominal and pelvic applications for PET/MRI are numerous. For example, MR has shown a superior sensitivity for the detection of focal liver lesions, especially when <1 cm in size. PET can provide information on their potentially neoplastic nature, thus making PET/MRI an excellent method to screen for metastases or monitor embolization theraoy for liver lesions.[15-17] Liver screening in colorectal cancer reduces patient mortality by 25%. Outcome is improved when liver metastases are treated surgically at the time of initial primary diagnosis or during early follow up.

Role for therapy procedure planning

The usefulness of PET in the evaluation of treatment response in oncologic patients has made major progress with regard to the management of patients. FDG-PET has demonstrated efficacy for early therapy assessment in multiple oncological applications\. MRI has proven to be useful in imaging cancer and it is superior to CT in T-staging of many malignant processes such as in brain and breast neoplasms, among others. It offers high soft-tissue contrast allowing excellent anatomical delineation. Sequences like DWI[18, 19] dynamic contrast enhanced MRI, and other perfusion MR imaging techniques (ASL and blood-oxygenation level dependent imaging) as well as MR spectroscopy may provide important information such as tissue composition, tissue vascularization or different physiologic processes beyond anatomic imaging.

Future Prospects and needs

Especially in clinical neurosurgery the use of stereotactic methods, when combined with 3D modeling would benefit the planning and surgical treatment immensely. The same is due to radiotherapy of brain tumors. The future applications of fMRI and multimodal imaging techniques will open up totally new ways to understand the cognitive and psychiatric disorders. The combination of these techniques with already existing international databases and their use will also improve the diagnostics and treatment of brain and other nervous system disorders much. At the same time the need to educate new clinical neuroscientists and clinicians who can understand and use these techniques will become an absolute necessity. In fact it is necessary to train a new generation of specialists to fulfil all these demands.

CONCLUSION

PET/MRI is a promising new imaging modality, which has started to enter the clinical arena. PET/MRI couples the MR strengths of superior soft-tissue contrast compared to CT and sophisticated sequences to characterize the microenvironment of the neoplasm with PET's molecular and metabolic information of tumor biology.

REFERENCES

1. Osborn A.G.: Diagnostic neuroradiology. Mosby Press.Mosby – Year Book Inc., 1994.
2. Gonzalez et al., Head & spine imaging. Wiley Medical Press., 1985.
3. Taveras, J.M., Neuroradiology, Third ed. Williams and Wilkins Press., 1996.
4. Mansi L, Ciarmiello A and Cuccurullo V. PET/MRI and the revolution of the third eye. Eur J Nucl Med Mol Imaging., 2012; 39: 1519-1524.
5. Fletcher JW, Djulbegovic B, Soares HP, Siegel BA, Lowe VJ, Lyman GH, Coleman RE, Wahl R, Paschold JC, Avril N, Einhorn LH, Suh WW, Samson D, Delbeke D, Gorman M and Shields AF. Recommendations on the Use of 18F-FDG PET in Oncology. J Nucl Med., 2008; 49: 480-508.
6. Ben-Haim S and Ell P. 18F-FDG PET and PET/CT in the evaluation of cancer treatment response. J Nucl Med., 2009; 50: 88-99.
7. Schöder H, Larson SM and Yeung HWD. PET/CT in oncology: integration into clinical management of lymphoma, melanoma, and gastrointestinal malignancies. J Nucl Med., 2004; 45(1): 72S-81S.
8. Zaidi H, Montandon ML and Alavi A. The clinical role of fusion imaging using PET, CT, and MR imaging. Magn Reson Imaging Clin N Am., 2010; 18: 133-149.
9. Slomka PJ. Software approach to merging molecular with anatomic information. J Nucl Med., 2004; 45(1): 36S-45S.
10. Delso G, Fürst S, Jakoby B, Ladebeck R, Ganter C, Nekolla SG, Schwaiger M and Ziegler SI. Performance measurements of the Siemens mMR integrated whole-body PET/MR scanner. J Nucl Med., 2011; 52: 1914-1922.
11. Ahuja V, Coleman RE, Herndon J and Patz EF. The prognostic significance of fluorodeoxyglucose positron emission tomography imaging for patients with nonsmall cell lung carcinoma. Cancer., 1998; 83: 918-924.

12. Boiselle PM, Ernst A and Karp DD. Lung cancer detection in the 21st century: potential contributions and challenges of emerging technologies. AJR Am J Roentgenol., 2000; 175: 1215-1221.
13. Dizendorf EV, Baumert BG, Schulthess von GK, Lütolf UM and Steinert HC. Impact of whole-body 18F-FDG PET on staging and managing patients for radiation therapy. J Nucl Med., 2003; 44: 24-29.
14. Hicks RJ, Kalff V, MacManus MP, Ware RE, Hogg A, McKenzie AF, Matthews JP and Ball DL. (18)F-FDG PET provides high-impact and powerful prognostic stratification in staging newly diagnosed non-small cell lung cancer. J Nucl Med., 2001; 42: 1596-1604.
15. Mainenti PP, Mancini M, Mainolfi C, Camera L, Maurea S, Manchia A, Tanga M, Persico F, Addeo P, D‘Antonio D, Speranza A, Bucci L, Persico G, Pace L and Salvatore M. Detection of colo-rectal liver metastases: prospective comparison of contrast enhanced US, multidetector CT, PET/CT, and 1.5 Tesla MR with extracellular and reticulo-endothelial cell specific contrast agents. Abdom Imaging., 2010; 35: 511-521.
16. Wissmeyer M, Heinzer S, Majno P, Buchegger F, Zaidi H, Garibotto V, Viallon M, Becker CD, Ratib O and Terraz S. 90Y Time-of-flight PET/MR on a hybrid scanner following liver radioembolisation (SIRT). Eur J Nucl Med Mol Imaging., 2011; 38: 1744-1745.
17. Muhi A, Ichikawa T, Motosugi U, Sou H, Nakajima H, Sano K, Sano M, Kato S, Kitamura T, Fatima Z, Fukushima K, Iino H, Mori Y, Fujii H and Araki T. Diagnosis of colorectal hepatic metastases: Comparison of contrast-enhanc-ed CT, contrast-enhanced US, superparamagnetic iron oxide-enhanced MRI, and gadoxetic acid-enhanced MRI. J Magn Reson Imaging., 2011; 34: 326-335.
18. Thoeny HC and Ross BD. Predicting and monitoring cancer treatment response with diffusion-weighted MRI. J Magn Reson Imaging., 2010; 32: 2-16.
19. Bains LJ, Zweifel M and Thoeny HC. Therapy response with diffusion MRI: an update. Cancer Imaging., 2012; 12: 395-402.