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PET/MRI: Current Prospects and Challenges

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Abstract
PET/MRI is a hybrid imaging technology, increasingly being used in research applications as well as in clinical practice. The combined PET/MRI system is the latest in fusion imaging. The device provides specific molecular information related to cell surface receptors and enzymes and gene expression with high sensitivity, delivered by PET. Simultaneously, it also captures important anatomical data, superior soft tissue contrast, spatial resolution and information about perfusion and permeability, shown by MRI. Therefore it proves to be a highly sensitive and evaluator clinical investigation technique. PET/MRI is an expensive technology and its availability is extremely limited across the world. It still need further technical and clinical upgradations for better prospects and prove beneficiary towards the patients. However, initial experience with this new imaging system is very promising for oncology, cardiac imaging and neuro imaging. Not only pediatric and young oncologic patients but pregnant women would also be benefitted from PET/MRI. There are potential competitive advantages of PET/MRI over PET/CT. But, it is struggling to show its superiority over its arch-rival PET/CT in many cases. The aim of this paper is to review the current status of PET/MRI in clinical applications and its challenges.
Key words - *PET-MRI, hybrid, oncology, staging, Pediatric*

Introduction

PET/MRI is a hybrid imaging system, combines magnetic resonance imaging (MRI) and positron emission tomography (PET) into one powerful and simultaneous whole-body system, with substantial and innovative results. PET/MRI scanners are among the most exciting and talked about developments in radiology and nuclear medicine and represent the next generation of imaging technology [1]. These systems require special devices that balance tradeoffs between PET attenuation and MRI performance. PET/MRI

was introduced in clinical setting in 2007 for brain imaging [2,3]. Since then it has undergone much technical development and optimization to conceptualise the co-existence of the two fundamentally different scanner technologies in an integrated manner. The latest 3.0 Tesla hybrid modality combines the highest anatomical details as well as biochemical and functional information provided by MRI with the metabolic, molecular and physiologic information detected by PET [4]. The merger of both proves to be a more accurate and dependable way to diagnose different diseases. The preliminary experience with this new diagnostic imaging technology proves that the hybrid scanner has the potential to improve patient care by increasing understanding of the causes, effects and development of disease processes for better diagnosis of cancer and other complications. Performing the tests simultaneously, capturing metabolic activity and anatomy together offers doctors a more precise and accurate assessment of disease giving an improved understanding of the physiologic process. The precision it offers cannot be emphasized enough, because body parts are continually in motion. A separate PET and MRI scan of the same spot may produce slightly different images. When done simultaneously, the images are completely aligned, giving exception-ally precise image quality. For patients with cancer, the PET/MRI can be used for diagnostic and staging. The fact that, it can more accurately localize the tumor, it is ideal for surgical planning. It can also be used for cardiac imaging, neurode-generative disease, psychological disorders and multiple sclerosis [5]. The integrated device is probably the future of diagnostic imaging. There are potential competitive advantages of PET/MRI over PET/CT. The patients are exposed to much lower levels of radiation as compared to PET/CT. The unique combination of PET/MRI reduce the radiation burden to the patient, where PET is the only source of radiation. This not only benefits patients who have to undergo multiple scans, but is also loyal for sensitive populations such as children, young adults, pediatric patients and pregnant women. The new scanner also helps improve the overall patient experience requiring just one appointment for two modalities. During the testing itself, patients need minimal changes in positions between tests, which in turn, allow physicians to compare test more easily and get detailed information more accurately and quickly as possible [5], [6]. The device is also being used for preclinical research, including the study of radio-isotopes and new tracers for cancer. The current applications is limited to the use of 2 – deoxy - 2 - (^{18}F) fluro-D-glucose (FDG). There is a substantial preliminary experience with other tracers, including[^{18}F]-Fluorocholine, [^{11}C]-acetate and [^{18}F] - fluoroethyltyrosine as well as [^{11}C] - pittsburgh compound B and [^{15}O] and [^{90}Y] carrying tracers [4]. High - resolution small - animal CT exposes the rodents to a significantly high radiation doses than those associated with clinical CT and, for vascular contrast - based imaging, it requires relatively large amount of dedicated iodine - based media to improve visualization and discrimination of soft tissues. Thus other than for bone and lung, CT is generally not the modality of choice for anatomic imaging of small laboratory animals. Combining PET/MRI thereby, provides marked soft-tissue contrast without any potentially excessive radiationexposure, makes it more logical as an approach for pre – clinical studies [2]. It is also useful in stem cell therapy research because fusion helps to study anatomy,function and biochemistry. It could facilitate tracking of stem cell migration into damaged areas of brain. Most evidence by case review showed potential clinical utility of PET/MRI based on studies performed with side by side comparison or software – fused MRI and PET images. Also data on distinctive utility of hybrid PET/MRI are rapidly emerging [6]. Currently three companies offer combined PET/MRI systems: Philips, Siemens and General electric (GE) all over the globe. The first two clinical whole-body systems

were installed by Philips at Mount Sinai medical centre in United State [7] and Geneva University hospital in Europe in 2010 [8]. The world's first Bruker clinscan 7 – T PET/MR scanner was commissioned at CAI, Brisbane, Australia in 2012. This system allows simultaneous acquisition of MRI and PET images of an animal sample. The MRI system is comprised of a 7 Tesla, 30 cm bore superconducting magnet, with operating software identical to the Siemens clinical MRI platform. This enables the most direct translation of research outcomes from animals to humans, benefiting a wide range of biochemical and scientific research. The PET insert has been developed to provide optimal performance in the high magnetic field of the MRI system. [9]. The first PET/MRI in India was introduced by Siemens healthcare at Indraprastha Apollo hospital, New Delhi in 2013. The project is beneficial for the people of Asia, middle east and Africa, who visit India for better treatment, apart from India itself where the incidence of cancer is on rise [10]. Being the technology's first installation in South Asia, India is on the global fore front in medical imaging expertise [11].

Clinical Applications

Presently, the main clinical fields of PET/MRI are oncology, Neurology and Cardiology. Various research studies and clinical trials are actively conducted to understand benefits of the new hybrid diagnostic technology. The technology combines the exquisite structural and functional characterization of tissue provided by MRI with extreme sensitivity of PET imaging of metabolism and tracking of uniquely labeled cell types or cell receptors. There is the possibility of utilizing PET/MRI with Ion therapy, for the purpose of cancer treatment. With MRI's ability to accurately depict the proton density of tissue it proves to be a good match for the benefits and technical challenges of treatment plans that utilize Ion therapy systems [12].

Oncologic Imaging

The strongest evidence for a clinical indication of PET/MRI exists in the head & neck cancer. Due to frequent distant metastasis the whole body approach of the latest hybrid imaging technology is of significant advantage of distant metastasis staging (M-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 (T-Staging) and regional lymph node Staging (N–Staging). PET/MRI can be useful for radiation therapy and pre-surgical treatment planning in head and neck cancer patients [13].

Pediatric Oncology

PET/MRI has potential to reduce overall radiation exposure to the patient as compared to PET/CT, which can lead to a significant radiation burden. A recently conducted study in pediatric patients shows a triple risk of leukemia after a cumulative CT dose of 50 milli gray (mGy) and a nearly triple risk of brain tumors after a cumulative CT dose of 60 mGy. This study emphasized the need to reduce the CT dose in this vulnerable population to the lowest dose possible and to try to establish alternative diagnostic procedures without ionizing radiation [15]. For certain cancer during pregnancy a PET/MRI imaging can be crucial for further treatment planning [8].

Foot Pain Diagnosis

According to a recent study, a single scan by PET/MRI could diagnose the cause of foot pain better and with less radiation exposure to the patient than other methods. Foot pain can be clinical symptom of many different issues, from stress fractures to tumors. Multiple imaging modalities are available to help diagnose specific types of foot pain, but none helps in effectively diagnosing as PET/MRI [15]. It is superior for correct diagnosis for various diseases like the coronary arterial disease, recurrent prostate cancer

and breast cancer. The modality has made it feasible to detect the possibility of a perfectly healthy individual having cancer in future. It can detect the cancer as early as five years or more [16].

How often can be a patient screen for PET/ MRI?

There is no set rule on how frequently a person can opt for a PET/MRI scan for cancer screening. But oncologists recommended a whole body PET/MRI scan at 35 once in five years till the age of 45. Beyond 45, consider it once in three years and beyond 50, once in two years. And if everything is fine, then reduce its frequency to once in three years to five years. However, if there is a family history of a cancer, get yourself screened more frequently. PET/MRI can also give false positive results indicating cancer in the future. So it should be exercise with caution [17]

Challenges

Combining of two advanced imaging technologies without degrading the original optimum performance is most challenging.

Magnetic field of MRI has a negative impact on PET scanner detectors. These tubes do not work inside a magnet. To overcome the above problem silicon based avalanche photo diode detectors were employed. These detectors are magnetic field insensitive and are used now.

PET's electrical and radio frequency components can disrupt MRI signal significantly. To overcome this, very short optical fiber bundles were used to appropriately place the photo detectors and PET electronic with respect to the MRI radiofrequency and gradient coils [18]. Recently Siemens debuts new Syngo MR E11 software platform and applications designed for Siemens bio-graph mMR PET/MR scanner. New body-compass technology is designed to enable motion free PET images with MRI based motion compensation beyond gating, which could be particularly beneficial in delineating abdominal and lung lesions which are prone to motion. The advance PET attenuation correction with the unique whole – body 5 - compartment model including bone for accurate quantification in PET/MRI. Deliver exceptional quality and speed with MRI applications like RESOLVE, FREEZE it and Dot GO. The first siemens MR systems to feature Syngo MR E11 will be the MAGNETOM Aera 1.5T and MAGNETOM Skyra 3T systems. Syngo MR E11 for biograph mMR is currently under development and commercially not available [19],[20]. Recently scientists at Lawson Health research institute, in collaboration with Ceresensa Inc., have produced the first commercial imaging product available in the world for PET/MRI scanners. The novel PET - Transparent MRI head coil provides unparalleled images to advanced the study, diagnosis and treatment of a wide range of disease. At Lawson, the coil will be used for research in Schizophrenia and depressive disorders, Alzheimer's disease and fronto–temporal dementia, and the study of brain damage resulting from chronic dialysis [21]. Studies also revealed that PET/MRI is comparable to PET/CT in most cases and beneficial for bone metastasis and prostate cancer, but it clearly falls short in lung nodule assessment. In addition, PET/MRI's higher price tag, operative costs and, logistics are a hindrance for many imaging centers and hospitals [22]. On the other hand, well proven PET/CT is economically cheaper than PET/MRI in all counts and, widely available all over the world and, still enjoying the status of first choice by many radiologists.

Conclusion

PET/MRI is a promising diagnostic imaging technology with fast developing combining form of two different advanced technologies. The clinical experiences shows its tremendous potential in nuclear imaging and recently conducted research with PET/MRI shown positive results with fast and steady progress. However to give a upper hand over its rival PET/CT, further studies with patients are needed to confirm the overall clinical relevance of PET/MRI. IT is relatively a new technology compare to well

established PET/CT, with further technical enhancements, the clinical outcome would definitely be more better. Certainly the PET/MRI, will grow all over the world in near - future.

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