PET-MRI Instrumentation

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ABSTRACT
Positron emission tomography-magnetic resonance imaging (PET-MRI) is the recent approach to functional and anatomical imaging. The state-of-the-art PET-MRI scanners simultaneously acquire functional PET and anatomical or functional MRI data. As function and anatomy are not totally independent of one another the images to be reconstructed are likely to have shared structures. PET provides metabolic information and the MRI anatomic structure. Thus, the two modalities provide complimentary information, and it has greatly enhanced its clinical applications like imaging in oncology, neurology, and cardiology. This paper gives an overall understanding of PEP- MRI system.

Keywords- PET-MRI, PMIs, APDs, 3DMRIs

I INTRODUCTION

The two imaging modalities can be combined by inserting a PET system into an MRI system and operating them simultaneously for highly accurate spatial and temporal registration. This provides a powerful tool to characterize disease in living subjects. However, this is a difficult instrumentation problem since combining PET and MRI technologies would create substantial mutual interference between the two modalities: The standard PET system design would have a significant electrical interfere with the MRI system's performance, and the latter creates an extremely noisy environment for the former to operate. This requires conductive shielding around the PET components.

II CHALLENGES

There are major concerns while creating a combined PET-MRI system; the first is putting a PET **Emeritus Prof., AISECT University, Bhopal, and Ex-Scientific Officer, BARC, Mumbai* system with photomultiplier tubes (PMTs), which are extremely susceptible to magnetic fields, into a high magnetic field (and having PET detector units that do not interfere with magnetic fields), second, creating attenuation maps for PET images, and third, a proper construct for the PET-MRI system. However with the advancement of technologies PMTs are being replaced with solid state devices.

III PET DETECTORS AND RELATED ISSUES

For combined PET-MRI scanners the photomultipliers are being replaced with solid-state detectors such as avalanche photodiodes (APDs) and Silicon photomultipliers (SiPM) for PET systems. These devices can operate inside the MRI environment. These solid state devices are increasingly replacing the workhorse PMTs not only in PET systems but in many other applications of gamma detection. However simultaneous PET and MRI measurements employ electronic circuits and instrumentation that can interfere in multiple ways with each other.

IV ATTENUATION CORRECTION

Although CT and transmission scans do provide acceptable methods of attenuation correction, they are not as satisfactory, and various MRI-based techniques are also being considered for attenuation correction. However various researchers have provided solutions to the attenuation correction. It may be mentioned that attenuation correction in brain imaging is less challenging than in the torso.

One approach to MRI-based attenuation correction is by using segmentation. In this, a transmission scan is used to generate an attenuation map which is co-registered to the MRI images, and subsequently, the MRI image is segmented into areas with different attenuation values (bone, brain tissue, fluid, air in the paranasal sinuses). This attenuation map is then applied to the PET images.

In brain imaging, these methods have been found to have variations of around 3 and 10% from standard transmission attenuation correction techniques. However most studies have used only a small number of subjects. Data from torso imaging studies is still evolving, and there is a possibility that by using histogram matching and atlas-based approaches, it may be possible to generate MRI-based attenuation maps for torso imaging.

V SYSTEM CONSTRUCTION

The PET-MRI combined system is insert construct system and it involves building a removable PET detector ring that can be placed within the MRI gantry or around the subject when simultaneous acquisition is needed. In this situation, the PET ring must produce minimal disturbance to the magnetic field, the PET detector must be resistant to magnetic field fluctuations or have an external read-out and all parts must be shielded to prevent electromagnetic interference. Various options, which include using optical fibers or APDs, and SiPM are useful from practical point of view.

This system has the advantage of allowing simultaneous PET-MRI acquisition and the opportunity for it to be adapted to any center that already has an MRI system. The drawback, besides developing the technology to create excellent quality images with excessive interference, is a further decrease in the space within the bore of the MRI scanner.

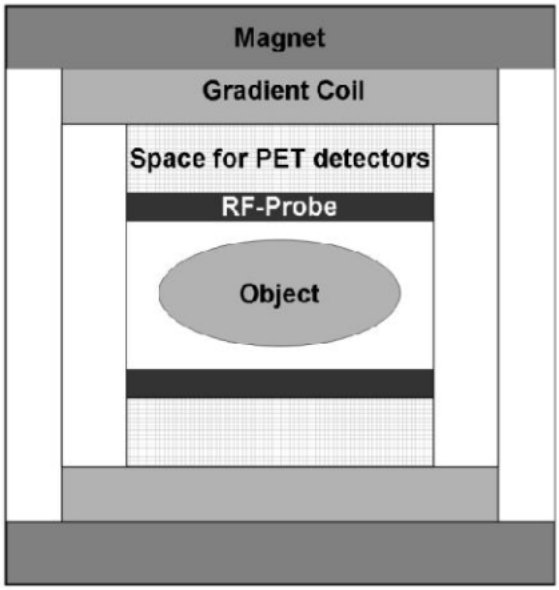

Fig. 1 Typical Topology of PET-MRI System: PET inside MRI System

Fig. 1 depicts a typical PET-MRI system. RF coil is located inside the MRI to do MR imaging. PET is inside the gradient system. The PET allows for the gradient to penetrate.

Fig. 2 depicts three dimensional (3D) view of the topology of PET-MRI System clearly depicting MR magnet, Gradient, PET insert, LSO detector, and position sensitive APD. APD is however is being replaced by SiPM.

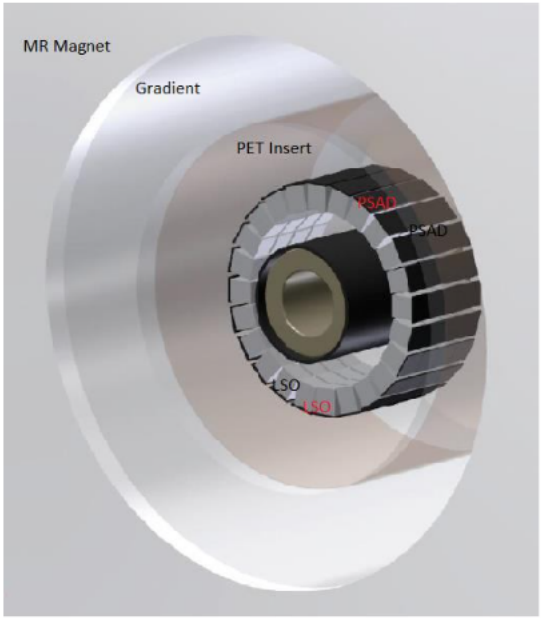

Fig. 2 PET-MRI System–3D View

Siemens has pioneered PET-MRI system known as Biograph mMR and it has been commercially available since the last four years. It has been used in oncologic, neurological and other medical imaging. The inherent benefit of the simultaneous acquisition is improved registration allowing optimal localization of PET findings to anatomic imaging and shortened overall imaging times through acquisition of PET and MRI in a single session. This also provides comfort to the patient who has to undergo only one scanning.

Fig. 3 depicts three images viz. PET. MRI. And PET-MRI. It is evident that PET and MRI give complementary images and PET-MRI has both anatomical and functional details.

VI IMPACT ON NUCLEAR MEDICINE COMMUNITY

PET-MRI is an exciting modality which gives us unprecedented simultaneous insight into form and function *in vivo*. While we are well aware and comfortable with the appearance, distribution, and implications of changes in radiotracer distribution, we will now have to deal with one of the most technically challenging imaging modalities, the MRI. The complexities of MRI physics,

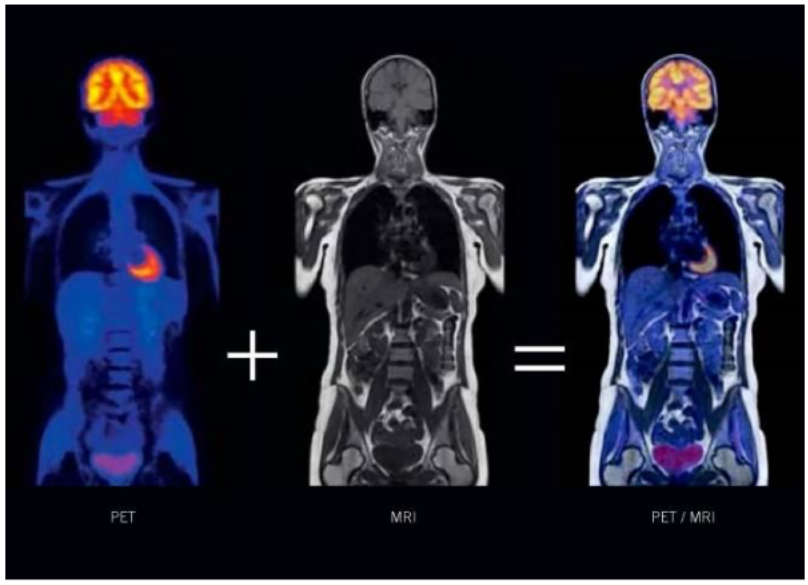

Fig. 3 PET, MRI, PET-MRI Images

MRI sequence optimization, artifacts, the functional aspects of MR imaging, and a huge volume of intricate anatomy, will all soon become the responsibility of the imager. Those who will deliver the best of both worlds will ultimately take the modality into the forefront of research and clinical care. If we are to make a greater impact in this field, now is the time to create the next generation of molecular imagers who will be equipped to deal with these challenges. For a start, we need to understand not just the limitations, but also the strengths of other imaging modalities and start incorporating these more regularly into our daily clinical routine and educational directives.

For example patients with cancer, the PET-MRI can be used for diagnostics and staging, and it can precisely localize the tumor, and a great help for surgical planning. With the PETMRI, patients are exposed to much lower levels of radiation than with the PET-CT. It may be mentioned that PET-CT systems are pretty common compared to PET_MRI systems. PET-MRI thus not only benefits patients who have to undergo multiple scans, but also beneficial to children. Moreover just one appointment for two modalities makes the patient more comfortable.

During the scanning, patients need minimal changes in positions between tests, which allows physicians to compare tests more easily and get information as accurately and quickly as possible.

VII CONCLUSION

PET-MRI is a modality with tremendous potential for combining form and function *in vivo*. The combined scanner is proliferating in clinical practice. Significant challenges still exist before this becomes a routine part of our imaging arsenal. Moreover there is plenty of scope to improve the performance and challenge to engineers and

doctors to work together to realize this potential. Meanwhile, we should be developing an infrastructure that will equip us to cope with the challenges that lie ahead, by learning how other imaging modalities will supplement what we already know.

Hybrid PET/MRI scanners have become commercially available since the last four years, but are not yet widely distributed.

The real challenge of this exciting new technology would be proliferation of its use to masses and it does not seem to be possible in the near future.