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Review

The advent of MR/PET Imaging

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ABSTRACT:

Advancements in imaging took a leap in the last decade, when PET-only systems were phased out and replaced with PET-CT systems. This led to a functional and anatomic image of tissues of high contrast and greater application. Another breakthrough in oncology imaging is expected with the merger of MRI and PET, where imaging of specific body locations with no additional radiation burden and better tissue contrast is achieved.

Key words: ***CT-Computed Tomography, PET-Positron Emission Tomography, MRI-Magnetic Resonance Imaging***

Introduction

An effective management of a cancer patient depends on the correct detection of tumor and staging of disease.[1] A cancer patient undergoes several investigations including different imaging studies, which are later correlated to arrive at a definitive diagnosis. Such processes are usually tedious and time consuming. Moreover, well defined and reproducible landmarks are necessary for correct interpretation of these imaging modalities. Patient positioning also varies in various procedures leading to inconsistencies and errors. Also, there may be problems due to patient movement or motion of internal organs such as heart or bowel peristalsis. To overcome such problems, developments in imaging in oncology led to fusion of PET with CT[2] and more recently PET with MRI.[3]

Review and Discussion

In PET alone imaging, the most often used radiopharmaceutical is 18F-FDG. There is derangement of glucose utilization in cancer cells. Taking advantage of this derangement, FDG mimics the glucose utilization, and photons are emitted from this 18F-FDG.[4] In MR imaging, a scout view is obtained and the imaging field is then defined. In this way combining both of these modalities leads to an

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anatomic and functional registration of tissues. However, a different gantry is required to combine MR and PET as both have different detectors.[2]

MR-PET imaging

MR imaging usually takes longer time than a multi-detector CT making the acquisition times for MR and PET become quite similar. Thus, the "simultaneous acquisition" method is usually the preferred option (Fig. 1). PET/CT imaging usually involves "sequential acquisition" (Fig. 2), which leads to a longer time for MR/PET; thus leading to increased chances of patient movement and motion artifact causing misregistration of the final image. Hence the simultaneous acquisition allows interrogation and measurement of patient's tissues at exactly the same time.[5]

Simultaneous acquisition (Figure 1)

The PET detectors should be able to operate inside the magnetic field without interfering with the MR imaging for a combined MR/PET imaging. These types of detectors have successfully been constructed and are typically based on silicon avalanche photo-detectors (APDs).[6] Several animal systems based on this technology have been constructed with one system introducing a PET insert for one of their MR systems in 2007. However, the system was limited to brain only imaging.[7] A recent clinical study comparing PET/CT and MR/PET imaging showed that the image quality was similar for both systems.[8]

Sequential acquisition (Figure 2)

A different system design is used in another commercially available MR/PET system. The conventional PET and MRI gantries are placed at some distance from each other in order to minimize interference between the two systems. The two devices use a common patient bed, which can be moved into either imaging gantry. This solution does not require special PET detectors, although additional magnetic shielding is placed around the PET gantry to minimize the effect on the PMTs. This type of acquisition has the drawback of not allowing simultaneous PET and MR imaging, which prevents imaging of physiological and biochemical processes at the same moment in time by the two modalities. Since the PET and MRI data sets are acquired sequentially and since MR imaging usually takes much longer than CT, the imaging sessions are substantially longer compared to corresponding PET/CT imaging procedures.[7]

Advantages of MR/PET Imaging

The combination yields a simultaneous anatomic and functional registration of the tissues. A higher tissue contrast is obtained, and sophisticated MR imaging techniques such as perfusion and diffusion imaging[9], and MR spectroscopy, without adding extra radiation to the patient may be incorporated. Moreover, no ionizing radiations are involved in MR imaging so the total absorbed radiation dose to the patient is solely due to the radiopharmaceutical used for PET imaging. This is much more favorable than CT, which has a relatively high radiation burden. It is very likely that this technology will be extended to clinical whole body imaging in the very near future.[3]

Challenges for MR/PET Imaging

There are a number of challenges in combining PET and MRI. The PMTs (photo-multiplier tubes) used in conventional PET detectors are highly sensitive to magnetic fields and cannot be used near the MR magnet. Solid-state detectors are less sensitive to magnetic fields and have been shown to operate relatively undisturbed in strong magnetic fields.

These detectors have to be constructed without any ferromagnetic materials that would otherwise produce heterogeneity within the magnetic field. Therefore different approaches have been sought to overcome these challenges for a better combined MR/PET systems.[6]

The slices for MR imaging are usually thick slices (5—7 mm in z plane), whereas PET has image slices of 2—4 mm. Another challenge for a combined MR/PET system is the attenuation correction.[10] An additional complication is that not all tissue types are visualized in MRI (e.g. bone). This may require the use of deformable anatomical atlases to generate the correct attenuation coefficients. The conversion of MR images to attenuation maps is a complex problem and is an area of active research. A number of different approaches are currently being investigated and developed.[3, 7]

Final Considerations

The radiologist or nuclear medicine specialist must be eager to participate in the changing field of combined and correlative imaging in oncology. The detailed anatomic framework required for accurate interpretation of functional images, is of paramount importance in oncology. Such requirements were fulfilled when PET was combined with CT to provide an image of superior quality having both an anatomic and functional registration. Moreover, the combined imaging process saved patients time. Fusion of image by such a process led to improved lesion localization. It may be expected, that with better systems being developed, MR/PET will develop as an imaging modality of choice for oncology patients. The simultaneous acquisition, used in MR/PET, will definitely benefit image registration and reduce artifacts leading to an accurate image.

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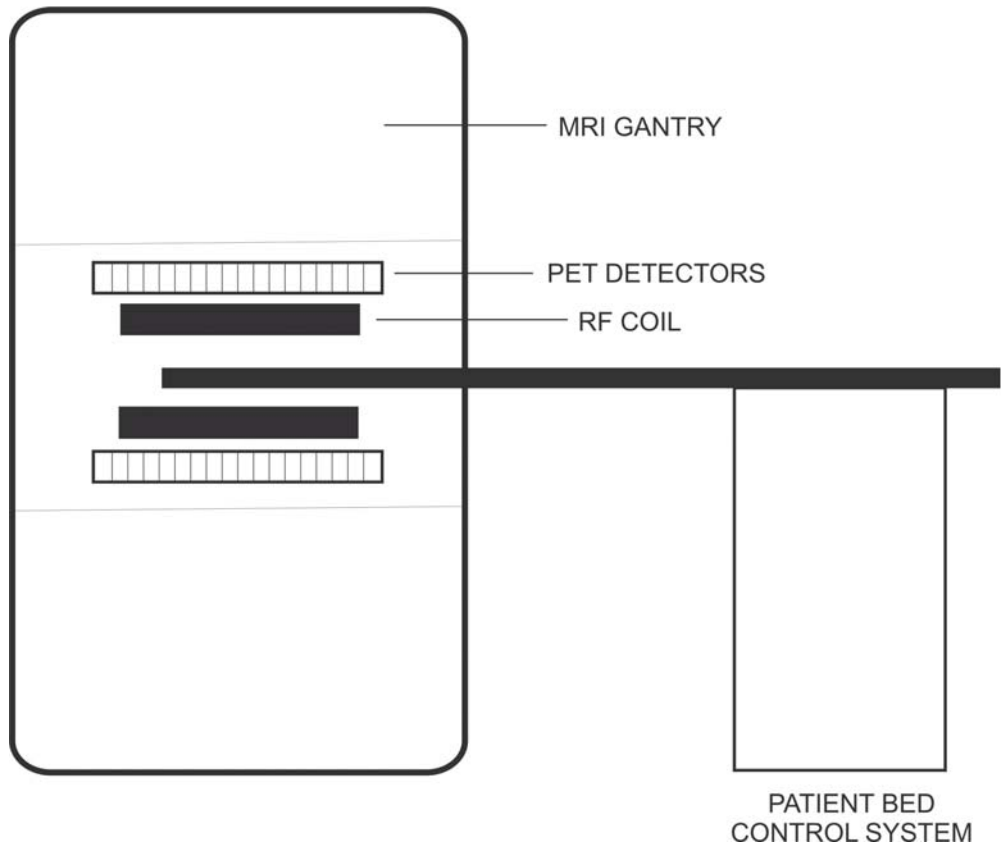

Figure 1: Simultaneous acquisition of MR/PET data. The radiofrequency coil of MR imaging is located within the ring of PET detectors.

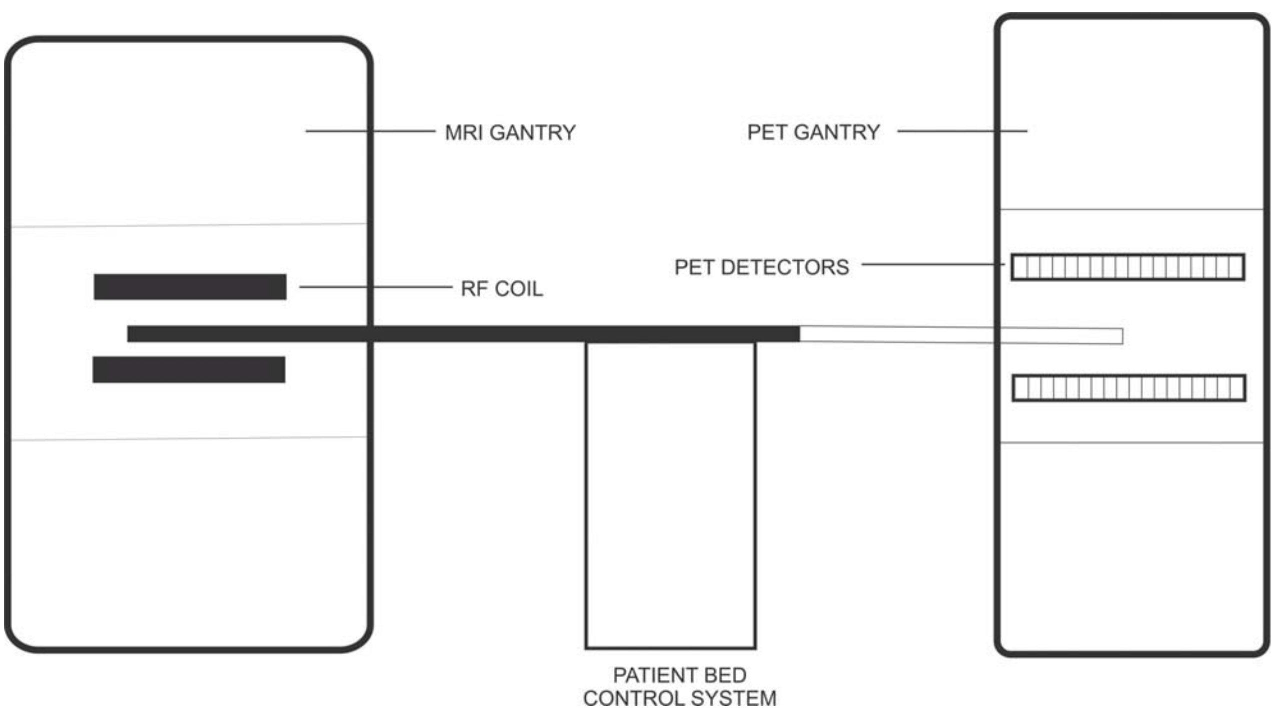

Figure 2: Sequential acquisition of MR/PET data. The two gantries of PET and MRI are different with additional shielding of PET detectors against the magnetic field.