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REVIEW ARTICLE

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The Impact of PET/MRI Fusion on the Diagnostic Imaging Industry

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Abstract

The multimodal imaging technique has gained the spotlight in the present era due to its striking and immense applications. It is the combination of two or more modalities that complement one another to yield detailed information. Indubitably, it is an emerging and crucial technique due to its broad clinical and research applications. The diagnostic techniques with the dual modality are aligned for obtaining molecular data. Positron emission tomography (PET) is a progressive imaging technique in nuclear medicine. To flourish in the imaging industry, PET was combined with computed tomography (CT), but the fusion of the two provides some challenges, such as less soft tissue contrast and inefficiency of acquisition in simultaneous mode. As a result, another hybrid imaging technology, PET and MRI (PET/MRI), has been developed to provide more soft tissue contrast and less radiation dose exposure, leading this technique to be used extensively despite its shortcomings. This review study discusses the fusion of PET/MRI, technical challenges for their combination, commercially available models, and clinical applications observed in the wide areas of oncology, the cardiovascular system, the central nervous system, pediatrics, and inflammatory diseases. (**International Journal of Biomedicine. 2023;13(3):46-53.**)

Keywords: hybrid imaging • PET/MRI • technical challenges • dose advantage

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Abbreviations

CT, computed tomography; **FDG**, F-fluorodeoxyglucose; **MRI**, magnetic resonance imaging; **PMT**, photomultiplier tubes; **PET**, positron emission tomography; **TOF**, time-of-flight.

Background

Multimodal imaging has become increasingly significant for diagnosing diseases at the molecular level, leading to enormous advances in the medical imaging field. It is the combination of two or more techniques that complement each other to augment the efficacy. The diagnostic technique involves envisioning, characterizing, and assessing living organisms at basic cellular and molecular states. The conventional medical imaging modality assesses anatomical or functional characteristics. The anatomical evaluation is performed by computed tomography (CT) or magnetic resonance imaging (MRI), whereas functional evaluation is done by PET or MRI technique.[1] PET is the nuclear imaging technique with the basic principle of performing sensitive assays with even less radioligand concentration. It evaluates the functionality at the molecular basis from biological to pathophysiological process. It incorporates radiotracers such as 13N, 11C, 18F, and 150, which pass through the region of interest.[2] MRI utilizes magnetic fields and radio waves with different parameters to evaluate anatomical images with high resolution, physiological, biochemical, and metabolic activities of the body.[3,4]

The concept of fusion of PET/MRI was conceived by Simon Cherry and Paul Marsden in the 1990s to make use of the merits and demerits of the techniques. While they were performing an animal study, it was necessary to attain the anatomical information with soft tissue contrast provided by MRI and the molecular details by PET.[5] The PET and MRI

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techniques are merged into a single modality to attain beneficial features simultaneously. The growth has been steady for the past 20 years as it has gained attention as a powerful tool used in clinical research. The necessity of fusion is highlighted as it can combat the pros and cons of conventional medical imaging. The pre-clinical study performed in the 1990s grasped attention, leading to the commercial launch.[6] This study demonstrates the potential of PET/MRI fusion, which paved the way for the growth of dual-modality imaging methods to strengthen them by considering the pluses and minuses of each technique.

Principle of the PET/MRI technique

PET technique is a painless, quantitative method that assesses the biological function by observing the flow of blood, neurotransmitters, radioactive tracers, and metabolites. In this technique, a radioactive tracer emitted after injection through the intravenous route is detected. The nucleus of the tracer releases a positron that causes a collision with electrons of the cell projecting photons which are examined by the camera present in the PET scan and are processed and converted to electrical signals, which takes about 10-40 min. It has applications in various fields, such as neurology, cardiology, cancer detection, atherosclerosis, and glucose consumption. PET technique offers broad advantages as it detects radiotracers in *in vivo* studies by considering sensitivity and quantitative precision. It employs molecular agents that display details of tissues and organs, leading this technique to have moderate space in the cancer field as it provides both diagnosis and cancer stages.[7] The last few decades have seen an immense revolution in scientific activity to modify and enhance the efficacy of PET technology. The advancement in this technique is the result of acquisition with the gating method, detectors integrated with enhanced geometry, and combination with other operational methods, such as MRI and CT, to magnify its potency. With its strength, there are also some shortcomings in this imaging modality; notably, the detection of photons is restricted due to the axial coverage from only 15 to 30cm; bounded temporal resolution thereupon causes risk and challenge to dynamic radiology with kinetic methodology.[8] Small-size tumors do not absorb the imaging tracer, which it lacks to be detected, and anatomical information of the body cannot be revealed with the PET technique. The total body-PET method provides distinctive features like increased resolution, detection sensitivity, expeditious method, large range of scans, and a low dose of tracer to offer better scan image quality to a profound understanding of disease and its stages, diagnosis, progress, or deterioration and prognosis of the illness.[4]

MRI is a painless diagnostic technique that postulates information about the body by using a strong magnetic field and radio waves to provide cross-sectional quality images. Due to the wide applications of this technique, it has broadened the horizon of imaging technology spectra. In this process of obtaining MR images, a patient is placed inside a huge magnetic area that causes the induction of a strong magnetic field externally. Due to this magnetic power, there is an alignment of nuclei of various atoms with the magnetic field, which, upon exposure to radio waves, produces energy that is analyzed by the system, creating an image.[9] MRI is often divided into structural MRI and functional MRI (fMRI). Structural MRI illustrates information about the anatomical structures, whereas fMRI explicates physiological activity. At the same time, MR image quality is determined by the interaction of appropriate parameters in each pulse sequence to obtain the maximum image quality to ensure high diagnostic accuracy in a reasonable scan time.[10]

MRI can provide 3D images with T1 and T2 relaxation times, which is cardinal for tumor assessment with high temporal and spatial resolution.[11] The grading of tumors is exceptionally stipulated by functional MRI as the advanced system applications, such as MR spectroscopy (MRS), perfusion-weighted imaging, and diffusion-weighted imaging.[12] However, MRI is contraindicated with patients with metallic objects in their bodies as they represent image distortion and safety issues in the subjects with implantations, and since bone does not give an MRI image, only bone marrow analyses are done.[9] One of the demerits noticed with MRI versus PET is that the sensitivity of functional information is less. Understanding PET and MRI functions is crucial, because when the modalities are combined, they complement each other and yield information simultaneously (Figure 1).

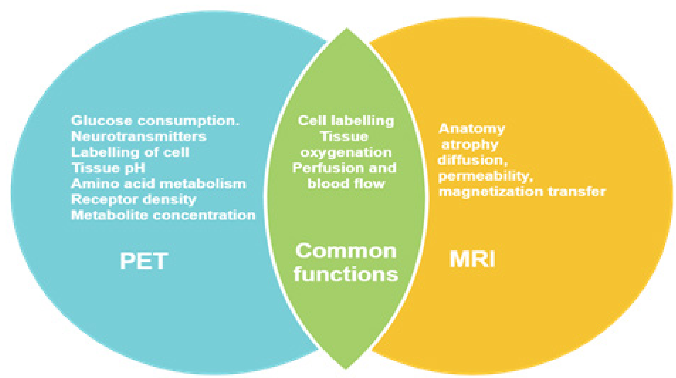

Fig. 1. *The functions of dual modality (PET/MRI) complement each other and can be acquired simultaneously.*

Predominant factors and merits of PET/MRI over PET/CT

The amalgamation of PET/MRI techniques has a fledgling and crucial impact in various fields, such as oncology, neurology, cardiology, and psychiatry. The concept of dual-modality was developed in the 1990s when the combination of PET/MRI and PET/CT was on track for development to expect a higher outcome. PET/CT has special applications, but shortcomings were noted. Many technical challenges in PET/CT technique set it back and initiated the spotlight on PET/MRI as it has fewer obstacles. The strengths of PET/MRI over PET/CT are low exposure to radiation, which reflects its safety, higher contrast with soft tissue, and it can be used to analyze any body part.[13] The imaging design of PET/CT is sequential, which causes it to obtain information from two systems; software is also installed to correct CT attenuation. Regardless of the same acquisition settings for both pediatrics and adults, the dose of CT in babies and children surpasses the dose given to adult subjects. Therefore, the benefit of replacing CT with MRI is underlined in pediatric patients. The approach to malignant cancer in pediatrics is of major concern and challenging due to the diagnostic imaging radiation dose. The preference for MRI over CT can reduce the radiation dose by almost 50%, which helps its use in children with cancer.[14] In addition, the radiation dose is of consideration in patients with lymphoma as they have to be scanned multiple times, which exposes them to radiation of 23-26 mSv; in this order, the PET contributes about 5-7 mSv dose. Hence, replacing CT with MRI can abbreviate radiation exposure effectively. The other observed demerits of PET/CT are the probability of error due to the patient's motion during the examination, and the scanning process takes a long time. PET/MRI has beneficial outcomes in motion correction to obtain the information from MRI, and it can be used potentially in clinical and pre-clinical aspects.[3,15]

Manufacturing of Clinical PET/MRI integrated system

The first clinical integrated scanner, "BrainPET," was developed in 2007 by Siemens Healthcare after the pre-clinical studies revealed its effect. In the BrainPET design, the PET system was inserted into the MRI scanner, which was a 3-Telsa standard MRI scanner manufactured by Magnetom TIM Trio. It was based on simultaneous acquisition[16] (Figure 2).

Fig. 2. *Siemens MR-BrainPET prototype (PET insert into an MR scanner).*[15]

Further, Philips designed a whole-body PET/MRI model which has gained acceptance in Europe and endured with Conformité Européenne (CE), which certifies the standards, and it also received clearance by the Food and Drug Administration (FDA) (Section 510(k)) in the US (Figure 3). The model is based on the sequential design in which PET was placed adjacent to the MR scanner, 8 feet apart. A patient table is employed to obtain information in sequential order. A beneficial point has been obtained by modifying the state-of-the-art, time-of-flight (TOF)-PET which has caused the detectors of PET to work in the arena of MR scanners. Simultaneous data cannot be achieved with this technique.[17]

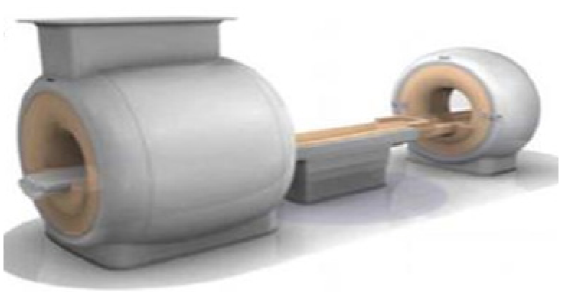

Fig. 3. *A whole-body sequential PET/MRI scanner (Philips Ingenuity TF PET/MRI).*[15]

General Electric (GE) designed a table in the year 2013 compatible with both PET and MRI, which led them to shift the patient between the scanners known as SIGNA PET/MR (Figure 4). The design of this product contains a component of MR which holds a bore of 60 cm 3-Tesla superconductive magnet, gradient coils, and transmitter. It is equipped so that the components of PET are placed between the body coil and gradient coil, which is shielded with radiofrequency. An appropriate temperature is maintained with the use of cold water. The performance of this design is explicit in terms of timing resolution, which is below 400 ps, energy resolution documented to be 10.3%, and scanner sensitivity is 23.3 kcps/MBq.[18]

Fig. 4. *SIGNA PET/MR (General Electric).*[15]

Biograph mMR is the first whole-body integrated scanner designed by Siemens in the year 2010 which has been granted the CE mark by Europe and received clearance from the FDA (Figure 5). This is based on Automatic Data processing (ADP) technology and has been advanced with gradient design by placing the PET detectors between a gradient coil and RF body coil. This design comprises a whole-body integrated scanner, which utilizes about a full 60cm bore magnet. The full gantry of PET is occupied by 56 detectors which make up eight rings, and the inner temperature of the detectors is maintained using cold water. The system's performance is measured using spatial, timing, and energy resolutions. The stated spatial resolution is 4.3 mm Full-width at Half Max (FWHM) from the field center at the distance of 1cm, timing resolution is 2.93 ms, and energy resolution is 14.5%. The sensitivity of the scanner noted is 15.0 kcps/MBq, and the data of the mMR scanner is obtained in 3D mode; the images of PET are obtained by the back projection that is filtered, or the statistics of Poisson distribution are followed.[19]

Fig. 5. *Siemens Biograph mMR whole-body scanner.* [15]

Technique challenges of PET/MRI fusion

The complexity in the design is caused by magnetic field consequences in physical challenges. The main objective is to obtain the integrated system without altering the functionality. The models are designed as sequential and simultaneous approaches. The sequential design is simple and economical, obtained by Philips Healthcare TF-PET/MRI. In the sequential approach, the software is co-registered, and the scanning procedure of PET and MRI is done one after another. This also gives a plus point for patients with claustrophobia, as this process is carried out in different modalities. In addition, in a sequential design, there is an additional shield with minimum exposure to the magnetic field. The drawback observed is the space, as it requires a larger area of 4.3×13m and causes motion artifacts to the organs, indicating its need for concurrent imaging. In the simultaneous approach, both modalities are constructed within the whole system to be placed in the same gantry. This design has two models; PET inserted MRI scanner and a fully integrated system. This model also has the benefit of less space.[20]

Due to its high potential, the obstacles to merging PET and MRI should be studied, and their compatibility must be assessed to impact the diagnostic imaging field. The hurdles to merging and maintaining PET and MRI with high performance are mentioned below (Figure 6):

1)The effect of PET on the MRI system
2)The effect of MRI on PET
3)Quantitative imaging
4)Space and time-bound

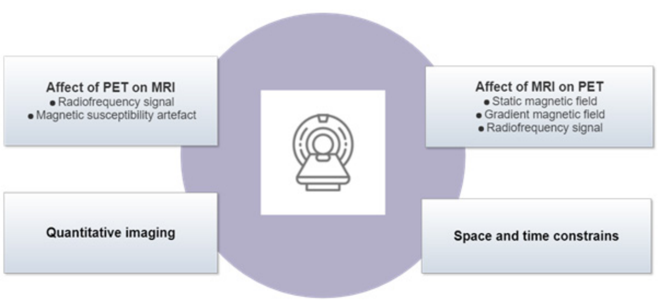

***Fig. 6.** Technical challenges of combining PET/MRI.*

The PET detectors are located in the magnetic bore, affecting the magnetic quality due to rationales like interference of a radiofrequency signal (RF) and magnetic susceptibility artifact. The linear measure of the gradient field is influenced by the arrangement of PET components in the magnetic bore as it affects the magnitude and direction of magnetic flux that is supposed to be identical in the field. These minute changes can impact the susceptibility of the magnetic area. This variation can be rectified by shimming that presents homogeneity in the field.[21] The simultaneous TOF-PET/MRI contains a metal implant at the adjacent site that could emerge as the susceptibility artifact. Lead, and tungsten is the gamma-shielding substance in PET that produces an eddy current that causes distortion and intermittence. The homogeneity and occurrence of susceptibility artifacts could be maintained by employing non-magnetic materials.[17]

The RF signal is the other ground of technical challenge in PET/MRI systems. The stimulation of the MRI B1, which is applied perpendicular to the main magnetic field, causes the generation of an NMRI signal which is weak in characteristic; thereby, the coil in MRI is to be particularly sensitive, and the room of the procedure should be Faraday shielded. The received MRI image is distorted by the RF signal ranging between 120MHz- 3 T. This frequency is primarily present in digital technology like clock pulse, directing its need to be shielded to obtain a precise MR image. This precaution can prevent the non-linearity in the production of magnetic flux and eddy current.[22]

The effect of MRI on the PET system

The PET function is affected by the presence of a static magnetic field, a gradient magnetic field, and a radiofrequency signal as they interfere with photomultiplier tubes (PMT) and PET detectors. The weak feature of the static magnetic field will alter the functionality of PMT in block detectors as it deflects the flow of electrons from photocathode to dynode to anode chain. This occurs due to the Lorentz force, leading to loss or misinterpretation of diagnostic information. The resolution can be performed by shielding the PMT with steel or mu-metal with the exception of preventing it just from weak fields. The replacement of PMT can be done with Avalanche photodiode, a field insensitive-PMT, and position-sensitive PMTs but with the downside of intolerance to the tesla field in the MRI system. The approach to this obstacle is to expel the PMT from the system or to replace it with light detectors compatible with magnetic fields.[23]

To achieve larger skin depth at less frequency, the gradient magnetic fields are switched around 1kHz rate, but this alteration leads to the induction of eddy current, which increases the temperature and causes vibration of electronics in the PET. Therefore, the electronics with high frequency should be shielded with materials like copper or aluminum. The attribute of copper, such as its non-magnetic and non-ferromagnetic nature, protects by isolation with 99% of electronics present in PET. The gradient pattern reduces the system's sensitivity by 5% to 20%.[24] The solid-state photo detectors and electronics present near the coil should be of robust character. The robustness can be accomplished by redesigning the PET system.[4] Interference by RF is another technical obstacle that can affect the electronics situated in the magnetic bore, leading to a drop in the count of the PET rate and induction of a noise signal in the PET system resulting in heating and eddy current. The conducting shield is used for the PET detectors and electronics present in the magnetic bore that can minimize the interference of RF.[23]

Quantitative imaging of the PET/MRI system

In quantitative imaging, the attenuation is corrected by the linear attenuation coefficient at 511 keV. Attaining attenuation correction maps from emission data and MR image is complex and has brought attention to this arena. Many methods have been developed to combat this challenge, yet they have failed.[25]

Space and time constraint

The PET scanners are MRI-compatible and designed within the magnet's bore to obtain concurrent images. Acquisition time is the paramount aspect for considering the system; notably, a CT system takes a shorter time of about 15s - 1min, while it might consume 20-40 min for different MR diagnostic images. The evolved PET technology containing a 3D scanner reduces the acquisition time to 3-15 min for brain imaging and 10-20 min for scanning the whole body.[4] Concerning the TOF, availability of 3D imaging, and longer axial field of view, the advanced technology of PET is more sensitive and accurate. The acquisition time varies with simultaneous and sequential models, which require longer imaging time, and in the latter system, the time depends on a slow acquisition system. In the sequential acquisition system, space should be contemplated as the design is compact, where the standalone systems have to be placed within a minimum area.[20]

Pre-clinical implementation of PET/MRI fusion technique

The amalgamation of PET/MRI modality is the desirable approach for pre-clinical examination as it provides soft tissue contrast with less vulnerability to radiation dose. CT is not the preferred approach to acquire anatomical details of laboratory animals except for lung and bone. The fusion offers a dose advantage over the CT technique, which requires a high radiation dose. In vascular-contrast imaging, the iodine is administered in substantial quantities to have better imaging quality regarding visual appearance and to differentiate soft tissues. These reasons provide PET/MRI as a first-hand approach for animal investigations.[21] The 7T PET/MRI animal scanner has exhibited promising results in the oncology field, which was also confirmed with a histopathological study. A PET/MRI scanner was used to scan a mouse with a CT26 colon tumor. Necrotic lesions were clearly distinguished with MRI curves obtained with a time-to-signal graph. This attainment would not have been achieved with exclusively PET, demonstrating the significance of the PET/MRI combination. MR contrasting agents and PET tracing agents, like [18F] fluoro-L-thymidine and [11C] methylmethionine, in adjunct diagnose tumor proliferation in the brain and spinal cord in the animal study.[26]

Clinical implementation of PET/MRI fusion technique

The promising growth of the fusion technique highlighted the need in the market to resolve its challenges for clinical implication. The integration of the PET/MRI system should be technically modified without altering the functionality of each modality. Apart from the primary use of anatomical and functional imaging, it offers various services in many fields, such as cancer, pediatrics, and central nervous and cardiovascular systems (Figure 7).[3]

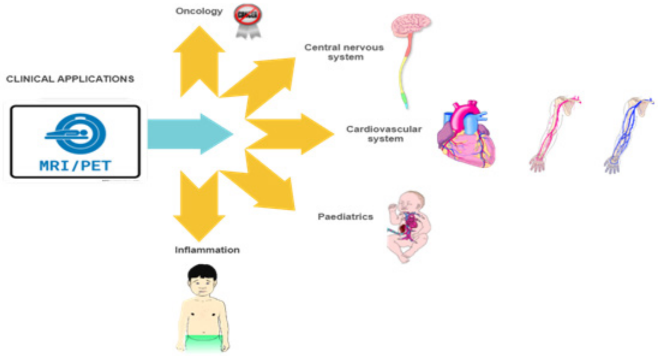

Fig. 7. Clinical applications of dual-modality PET/MRI.

Oncology

The PET/MRI technique offers the examination of tumors to a larger extent as it can differentiate soft tissue, which has availed the assessment of head, neck, rectal, prostate, and gynecological cancer in depth. Evaluation of reoccurrence after surgery and radiation is complex as radiation can cause fibrosis, scarring, and tissue distortion, which can be assessed with the PET/MRI process.[27] Along with soft tissue discrimination, MRI assists in T-staging cancer. Combining MRI with PET provides a way to determine cancer staging efficiently. Radiation dose is the chief concern, particularly in the pediatric population suffering from cancer, prompting an investigation to decrease the dose and ensure safety. An investigation on 15 children with multifocal malignant diseases showed that the effective dose of a PET/MR scan was only about 20% that of the equivalent PET/CT examination.[28] A comparative study between PET/CT and PET/MRI was conducted on 32 subjects suffering from different types of cancer by administering an 18F-fluorodeoxyglucose (FDG) single injection to determine which one has the better image outcome and time constraint. The study showed that simultaneous PET/MRI has better image quality, lower radiation dose, and less scanning time than PET/CT.[29] A similar finding on 80 subjects indicates the superiority and feasibility of PET/MRI in image quality.[30] This modality gives superior results in the head and neck region as they require high soft tissue contrast. The metabolic information provided by FDG-PET complements the MR scanning of head and neck tumors, indicating its benefit in this region.[31] Another study was conducted on 20 patients to determine the primary tumor and metastasizing of lymph nodes; the study revealed the supremacy of PET/MRI over MRI and PET in a standalone mode, which was also positively correlated with the histopathological examination.[32] Other investigations reported different results, indicating the statistically equivalent performance of both modalities, PET/MRI and PET/CT, in assessing head and neck tumors.[33] A contrary outcome was that no significant observation was determined regarding the functionality of both modalities, indicating further study in a large group of patients.[34]

The characteristic of lymphoma subtypes is exacerbated glucose metabolism, which can be primarily diagnosed at different stages and given follow-up treatment by PET 18F-FDG. An advancement in technology led to providing the effect of 18F-FDG-PET-MRI on image quality, where the reports indicated satisfactory image quality in addition to evaluating patients' response to lymphoma therapy.[32] The benefit of diagnosing with PET/MRI modality is also noted in benign prostatic hyperplasia, in which choline uptake is elevated and distinguished from tumor lesions.[35] This modality also provides a strong role in detecting prostate cancer and its staging. However, the suggestions demonstrate high complementary outcomes with 18F-choline-PET and diffusion-weighted MRI, but PET reported the presence of tumor lesions, and no such observation was shown with MRI diffusion-weighted imaging.[36] In addition, this fusion modality is efficient for assessing bone metastases, as revealed by a study conducted on 119 patients that found PET/MRI to be superior.[37]

Central nervous system

PET/MRI has neurological applications, which has widened the horizon to assess and implement it in the diagnostic and clinical role. PET and MRI can be used to evaluate blood flow and oxygenation; their amalgamation is used to simultaneously measure functional activity. PET/MRI diagnostic power can provide an array of research and develop new targets for neurological diseases. Alzheimer's disease is one of the progressive neurological diseases affecting memory and cognitive development, which interferes with normal daily activities. The incidence rate is widely increasing in the world. The disease occurs due to an abnormal accumulation of proteins in the brain. The amyloid protein is accumulated around the brain, and the tau protein is aggregated within the brain, causing this form of dementia.[(38)] PET modality is used for qualitative and quantitative measurement of changes in the brain due to Alzheimer's disease. It evaluates alterations in the glucose metabolism in the brain and determines the disease's progression and therapeutic efficacy.[(39)] Structural MRI can assess the disease-affected morphological changes in the brain, and volumetric measurement has strengthened its potential as it can evaluate disease at the early stage. The findings observed are atrophy in the medial temporal lobe in mild cognitive impairment and Alzheimer's patients. The simultaneous development of PET/MRI has generated the area of comparison of alteration in morphology and metabolism, which has led to a better understanding of disease and therapy implications. An exploratory investigation conducted on Alzheimer's patients in 2010 demonstrated a decrease in hippocampus glucose metabolism, compared to the control group. The progress from the initial stage to the disease outcome is accurately determined by combining PET, MRI, and cerebrospinal fluid biomarkers. The development of advanced MRI techniques such as diffusion tensor imaging and arterial spin labeling can provide detailed information in addition to anatomical detail provided by MRI and metabolic details by PET, accentuating the significance of this dual modality.[(40)]

Neuro-oncology studies neoplasms in the brain and spinal cord, where the investigation and approach are complex. MRI is the optimal choice for imaging neoplasms in the cranial region. This technique provides anatomical information; added gadolinium enhances MRI, which can evaluate the blood flow and integrity of the blood-cerebrospinal fluid barrier.[(41)] It has significant limitations, such as the use of gadolinium contrast can disrupt the barrier and does not provide information on tumor activity in detail; classifying gliomas along with their proliferation is not well explored. Furthermore, the response of therapy is not determined with MRI.

The PET modality gives molecular details, such as the conversion of radio-labeled amino acids in the neoplasm and matrix metalloproteinase secretion. In combination the techniques complement each other and can help provide a detailed assessment, as demonstrated by different studies.[(2,42)] The efficacy of tumor assessment was found to be augmented more in PET/MRI than in PET/CT in a research study using C-methionine, Ga-DOTATOC with PET/MRI on 10 patients experiencing intracranial masses.[(2)] A study conducted on 28 patients suffering from gliomas illustrated the grading of tumors by fusion of simultaneous C-methionine PET and MR spectroscopy. It revealed that the partial correlation shows the differences in distribution, which can be employed for the surgical processes.[(42)] The merging of these techniques could provide more depth, such as sites for biopsy, the proliferation of cells, and separating the tumor cell to prevent inflammation and necrosis. In addition, combining PET and MRI with enhancers like gadolinium and tracer uptake somatostatin helps to plan the surgery and to monitor and determine the reoccurrence.[(43)]

Cardiovascular system

PET modality is considered the gold standard to evaluate the viability of the myocardium non-invasively. The MRI modality gives anatomical details that provide insight into a ventricular structure and function and diagnose myocardial infarction. Amalgamation can illustrate the cellular and molecular mechanisms behind infarction. The infarcted myocardium is described by MRI, followed by gadolinium, and the viability is examined by PET. Thus, the scars in the myocardium can be detected by the fusion of the mentioned techniques. The simultaneous acquisition of information by PET/MRI can be used to assess cardiovascular diseases. As the combination can bring forth anatomical and functional information, the probability of differentiation between epicardial stenosis and microvascular dysfunction increases.[(43)] PET/MRI has applications for detecting myocarditis and sarcoidosis. Several case studies have indicated the potential of fusion in cardiac sarcoidosis diagnosis, where early detection can manage fatal complications.[(44,45)] The apparent implication of PET/MRI in cardiac tumors is noted as its potential in the oncology field is fully investigated. Also, the identification of atherosclerotic plaque imaging can be identified using PET/MRI dual modality as its potential is observed in PET/CT.[(46)] Therefore, the fusion of PET/MRI has a strong application in cardiovascular imaging.

Pediatrics

Radiation dose is of significant concern in the pediatric population. The imaging techniques like PET/MRI fusion possess an excellent possibility for imaging pediatric patients with low radiation doses. The integration of MRI free from ionizing radiation and 15O or 11C nuclides having short half-lives provide doses in an acceptable pattern that has paved the way for fetus imaging in vivo. A study on 15 pediatric patients suffering from malignant diseases at multifocal sites demonstrated that the effective dose of a PET/MR scan was only about 20% that of the equivalent PET/CT examination; however, the PET/MRI takes longer, but its reliability and stability have been determined[(28)] (Figure 7).

Conclusion

The dual-modality method has evolved at a steady rate in the past 20 years to complement the anatomical and biological findings. The fusion of PET and MRI has offered a multitude of functions by providing anatomical, metabolic, and molecular information. This modality has been preferred over PET/CT or PET alone. The predominant suppressing factor is the lower soft tissue contrast presented by PET/CT. Another demerit is the inefficiency of developing a simultaneous acquisition model. PET/MRI has the upper hand in providing soft tissue contrast, low exposure to radiation, and dynamism in acquisition models, which helps characterize tissues.. This substantiating approach has gained attention in clinical and pre-clinical research with widespread potential in cancer, the central nervous system, the cardiovascular system, pediatrics, and inflammatory diseases. Besides its magnificent applications, there are technical challenges, such as space and time constraint, quantitative imaging, the effect of PET use on MRI, and the impact of MRI use on PET. These shortcomings should be studied and improved by brainstorming notions for a better frame system. Furthermore, intensive research is required to tackle the obstacles and explore other potentials in clinical and pre-clinical departments to drive the impact of PET/MRI.

Competing Interests

The Author declares that there is no conflict of interest.

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