

**E16 – The Use of Hybrid Imaging in Oncological and Neurological Diagnoses and
Treatments**

2026 Spring Symposium

Abstract

Hybrid imaging involves the combination of various imaging modalities to produce a more comprehensive study of the human body. The development of hybrid imaging follows the invention of imaging modalities such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), and Single Photon Emission Computed Tomography (SPECT). Hybrid imaging has become one of the most beneficial aids in oncologic and neurologic diagnoses and treatments. The ability to image anatomy and functionality simultaneously allows for a better understanding of patient pathology, treatment planning, and assessment of treatment effectiveness. As technology advances, more developments are being made to improve hybrid imaging and its use in the clinical setting to aid in diagnosis and treatments of oncologic and neurologic conditions.

Keywords: Magnetic Resonance Imaging (MRI), Computed Tomography (CT), positron emission tomography (PET), single photon emission computed tomography (SPECT)

The Use of Hybrid Imaging in Oncological and Neurological Diagnoses and Treatments

Introduction

When you think of medical imaging, what types of exams do you think of being within that category? Common answers to this question are MRIs, CT scans, X-rays, mammograms, etc. People don't often think about the possibility of combining modalities to aid in the diagnosis and treatment of various medical conditions. Hybrid imaging makes this possibility a reality by effectively combining different modalities of imaging, in order to form a more accurate representation of anatomy, functioning, and pathology. This paper will discuss what hybrid imaging is, its development, and how it is used in the diagnoses and treatment of oncological and neurological conditions.

Discussion

What is Hybrid Imaging?

Hybrid imaging is a general term used to describe the combination of at least two modalities to form one combined image (Knipe, 2025). While there are a variety of combinations of modalities that can be used in hybrid imaging, some of the more common types include PET/CT, PET/MRI, and SPECT/CT. Hybrid imaging not only combines different images, but it allows for a combination of functional information with structural information. This combination of information being in one place allows for a better understanding of the patient's anatomy, which then allows for a more accurate diagnosis and treatment (Adenekan, 2025). Now that a basic understanding of hybrid imaging has been established, we can consider specific types of hybrid imaging.

PET/CT Imaging

PET/CT is a form of hybrid imaging that combines the use of both PET and CT scans. Typical PET scans utilize small portions of radiopharmaceuticals that are injected intravenously to evaluate the function of tissues. Some of these functions include metabolism, blood flow, and absorption (*"PET scan: What it is, types, purpose, procedure & results"*, 2025). These radiopharmaceuticals travel through the body and gather in areas of the body with higher metabolic activity, such as areas of inflammation or tumors, and emit positrons. These positrons interact with electrons in the body then release two gamma rays (*"SPECT scan vs. PET scan: Key differences explained"*, 2025). Radiopharmaceuticals tend to gather in areas of cancer or inflammation, because of the increased metabolic function of tumors compared to normal tissues. After the injection of the radiopharmaceutical, an image is formed by using a computer to integrate the detection of the gamma ray emission from the radiopharmaceuticals and format it into an image (*"PET/CT"*, 2025). These regions of higher gamma ray emission appear on PET images as darker, black areas within the patient's anatomy, as seen below in Figure 1.



Figure 1. Upstate Medical University. <https://www.upstate.edu/ura/pet-ct-scan.php>

Unlike the gamma rays used in PET scans, CT scanners form images with the use of X-rays. The CT scanner works by creating X-rays while continuously rotating around the patient during the scan to create cross sectional images of the patient. Some CT exams, if necessary,

utilize contrast media to help highlight certain anatomy and pathology. The cross sections created from the scan are then formatted by a computer to create 3D images of bones and soft tissues (*“What is a CT Scan?”*, 2025). These 3D images can be reformatted from the axial plane into sagittal and coronal views of the anatomy as well. Figure 2 below shows the axial, coronal and sagittal views of a CT as a cross section through the abdomen. These reformats allow for a more comprehensive view of the patient’s anatomy and create a 3D visual.

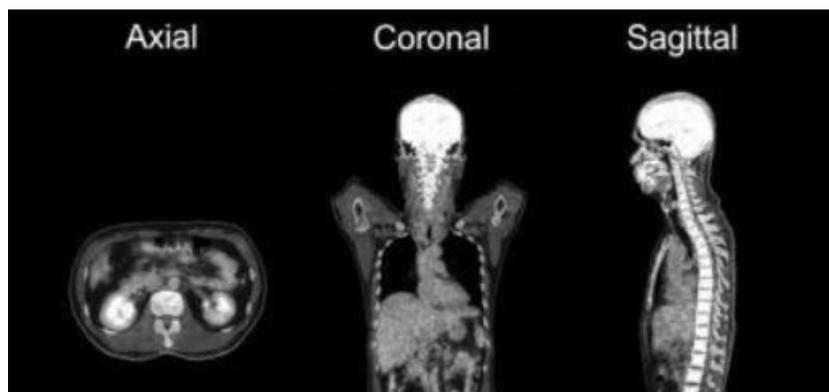


Figure 2. CT Prep. <https://cancercarespecialists.org/additional-services/imaging/ct-prep/>

PET/CT is a form of hybrid imaging combining these two modalities. PET/CT takes a CT scan of the patient and overlays a PET scan of the same section of anatomy atop it, creating a new image. This combination of PET and CT imaging allows radiologists to evaluate the anatomical structures of the patient along with their functionality at the same time. Figure 3 below shows the process of overlaying the CT and PET images. On the left side of the image is a CT scan in the coronal plane showing the patient’s chest and abdomen. The image in the middle is a PET scan showing the same region of anatomy as the CT scan. On the PET scan, the darker areas highlight the functional capability of those areas. The image on the right shows the fusion of the CT and PET scan to create the PET/CT image. The brighter areas correspond to

the darker areas on the PET scan, and when combined with the CT scan, allows the scanner to correlate the areas higher gamma ray emission with the exact anatomical location.



Figure 3. Upstate Medical University. <https://www.upstate.edu/ura/pet-ct-scan.php>

SPECT/CT Imaging

Similarly to PET/CT imaging, SPECT/CT imaging combines the use of nuclear medicine study with a CT scan. A SPECT scan is a single photon emission computed tomography scan. SPECT/CT scans typically use a radiotracer like Technetium-99m intravenously that travels through the body and emits single gamma rays which are then detected during the scan. SPECT/CT scanning is particularly useful in measuring blood flow and receptor activity, making it useful in cardiac, bone, and neurological cases (“*SPECT scan vs. PET scan: Key differences explained*”, 2025).

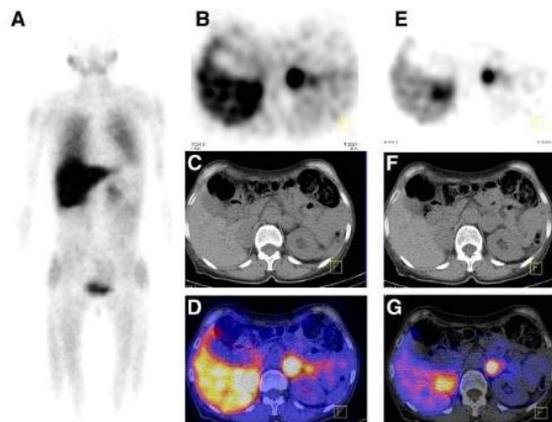


Figure 4. Buck et al. <https://doi.org/10.2967/jnumed.107.050195>

Figure 4 above shows the combining of the SPECT/CT scan on a patient with a tumor in the adrenal gland. Images A, B, and E show the single photon emission scan of a SPECT/CT scan. The darker areas in this scan are areas of gamma radiation being produced by the radiotracer as it collects in the area of pathology. Images C and F are CT axial images of the same area of pathology. The fusion of the SPECT/CT scan can be seen in images D and G (Buck et al., 2008). These hybrid images allow for combination of the anatomy visualized on the CT scan, with the color showing the functionality of the anatomy on the SPECT scan. This combination of imaging allows for a more comprehensive understanding of the anatomy of interest.

PET/MRI Imaging

PET/MRI is a type of hybrid imaging combining a PET scan with an MRI. An MRI is a type of medical imaging that utilizes a magnetic field and radio waves that interact with the hydrogen molecules in the body to create an image (“*MRP*”, 2023). Similarly to a CT scan, an MRI produces imaging in the axial plane that can be reconstructed into coronal and sagittal images. MRIs are typically used to evaluate the soft tissue anatomy such as the brain, spinal cord, nerves, muscles, heart, kidneys, pelvic organs, etc. These scans can also use contrast medias to help increase the visibility of certain anatomy and pathologies such as blood vessels, tumors, inflammation, and infections (“*MRI (Magnetic Resonance Imaging)*”, 2025). Figure 5 below shows a cross section of an MRI of the brain with a tumor on the left side characterized by the lighter colored area of tissue (Boss et al., 2010). The image of the MRI shows the clear distinctive areas of the soft tissue in the brain. With imaging areas of soft tissue,

like the brain, MRI has a superior level of detail compared to other modalities like CT and X-ray.

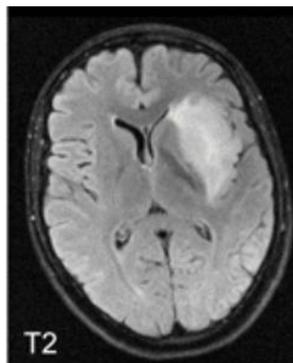


Figure 5. Boss et al. <https://doi.org/10.2967/jnumed.110.074773>

Due to the level of detail of soft tissue produced by an MRI and the functional analysis made available by the PET scan, the PET/MRI scan is often used to look at the anatomy and functionality of soft tissue regions in the body. PET/MRIs fuse the images from a MRI scan with those of the PET scan, to create a hybrid image that shows the functioning of the softer tissues of the body. Figure 6 below shows a comparison between a PET/CT and a PET/MRI scan of a cross section of a brain with a brain tumor on the right side of the frontal lobe (Boss et al., 2010).

While these two scans appear to be very similar, the main difference lies in the visibility of the soft tissues of the brain. In the CT scan, the region with the tumor is less visualized than it is in the MRI scan. Because of its ability to show the areas of soft tissue with higher resolution, the MRI is able to outline clearer borders of the tumor as well as show the functioning of the area in the brain on the PET/MRI image.

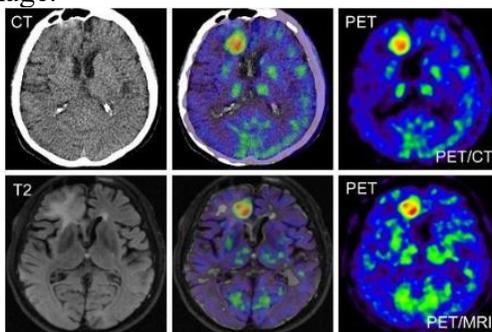


Figure 6. Boss et al. <https://doi.org/10.2967/jnumed.110.074773>

The Development of Hybrid Imaging

Now that we have established an understanding of hybrid imaging, we can look more into the development of this type of technology. Before the technology for hybrid imaging could even be considered, there had to be the creation of the imaging modalities. CT technology, PET technology, and MRI technology were all individually invented and continued to improve before the application of hybrid imaging technology.

The first of these modalities to be invented and used clinically was CT imaging. In 1968, Godfrey Hounsfield developed his first scanner, which took nine full days to complete one scan. His research and development of the CT scanner continued until the first CT exam was performed on a living patient on October 1st, 1971 (Schulz et al., 2021). While this was the beginning of the CT scanner's clinical use, it still required a lot of developments to improve image quality, scan speed, and effective image creation.

The second of these modalities to be invented and clinically used was the MRI. The research of the fundamental principles of the MRI scanner began in the 1940's with Felix Bloch and Edward Purcell, but the MRI scanner was not invented until 1973 by Paul Lauterbur. Although the creation of the MRI was in 1973, the first full body MRI scan was not performed until 4 years later by Dr. Raymon Damadian (Lieber, 2024). Much like the development of the CT scanner, MRI imaging had to undergo many technological developments to get to the level of imaging that is being done clinically today.

The last of these modalities to be developed was PET imaging. Though the first clinically used PET scanner was not successful until 1973, the development of PET scans started many years earlier. Scientists like David Kuhl, Luke Chapman, and Roy Edwards began working on

theories of using the energy released from interactions between positrons and electrons for medical imaging as early as the 1950's (*"Who invented the PET scan? complete history", n.d.*). This research of the foundations of positron emissions set the stage for scientists over the next 10 to 20 years to make major developments in the invention of PET scanners. In the 1960's Gordon Brownell and William Street did a lot of work improving the design and image quality of the early versions of PET scans. Then, in 1973, Michal E. Phelps, Michel Ter-Pogossian, and Edward Hoffman created the first clinically functional PET scan (*"Who invented the PET scan? complete history", n.d.*). Like the previous modalities, PET scanners underwent a plethora of changes and developments to create the technology used clinically today.

After the invention and development of these imaging modalities, there was still more work done in order to create hybrid imaging. The University of Pittsburgh Medical Center began clinical testing for the early prototypes of PET/CT scanners in 1998, roughly twenty years after the creation of the imaging modalities. This clinical testing led to the development of the first commercial PET/CT system by General Electric in 2001. Three years later, technological advancements in the PET/CT systems made it the favored equipment compared to the original PET scanners (Jones & Townsend, 2017). It wasn't until a few years later that the focus of clinical developments in technology moved to the ongoing creation of PET/MRI scanners. In 2006, the first clinical PET/MRI scanner was used, but it was only capable of imaging the brain. In 2010, Siemens introduced the first PET/MRI that was able to image the whole body (Jones & Townsend, 2017). Since these early creations of hybrid imaging, there have been many technological advancements that have improved the quality of hybrid imaging. New designs have shaped the imaging technology into the equipment we use today by improving resolution, reducing scan times, and improving patient experiences.

Clinical Usage of Hybrid Imaging in Neurologic and Oncologic Conditions.

Diagnosis of Oncologic Conditions

For most types of cancer, some form of imaging test is conducted to see inside the patient's body in order to make a proper diagnosis. The use of hybrid imaging in cancer diagnosis has helped to improve the process of diagnosing cancers due to its ability to determine anatomical structures and metabolic data simultaneously. For example, when conducted separately, CT scans are able to clearly identify tumor size and location but are unable to differentiate between benign and malignant tumors. PET scans are able to determine if tissues are cancerous based on metabolic activity but are unable to clearly define the tumors. Using PET/CT is particularly helpful in the diagnosis of various cancers due to its ability to identify exact tumor structures as well as metabolic differences at the same time (*"Combining Pet & CT: The Power of Hybrid Imaging in cancer diagnosis"*, 2025).

Treatment of Oncologic Conditions

While hybrid imaging isn't typically involved directly as a form of treatment of oncologic conditions, it is beneficial to the treatment process. Once there is imaging data for a patient's cancer diagnosis, hybrid imaging can be used to help formulate a treatment plan, assess the efficiency of the treatment, and assess for cancer recurrence after a completed treatment (*"PET/CT scans"*, 2025). For patients undergoing cancer treatments such as radiation therapy, PET/CT can be used to help pinpoint the exact locations and volumes of tumor tissues to more accurately treat the cancerous region while also sparing surrounding healthy tissues. By focusing treatment delivery on to more precise areas, the treatment is more effective and side effects for the patient can be reduced (*Advancements and applications of hybrid imaging systems in*

Medical Diagnostics”, 2025). SPECT/CT imaging is highly used in oncological treatment follow-up imaging with patients where bone metastases are suspected. SPECT/CT is highly sensitive and better able to detect bone metastases and aid in planning for treatment of it (*Advancements and applications of hybrid imaging systems in Medical Diagnostics*”, 2025).

Diagnosis of Neurologic Conditions

The understanding of neurological conditions can also benefit from the use of hybrid imaging. While there is a wide variety of neurological conditions that may benefit from the use of hybrid imaging, 3 conditions that hybrid imaging helps to diagnose are Alzheimer’s disease, dementia, and Parkinson’s disease. PET/MRI is particularly useful in the diagnosis of neurological conditions such as Alzheimer’s disease and dementia because they are able to detect structural changes in the brain such as hippocampal volume, atrophy, and vascular disease. When these structural changes are combined with the patterns of metabolism it provides insight into the patient’s neural dysfunction. SPECT/CT scans can also be used to assess for dementia by analyzing the cerebral blood flow patterns and areas of hypoperfusion that are associated with dementia. The use of hybrid imaging for early insight of patient conditions helps physicians in early diagnosis and monitoring of these conditions (*Advancements and applications of hybrid imaging systems in Medical Diagnostics*”, 2025). PET/MRI can aid in the diagnosis of Parkinson’s disease by creating an image analysis of structural brain data and dopamine activity in the brain. This allows for better ability to determine if the patient’s condition is due to Parkinson’s disease, or if it is due to certain atypical parkinsonian syndromes (*Advancements and applications of hybrid imaging systems in Medical Diagnostics*”, 2025).

Treatment of Neurologic Conditions

Hybrid imaging can help aid in treatment of a wide range of neurological conditions by aiding in the formation of the treatment plan and assessing the effectiveness of treatment. Some of the conditions treated with the use of hybrid imaging are epilepsy, stroke, cerebrovascular diseases, and dementia. PET/MRI scans are useful in the treatment of epilepsy due to its ability to determine the area of the brain where the seizures onset. This allows for treatments to be focused on this area of the brain to improve the effectiveness of treatment. Patients who are being treated for strokes or other cerebrovascular diseases can have PET/MRI scans to determine the tissues that are at-risk during acute strokes and reperfusion therapies can be focused on those areas (*Advancements and applications of hybrid imaging systems in Medical Diagnostics*”, 2025). All of these conditions can be monitored throughout treatment to assess the effectiveness of treatment, alter treatment plans, and provide data on the patient's condition overall.

Conclusion

Throughout this paper we have discussed that hybrid imaging is the combining of two modalities in order to create one image that provides structural and functional information about the patient's condition. Some types of hybrid imaging include PET/CT, PET/MRI, and SPECT/CT. Each of these hybrid imaging techniques followed the development of the individual modalities to become what they are today. Hybrid imaging is used in the medical field today in oncology and neurology to aid in diagnosis and treatments of various oncological and neurological conditions. Although the use of hybrid imaging has become more beneficial in medical imaging, there are still developments being made. With the rise of artificial intelligence and ever-changing medical technological advancements, there is much room for future advancements with hybrid imaging.

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