PET -4

IMPACT OF PET-CT IN NEW ERA OF MEDICINE

HISTORY

The first non-invasive technique to get images was a big revolution in itself. It was the radiography, invented by a German physicist named Wilhelm Roentgen, in 1896, and it used x-rays, an invisible electromagnetic radiation discovered also by him. To Roentgens astonishment, x-rays were able to penetrate the body, as it were transparent, and to produce a negative photograph of the body's interior, showing with startling detail the bones, cavities and other anatomical structures on its path. Roentgen could see immediately the medical value of his discovery, and the first radiograph ever made was from his wife's hand.

From the invention of the X-ray in 1895 to the plethora of medical imaging technologies available today, many of the advances of modern medicine stem from our ability to see inside the human body. However, x-rays can show only the anatomical structures, and nothing else. The function of these structures could be inferred from anatomical changes, but only when they happened. Enlargement, movement and flow of substances could be observed in some selected organs (for example, the heart or the intestines, or, by using some liquids which are opaque to the x-rays, named contrasts), but not much more.

Medical imaging uses state-of-the-art technology to provide 2- or 3-dimensional images of the living body. Imaging studies can diagnose disease or dysfunction from outside the body, providing information without exploratory surgery or other invasive and possibly dangerous diagnostic techniques. Radiography uses radiation to produce 2-D images (x-rays) or 3-D scans (CT). 3 D Images can be manipulated with software to provide views from any angle. Magnetic resonance imaging (MRI) uses magnetic fields rather than X-rays to produce 3-D images. Ultrasound uses sound waves to produce images of the interior of the body. Nuclear medicine uses the energy from small amounts of radioactive

"tracers" that have been introduced into the body to produce both 2-D and 3D images that reveal biological functioning.

Even in the field of oncology, diagnosis, staging, and re-staging of cancer, as well as the planning and monitoring of cancer treatment, have traditionally relied heavily on anatomic imaging with computed tomography (CT) or magnetic resonance imaging (MRI). These anatomic imaging modalities provide exquisite anatomic detail and are invaluable, especially for guiding surgical intervention and radiotherapy. However, they do have limitations in their ability to characterize tissue reliably as malignant or benign. Anatomic imaging generally has a high sensitivity for the detection of obvious structural alterations (e.g. enlarged structures, abnormal imaging characteristics) but a low specificity for further characterizing these abnormalities as malignant or benign. Necrotic tissue, scar tissue, and inflammatory changes often cannot be differentiated from malignancy based on anatomic imaging alone. In addition, lymph nodes which are not pathologically enlarged by size criteria alone but are harboring malignant cells pose a special diagnostic problem when using traditional cross-sectional imaging.

Therefore, much effort has been forth in the research and development of molecular imaging techniques to detect abnormal behavior of tissues. The nuclear medicine community has developed positron emission tomography (PET) for imaging the activity of an injected radionuclide labeled glucose analogue, Fluorine-18-deoxyglucose (FDG), as a means to discriminate benign from malignant tissues accurately in many clinical settings. This technique is based on the fact that malignant tissue typically exhibits markedly increased rates of glucose metabolism.

Just like glucose, FDG is actively transported into cells mediated by a group of structurally related glucose transport proteins. Once intracellular, glucose (and therefore also FDG) are phosphorylated by hexokinase as the first step in the glycolytic metabolism pathway. Normally, after being phosphorylated glucose continues along the glycolytic pathway for energy production. FDG, on the other hand, cannot enter the glycolytic pathway and becomes effectively trapped intracellularly as FDG-6-phosphate. Tumor cells display increased numbers of glucose transporters as well as higher levels of hexokinase. Most tumor cells are highly metabolically active with high mitotic rates that favor the more inefficient anaerobic metabolic pathway which adds to the already

increased glucose demands. These combined mechanisms allow tumor cells to take up and retain higher levels of FDG when compared to normal tissues.

An important concept regarding PET imaging is that FDG is not cancer specific and will accumulate in any areas of high rates of metabolism and glycolysis. Therefore, increased uptake can be expected in all sites of hyperactivity at the time of FDG administration (e.g. muscles and nervous system tissues); at sites of active inflammation or infection (e.g. sarcoidosis, arthritis, pneumonia, etc.); and at sites of active tissue repair (e.g. surgical or traumatic wounds, healing fractures, etc.).

PET provides imaging of the whole body distribution of FDG, thus highlighting the markedly increased metabolic activity of tumor cells. Sites of tumor involvement not obvious from cross-sectional images alone are often found, such as lymph nodes involved by tumor which are not pathologically enlarged by size criteria.

The immense value of PET for studying was highlighted by several path-breaking investigations. The first PET scanners had a small number of radiation sensors to build the image, and they could do only a slice at a time. The slices were also very thick. Thus, the images obtained with the PET had a low quality and definition. It was impossible to get the finer details of localization of function in the brain, so their clinical usefulness was quite limited, as compared with modern models. Modern PET scanners are very expensive and sophisticated pieces of equipment. They are also much easier to install and to operate, and have many new capabilities which clinicians use with advantage to perform many feats of brain imaging, such as a higher speed in obtaining results. For example, as shown here, they can be used to produce movies of parts of the body. Since PETs are so expensive (actually, it's rather the whole installation, including the cyclotron to produce the radiopharmaceuticals which adds to the cost), there are only about 150 installations around the world, which are highly concentrated on the USA (particularly in the East and West coasts), Europe (particularly in the Anglo-Saxon countries and France) and in Japan.

DEVELOPMENTS:

Traditionally, treatment planning for these patients has been based on CT alone. In many cases, CT is limited in its ability to tell us the exact dimensions of the tumor and which parts of an abnormality are biologically active. PET, on the other hand, has the advantage of giving us the information we need about biological activity.

Positron-emitting radionuclides are typically produced in cyclotrons by the bombardment of stable elements with protons, deuterons, or helium nuclei. The radionuclides produced have an excess of protons and thus decay by the emission of positrons. The positron-emitting radionuclide used for clinical whole-body PET/CT imaging is Fluorine-18-deoxyglucose (FDG). A PET scan allows physicians to measure the body's abnormal molecular cell activity to detect

•Cancer (such as breast cancer, lung cancer, colorectal cancer, lymphoma, melanoma and other skin cancers),

•Brain Disorders (such as Alzheimer's disease, Parkinson's disease, and epilepsy), and

•Heart Disease (such as coronary artery disease).

PET scans are simple, painless, and fast, offering patients and their families life-saving information that helps physicians detect and diagnose diseases early and quickly begin treatment. PET scanning and molecular imaging provide real life answers to better diagnose illness, guide treatment options, and give patients ultimate control over their critical and vital health care issues.

1. Breast cancer: staging of distant metastasis, restaging, and monitoring response to treatment (when a change in therapy is anticipated based on results)

2. Cervical cancer: staging as adjunct to conventional imaging

3. Colorectal cancer: diagnosis, staging, and restaging

4. Esophageal cancer: diagnosis, staging, and restaging

5. Head and neck cancer (non-thyroid, non-CNS): diagnosis, staging, and restaging

6. Lymphoma: diagnosis, staging, and restaging

7. Melanoma: diagnosis, staging, and restaging

8. Non small cell lung cancer: diagnosis, staging, and restaging

9. Solitary pulmonary nodules: characterization

10. Follicular cell thyroid cancer: restaging of recurrent or residual disease previously treated by thyroidectomy and radioiodine ablation in the setting of serum thyroglobulin > 10 ng/ml and a negative I-131 whole body scan

11. Myocardial viability: primary or initial diagnosis or following an inconclusive SPECT prior to revascularization

12. Refractory seizures (brain): pre-surgical evaluation only.

Thus, PET has many clinical utilities, however as every coin has two sides there are certain limitations also with the PET imaging. An unwanted effect in PET imaging is the attenuation of the emitted gamma rays by the patients' body tissues. As a result of this, positron decays from deep within the body appear attenuated relative to those occurring on the surface. In order to correct for this, transmission images, as well as the emission images, are acquired by the PET scanner. A mathematical algorithm using these transmission images is used to correct the emission images for attenuation. However, attenuation correction PET data acquisition represents around 30% of imaging time. In addition, the anatomical detail provided by PET images is limited. PET scans have a limited spatial resolution in the range of 5–7 mm and also contain few anatomical landmarks for localising pathological F-18-FDG foci apparent on the scans.

In order to deal with these drawbacks, integration of PET and CT into a single system has been proven to make eminent sense. Thus, Positron Emission Tomography (PET) and Computerized Tomography (CT) are both standard imaging tools that allow physicians to pinpoint the location of cancer within the body before making treatment recommendations. Taking the molecular imaging concept of PET one step further is the combined imaging modality positron emission tomography/computed tomography (PET/CT). The highly sensitive PET scan detects the metabolic signal of actively growing cancer cells in the body and the CT scan provides a detailed picture of the internal anatomy that reveals the location, size and shape of abnormal cancerous

growths. Alone, each imaging test has particular benefits and limitations but when the results of PET and CT scans are "fused" together, the combined image provides complete information on cancer location and metabolism.

In the past, difficulties arose from trying to interpret the results of a CT scan done at a different time and location than a PET scan, due to the fact that the patient's body position had changed. Doctors, especially cancer surgeons, were often frustrated in trying to match PET images with CT images to determine the precise location of a tumor in relation to an organ or the spinal column. They had little choice other than to "eyeball" the two separate images and make an educated guess as to the tumor's exact location - until 1992, when engineer Ron Nutt and physicist David Townsend came up with the idea of combining a PET and CT into one machine. Combining the best of both modalities into one image should optimize our ability to deliver treatments.

After working on their combined PET and CT concept for three years, Nutt and Townsend received a grant from the National Cancer Institute. This enabled the completion of a prototype machine, which was installed at the University of Pittsburgh medical center in 1998. The pair designed the machine to be more patient-friendly by making the diameter of the PET/CT tunnel 28 inches, far more spacious than the typical MRI tunnels. Time Magazine honored PET/CT as the "Medical Science Invention of the Year" in 2000, noting that the PET/CT scanner has "provided medicine with a powerful new diagnostic tool."

PET/CT fuses functional information in the form of PET data and anatomic information in the form of CT data acquired almost simultaneously so that these information sets can be viewed and interpreted together. In PET/CT, both the multidetector CT apparatus and the PET detectors are mounted in the same gantry, one immediately behind the other. Both PET and CT scanning are performed with the patient lying in the same position on the imaging table resulting in optimal correlation of anatomic and metabolic information. For interpretation, the PET data is actually superimposed upon the CT data (co-registration) resulting in improved anatomic localization of normal and abnormal FDG activity. This fusion process has proven beneficial in more exactly localizing tissues involved by tumor. Better co-registration is especially significant in regions of complex anatomy, such as in the abdomen and in the head and neck. More exact localization of

the involved tissues results in more accurate staging and more appropriate treatment planning including surgical therapy, radiotherapy, and medical therapy.

PET/CT has a wide range of applications in clinical conditions like as enumerated below:

- Determines extent of disease
- Determines location of disease for biopsy, surgery or treatment planning
- Assesses response to and effectiveness of treatments
- Detects residual or recurrent disease
- May assist in avoiding invasive diagnostic procedure.

WORKING AND DESCRIPTION OF VARIOUS IMAGING MODALITIES:

The combination PET/CT provides physicians a more complete picture of what is occurring in the body - both anatomically and metabolically - at the same time. There are tremendous benefits of having a combined PET/CT scan:

- Earlier diagnosis
- Accurate staging and localization
- Precise treatment and monitoring

With the high-tech images that the PET/CT scanner provides, patients are given a better chance at a good outcome and avoid unnecessary procedures. A PET/CT image also provides early detection of the recurrence of cancer, revealing tumors that might otherwise be obscured by scar tissue that results from surgery and radiation therapy, particularly in the head and neck.

The PET scanner is a system that is able to detect the gamma rays emitted from the annihilation reaction and then compute cross-sectional images of tracer distribution. This process produces emission images which depict the distribution of ^{18} [F] activities in the body. Typically, 200 to 300 axial images are acquired in batches of 30 to 50 from head to pelvic floor, thereby providing a survey of the most important body structures.

An example of how PET-CT works in the diagnostic work-up of FDG metabolic mapping follows:

- Before the exam, the patient undergoes a minimum of 8-hour fasting and rest;

- In the day of the exam, the patient rests lying for a minimum of 15 min, in order to quiet down muscular activity, which might be interpreted as abnormal metabolism;

- An intravenous bolus injection of a dose of recently produced 2-FDG or 3-FDG is made, usually by a vein in one of the arms. Dosage ranges from 0.1 to 0.2 mCi per kg of body weight;

- After one or two hours, the patient is placed into the PET-CT device, usually lying in a supine position with his/her arms resting at the sides, or brought together above the head, depending on the main region of interest (ROI)

- An automatic bed moves head first into the gantry, first obtaining a topogram, also called a scout view, which is a kind of whole body flat sagital section, obtained with the X-ray tube fixed into the upper position.

- The operator uses the PET-CT computer console to identify the patient and examination, delimit the caudal and rostral limits of the body scan onto the scout view, selects the scanning parameters and starts the image acquisition period, which follows without human intervention;

- The patient is automatically moved head first into the CT gantry, and the x-ray tomogram is acquired;

- Now the patient is automatically moved through the PET gantry, which is mounted in parallel with the CT gantry, and the PET slices are acquired;

- The patient may now leave the device, and the PET-CT software starts reconstructing and aligning the PET and CT images.

A whole body scan, which usually is made from mid-thighs to the top of the head, takes about 40 min. FDG imaging protocols acquires slices with a thickness of 2 to 3 mm. Hyper metabolic lesions are shown as false color-coded pixels or voxels onto the gray-

value coded CT images. Standard Uptake Values are calculated by the software for each hyper metabolic region detected in the image. It provides a quantification of size of the lesion, since functional imaging does not provide a precise anatomical estimate of its extent. The CT can be used for that, when the lesion is also visualized in its images (this is not always the case when hyper metabolic lesions are not accompanied by anatomical changes).

FDG doses in quantities sufficient to carry out 4-5 examinations are delivered daily, twice or more times per day, by the provider to the diagnostic imaging center.

For uses in stereotactic radiation therapy of cancer, special fiducial marks are placed in the patient's body before acquiring the PET-CT images. The slices thus acquired may be transferred digitally to a linear accelerator which is used to perform precise bombardment of the target areas using high energy photons (radiosurgery).

The implications in different clinical conditions are summarized below:

Cancer:

* To assess tumor aggressiveness
* To monitor success of therapy
* To detect early any recurrent tumors
* To provide a whole-body survey for cancer that may have spread
* To identify benign and malignant growths

Heart Disease:

* To determine what heart tissue is still alive following a suspected heart attack
* To predict success of angioplasty (balloon) or bypass surgery
* To determine if coronary arteries are blocked

Brain Disorders:

* To diagnose Alzheimer's and other dementia
* To determine the location of epileptic seizures prior to surgery

*To diagnose movement disorders like Parkinson's disease

As far as the field of oncology is concerned, the most frequent indication for PET-CT is nonsmall- cell lung cancer (NSCLC). The second most frequent indication for PET-CT is lymphoma. While initial staging of lymphoma may not require PET-CT, with CT alone being adequate, therapy follow-up is of major importance in this disease entity, particularly because of the bulk lesions remaining after therapy. On CT, only slow regression of the size of these lesions over extended periods will be evident, while the additional PET information has relevant prognostic value. Patients without FDG accumulation in remaining tissue bulks do much better than those with FDG accumulation. The third most frequent indication for PET-CT is in the suspected recurrence of colorectal cancer. The critical information required is whether patients have metastatic disease to the liver only, or whether there is more extensive involvement. Here again, FDG-PET-CT enables better triage to surgery. Many other patients with malignant tumors are currently undergoing PET-CT with F-18-FDG and further information on the advantages of the technique is rapidly emerging. Another very relevant application is the use of PET-CT in the process of radiation therapy planning. The CT data acquired with proper patient positioning can be directly used for the planning process, and early results indicate that defining the relevant tumor volumes for therapy can be performed with higher precision using PET-CT rather than PET alone.

Also PET/CT fusion imaging is most valuable for cancers located in regions of the body that have a complicated anatomy, such as the neck and lower pelvis. These areas of the body contain organs, tissue, muscles, bones, lymph nodes, air, fluids, etc., all in close proximity—making the precise overlay of PET and CT particularly helpful. Similarly, PET/CT can aid in multifocal diseases, such as lymphoma, by providing more exact locations for biopsies and surgery.

The role of PET in the field of cardiovascular is also increasing day by day. Positron emission tomography (PET) has been important in cardiovascular research and in clinical cardiology. This technology has been used to locate tumors, identify metastasis, but its real power lies in the fact that in the near future it may in the diagnostic process replace PTCA or percutaneous transluminal coronary angioplasty- which is an invasive method with several severe risks. Therefore atherosclerosis and blood clogs will be

detected early on with as little pain and side-effect to the patient as one injection can cause. Although numerous radiopharmaceuticals have been used to render physiologic, biochemical, and clinical information, [F-18]-fluorodeoxyglucose (FDG) imaging is the most common, which is used for identification of jeopardized but viable myocardium that can be salvaged with revascularization. Myocardial perfusion imaging with PET agents provides higher resolution than single photon emission computed tomography (SPECT) agents, and PET agents can be used to determine absolute blood flow. Rubidium-82, used for myocardial perfusion imaging, was the first PET agent approved by the US Food and Drug Administration. PET myocardial perfusion imaging, especially quantitative myocardial perfusion imaging, has proven clinical value. However, imaging with SPECT is likely to remain the dominant method for myocardial perfusion imaging in most circumstances, because it is less expensive to perform.

Positron emission tomography-computed tomography (PET-CT) is the fastest-growing imaging modality worldwide. Integration of a PET scanner and CT scanner to provide co-registered images combines the high spatial resolution and anatomical detail of CT with the molecular, quantifiable images obtained by PET. Moreover, attenuation correction of PET images using the CT data enables PET-CT to be faster than PET alone, thereby improving imaging efficiency and patient throughput. PET-CT has been proven to be the most sensitive and specific examination for tumor staging through the complementary nature of the two systems in many tumors. PET is highly sensitive for identification of lesions, whilst CT localization of foci in co-registered images increases the specificity of these findings and can show pathology not resolved by PET alone. The current most frequent indications for PET-CT are non-small-cell lung cancer, lymphoma and suspected recurrence of colorectal cancer, where PET-CT data are valuable for staging, therapy/surgery planning and prognosis.

In addition to its research applications, PET/CT can improve clinical care. Taking the two scans virtually simultaneously ensures that the patient remains in place and, therefore, that the two images form a precise computer overlay—that the tumor "hot spot" on the PET scan corresponds directly to the physical mass on the CT scan. It also eliminates the common problem of a delay between the two studies, during which time the patient's condition may change

PET-CT currently offers the best of clinical molecular imaging. Combining the two imaging modalities to produce co-registered images has enabled the detailed differentiation and characterization of tissue alterations. The value of this technique has been proven in tumor imaging and new applications are emerging rapidly. New developments and indications for PET-CT particularly associated with advances in radiotracer and scanner technology is an exciting prospect.

Thus, functional imaging obtained by PET, which depicts the spatial distribution of metabolic or biochemical activity in the body can be more precisely aligned or correlated with anatomic imaging obtained by CT scanning. Two- and three-dimensional image reconstruction may be rendered as a function of a common software and control system.

PET-CT has revolutionized many fields of medical diagnosis, by adding precision of anatomic localization to functional imaging, which was previously lacking from pure PET imaging. For example, in oncology, surgical planning, radiation therapy and cancer staging have been changing rapidly under the influence of PET-CT availability, to the extent that many diagnostic imaging procedures and centers have been gradually abandoning conventional PET devices and substituting them by PET-CTs. Although the combined device is considerably more expensive, it has the advantage of providing both functions as stand-alone examinations, being, in fact, two devices in one.

PET/CT fusion imaging is most valuable for cancers located in regions of the body that have a complicated anatomy, such as the neck and lower pelvis. These areas of the body contain organs, tissue, muscles, bones, lymph nodes, air, fluids, etc., all in close proximity—making the precise overlay of PET and CT particularly helpful. Similarly, PET/CT can aid in multifocal diseases, such as lymphoma, by providing more exact locations for biopsies and surgery.

The only other obstacle to a wider dissemination of PET-CT is the difficulty and cost of producing and transporting the radiopharmaceuticals used for PET imaging, which are usually extremely short-lived (for instance, the half life of radioactive fluor18 used to trace glucose metabolism (using fluorodeoxyglucose -- FDG) is two hours only. Its production requires a very expensive synchrotron as well as a production line for the radiopharmaceuticals.

FUTURE PERSPECTIVES

Imaging with equipment that combines positron emission tomography and computed tomography (PET/CT) provides the special benefits of both in one procedure, that is, a highly sensitive imaging technique used in oncology, cardiology, and neurology and in infectious and inflammatory diseases. The information from the PET scan and from the CT scan is very different but complementary to each other. The PET scan shows areas with increased metabolic activity, while the CT scan shows detailed anatomical locations. A combination of these two images together enables a doctor to tell whether a region with high metabolic activity is significant, and if so, to state definitively where that location is. Often the PET/CT is repeated to monitor the effect of treatment of a particular disease. Most commonly PET utilizes 18F-FDG as a radiotracer, the short half life of which (110 min) reduces radiation exposure compared with other commonly used radionuclides such as 99mTechnetium (6 hours) and 201Thallium (72 hours).

The radiation exposure from 18F results in internal exposure to the patient and low level external exposure to other people in their vicinity. The radiation (X rays) from the CT scanner only radiates the patient and only during the CT scan. Whenever a repeat PET/CT scan is necessary, it should be performed with low dose CT. PET/CT dual-modality imaging is here to stay. There can be no question of that. Almost 3 of 4 new units sold today are PET/CT hardware fusion units. Clinical PET performed with 18 F-FDG has been the domain primarily of nuclear medicine since clinical units first became commercially available in the early 1990s, and PET technology has been developed almost exclusively by professionals in the field of nuclear medicine. Rapid improvements in PET technology have occurred in the last 5 years, including the introduction of commercially manufactured dual-modality PET/CT devices. The advantages of PET/CT units over dedicated PET units are inherent in the marriage of 2 modalities capable of providing the ideal combination of structural and metabolic information.

In a short time, PET-CT has proven to be a very successful imaging technique in many malignant diseases. Although in some tumors, such as prostate cancer, FDG is a poor

marker of disease, other markers such as F-18-choline seem to be able to identify prostate cancer lesions successfully. In general, development of alternative radiotracers is bound to increase the spectrum of successful application of PET-CT. New applications are also emerging. For example, FDG is also avidly taken up into macrophages and granulocytes, which are activated when fighting inflammation. Good indications for PET-CT are emerging here, although the field is less developed than that of tumor imaging.12 Finally, in the near future one can expect CT developments which will permit CT coronary angiography. Integrating such CT scanners with PET scanners may finally yield the cardiac 'one-stop-shop' examination, with CT providing anatomic information on the coronary arteries and possibly wall motion, while PET can provide rest and stress perfusion, the latter being done with radioactive ammonia, water or rubidium (Figure 5). Whether such systems will be of interest and competitive to other modalities will have to be demonstrated, but this is certainly a very interesting area of research.

These advantages and associated improvements in the ability to localize and characterize disease have now been embraced by a far larger medical community than just nuclear medicine. With this movement is the likely potential that at least some members of the nuclear medicine community physician professionals will be left in the dust. The reason is obvious and simple. Just as PET/CT has begun largely to replace dedicated PET, PET/CT with the incorporation of diagnostic CT scans that use oral and intravenous contrast material and have higher effective amperage will begin to re-place single-modality CT. Because many nuclear medicine physicians have not received the training or obtained enough experience to be proficient in CT cross sectional anatomy, many are currently not able to professionally interpret the CT component of PET/CT. As long as PET/CT dual modality imaging remained in the introductory mode that used the CT component for just attenuation correction and localization of 18 FDG PET abnormalities, diagnostic-quality CT scans were not generated and a formal interpretation of the CT information was not required. Given this circumstance and one similar but opposite for a radiologist who is not proficient in PET, some have proposed that the PET and CT components be interpreted and reported separately by physician professionals who are qualified to do so. Over the long run, this solution will not be viable. To ensure that the patients who are examined with PET/CT receive the best possible care, the physician professionals interpreting these clinical studies will need to be proficient in both PET and CT. At the highest level of integration, these physician

professional will evaluate and report on both the diagnostic-quality CT image data and the PET image data. This can be achieved only by professionals who are trained and experienced in both modalities. Unfortunately, current independent pathways for graduate medical education (GME) in nuclear medicine and radiology do not provide adequate training or experience to achieve this level of proficiency. Without such a curriculum, there can be no win/win scenario for either the patient or the professional communities. The remedy requires changes on 2 levels. On the GME level, programs must be of a length and scope sufficient for the resident to receive education and training in both cross-sectional imaging and PET. On the clinical practice level, continuing medical education (CME) and experience must be of a magnitude and mix sufficient for the practitioner to become proficient and confident in the evaluation, interpretation, and integration of both modalities. For residents, the level of training and experience that pro-grams currently provide will need to be evaluated and adjusted to meet the newly defined requirements for education in both PET and CT. For practicing clinicians, the involved professional communities will need to agree on, define, and establish pathways for CME and clinical experience, and these pathways will need to provide credentials that are recognized and satisfactory for clinical privileges in PET/CT. These processes are in motion and the pathways are being laid. This will certainly be a win for nuclear medicine and for the patient. Managing the efficient use of available medical resources is essential. Medical imaging and medical information management are two of the key technologies which are indispensable parts of the solution.

Thus many imaging technologies (image intensifiers, ultrasound, computed tomography, magnetic resonance) have found wide medical acceptance in the last four decades. The speed of innovation in these modalities remains high. Others imaging techniques, such as positron emission tomography, remain in niche environments. The primary reason for success is a modality's ability to supply new clinical information which is useful for the routine care of large numbers of patients. There is a lot more in future on the part of imaging to develop to give the best optimum care the patient.