Advancement of imaging technologies has always presented a challenge to practitioners as to how best use these new modalities to optimise patient care. The most significant advancement in diagnostic imaging technology is the introduction of hybrid or fusion imaging where anatomy merges with the function to produce the most superior diagnostic tool ever made. This is a technology that can confidently localise metastatic focus of thyroid cancer, accurately predict myocardial infarction, perform sensitive targeting in intensity modulated radiation therapy (IMRT), confidently confirm the diagnosis of Alzheimer disease, and clarify the nature of a pulmonary nodule. Perhaps it was best said by The Journal of Nuclear Medicine in May 2001: “Some believe hybrid technology to be the ‘Eureka’ factor that will propel nuclear medicine to the forefront of imaging in the 21st century.”

Shahrar Bonyadliou

Introduction

Prior to the introduction of PET-CT (Positron Emission Tomography - Computed Tomography) and SPECT-CT (Single Photon Emission Computed Tomography - Computed Tomography) to nuclear medicine, anatomical localisation, poor spatial resolution, and tissue attenuation have always been major disadvantages in this field, requiring scientific “guestimates”. Hybrid imaging systems capture anatomical as well as physiological information in one exam, automatically merging the data to form a composite image that allows the most accurate interpretation of both CT and PET studies. Due to inherent high photon influx, the use of X-ray tube transmission scans in CT provides optimal attenuation correction of PET and SPECT images. Additionally, attenuation correction using CT scan, in comparison with radioactive source, reduces the transmission scan from 25 minutes to 20 seconds.

The modalities involved in hybrid imaging include PET, SPECT, CT, and MRI (Magnetic Resonance Imaging). CT and MRI provide significant anatomical data that, when combined with functional data, bestow a synergistic effect, improving detectability as well as speed [1].

SPECT-CT

The first commercial hybrid SPECT-CT system (Hawkeye Millennium VG by GE Medical Systems) was introduced in 1998 following major experimentation in molecular imaging hybrid systems (Figure 1). CT-based attenuation correction of SPECT images consistently improved overall diagnostic performance, especially in the field of nuclear cardiology [2]. SPECT-CT can provide an excellent alternative to more expensive PET-CT if affordability of the technology is of concern or the institutions do not have access to FDG (PET imaging with fluorine 18 fluorodeoxyglucose [FDG]). The synthesis of SPECT radiopharmaceuticals is relatively less expensive. Because SPECT radioisotopes have longer half-lives than those of isotopes used in PET (hours versus minutes), longer acquisition times are possible in SPECT, which allows monitoring changes in tissues over time. This further strengthens the ability to narrow down the characteristics of a specific disease process, such as in parathyroid adenoma and neuroendocrine tumours. Finally, most SPECT tracers are less expensive, and in certain tumours more accurate than FDG.

Perhaps, myocardial perfusion imaging is an example of the clear benefit of hybrid imaging. Perfusion imaging is the procedure of choice in the management of high-risk cardiac patients. Many of these patients are morbidity obese, producing significant attenuation abnormalities that may not be evident after repositioning. The benefit of attenuation correction from CT in SPECT-CT is to accurately detect exact myocardial activity, eliminating unnecessary coronary angiography and CABG (Coronary Artery Bypass Grafting) procedures. With the introduction of 16- and recently 64-slice CT components, SPECT-CT provides a spectrum of diagnostic studies including CT coronary angiography, coronary calcium scoring and myocardial SPECT perfusion imaging in one stop.

Anatomic localisation is also of significant importance, more specifically in bone, thyroid, Prostascint, Oncoscint, octreotide, and MIBG (meta-iodobenzylguanidine) scintigraphies. These studies frequently demonstrate abnormalities requiring anatomical localisation by other imaging modalities. The thyroid studies have very low count rate with extremely poor image resolution requiring body markers. Any suspicious metastatic foci can be easily localised on fused SPECT-CT images (Figure 2). SPECT-CT has also proven to be highly effective in examining patients with neuroendocrine tumours.

A major difference between SPECT-CT and PET-CT is the potential for molecular therapy. At this point, there is no therapeutic PET compound available. However, SPECT radiotracers can, and many have been designed to, be target specific (e.g. Somatostatin receptor). First, the presence of a disease is identified and localisation is achieved with CT. This helps identify the exact distribution of the tumour, reducing morbidity from affecting critical organs when therapy is implemented. Then, the same radiotracer is used in combination with therapeutic radio-isotopes (such as yttrium-90 or I-131) to deliver a highly specific radiation to target the tumour, reducing morbidity of conventional chemotherapy or radiation therapy.

PET-CT

With the success of SPECT-CT in 1998, manufacturers began development of PET-CT in 1999 leading to the development of the first prototype in collaboration with a group of researches at the University of Pittsburgh. The first commercial PET-CT debuted in 2000 (Figure 3), and by 2002, the combined PET and PET-CT markets generated USD 481.23 million in revenue at an annual growth rate of 55% according to market research firm Frost & Sullivan.

Advantages of this technology include differentiation of benign lesions from malignant lesions, staging of malignant lesions, detection of cancer recurrence, reducing biopsy sampling errors, improving therapy monitoring, such as chemotherapy and radiation therapy (Figure 4). Antoch et al. demonstrated that hybrid PET-CT provides a synergistic advantage in staging of various cancers. PET-CT correctly staged 84% of patients as compared with 76% for side-by-side PET plus CT, 63% for CT alone, and 64% for PET alone. In this study, the added diagnostic advantage of PET-CT changed the treatment plan in a substantial number of patients [3]. S. Fant and colleagues correctly identified the site of the primary tumour in 44% of patients with unknown primary malignancies [4]. See- man and colleague showed that the combination of PET with CT or MRI was found to facilitate accurate correlation of molecular aspects and metabolic alterations with the structural findings in patients with known extensive, non-resectable metastatic gastrointestinal malignancies. Perhaps the most established
advantage of hybrid imaging is in lymphoma where PET-CT can confirm the absence of disease after first-line therapy.

Challenges
Although the introduction of PET-CT and SPECT-CT scanners represented an important development in the field of radiology, the hybridisation can be a little challenging. These technologies have introduced new challenges in management, including physician education about new findings, practices and pitfalls, proper siting of these equipments, educating staff, billing, reporting, and finally cost effectiveness.

The Future
There is now a challenge to take this new modality to the extreme with the introduction of 64- and later 256-slice CT components to hybrid systems. Philips Medical Systems debuted its 64-slice SPECT-CT and PET-CT systems at the 52nd Society of Nuclear Medicine Annual Meeting in Toronto, Canada (2005).

There are new hybrid systems under development that combine two anatomical imaging modalities. Dr Rebecca Fahrig and her colleagues from Stanford University have developed a truly hybrid X-ray/MR (XMR) system in which the X-ray tube and detector lie within the MR scanner. The X-Ray detector is a digital flat-panel detector (FPD), which is immune to magnetic fields. The equipment is used for delicate and sensitive procedures, such as shunt placement in patients with cirrhosis.

Conclusion
In summary, many clinical studies have indicated that hybrid devices are useful diagnostic tools that improve diagnostic and therapeutic accuracies that ultimately benefit the patient care.

References

The Author
Shahram Bonyadiou, M.D.
Assistant Professor of Radiology
University of Southern California
Keck School of Medicine
Department of Radiology
Division of Nuclear Medicine
bonyadlo@usc.edu