Original article

THE CLINICAL APPLICATIONS OF SINGLE-PHOTON EMISSION COMPUTED TOMOGRAPHY AND COMPUTED TOMOGRAPHY (SPECT/CT) IN ONCOLOGY

Sirianong Namwongprom, M.D.

Division of Nuclear Medicine, Department of Radiology, Faculty of Medicine, Chiang Mai University

Abstract

The accurate evaluation of a tumor’s stage is one of the most important steps for successful treatment. Radionuclide imaging, now widely used, is useful because it may reflect not only morphological characteristics but also metabolic activities. Conventional imaging techniques can provide anatomical information, necessary for the accurate detection and localization of structural and morphological abnormalities. However, it does not reflect the functional or metabolic status of a tumor. By contrast, the high sensitivity of the Nuclear Medicine techniques lack the necessary anatomic information. Therefore, both techniques will complement each other.

In evaluation of disease, fusion of the anatomical and functional imaging presented by single-photon emission computed tomography (SPECT) and computed tomography (CT) has been shown to improve diagnostic accuracy by enabling better localization and definition of organs and lesions. Technical developments have led to the development of better software techniques for image fusion and to the development of SPECT/CT systems. The advantages of combining SPECT with CT are numerous and are primarily due to the anatomic referencing and the attenuation correction capabilities of CT. This article describes recent advanced and clinical applications of SPECT/CT imaging in tumor imaging. Chiang Mai Medical Journal 2007;46(4):153-160.

Keywords: single-photon emission computed tomography (SPECT), computed tomography (CT), oncology
Clinical Applications

Bone scintigraphy (Tc-99m MDP): primary and secondary malignant bone diseases

In oncology, whole body bone scintigraphy is the standard procedure in the following indications: staging of disease (detection of metastases or local invasion), evaluation of treatment response, check-up of laboratory findings indicating bone involvement, differential diagnosis of new musculoskeletal symptoms, and prediction of pathologic fractures. However, bone scintigraphy lacks specificity. Because the diagnosis of bone metastases indicates short or limited survival and the need for additional or intensified treatment, accurate differentiation between benign and malignant lesions is extremely important. In the case of a negative study, no further imaging is needed. In some instances, such as suspicious abnormality on a planar bone scan, where local symptoms are suggestive of metastases, additional single-photon emission computed tomography / computed tomography (SPECT/CT) scans of that particular part of the body should be considered to increase diagnostic sensitivity and enable the correct diagnosis.

SPECT/CT improves the accuracy of bone scintigraphy by correctly classifying equivocal lesions, especially by identifying benign abnormalities in the axial skeleton and, thus, increasing the specificity of positive scan findings. This applies particularly to bone lesions located in anatomical regions that are otherwise difficult to interpret and cannot be sufficiently assessed by conventional imaging techniques because of the complex architecture of skeletal structures such as the spine, thoracic cage, pelvis, or skull, which require the additional use of CT or magnetic resonance imaging (MRI) (Fig. 1). SPECT/CT has proven to be extremely useful in identifying benign skeletal abnormalities, such as osteophytes, osteochondrosis, or degenerative spondylarthrosis. As a consequence, further imaging investigations will be necessary. Another benefit of SPECT/CT is the definition of suspicious bone lesions to guide a subsequent biopsy.

Thyroid cancer Imaging with I-131

Integrated I-131 SPECT/CT was found to have an additional value over planar imaging in patients with thyroid cancer after initial surgery and ablation of the thyroid remnant. It correctly characterized equivocal tracer uptake, as seen on planar imaging, as well as precisely localizing malignant lesions in the neck, chest, and skeleton (Fig. 2). SPECT/CT optimizes the localization of I-131 uptake to lymph node metastases versus remnant thyroid tissue, to lung versus mediastinal metastases, and to the skeleton. It also has further clinical impact on patient management by influencing clinical decisions in I-131 treatment, tailoring administered radioiodine dose, and/or adding of surgery or external radiation therapy when indicated.

Neuroendocrine tumor imaging (Somatostatin receptor scintigraphy using In-111 Octreotide)

Somatostatin receptor scintigraphy (SRS) of neuroendocrine tumors is often challenging because of the minute lesion size and poor anatomic delineation. SPECT/CT can improve reporting accuracy by providing additional anatomical information and lead to a change in the reported location of lesions with significant impact on patient management. SPECT/CT can define the precise organ
Figure 1. Whole body bone scintigraphy of a cervical cancer patient presenting with back pain that showed faint increased bony activity at L3-L4, best seen from an anterior view. (1A). SPECT/CT of abdominal region was performed and three areas of abnormally increased bony activity at L2-L4 (1B) were detected. Multiple bone metastases were diagnosed and the patient was transferred to the radiation therapy unit for palliative radiation treatment.
**Figure 2:** Whole body I-131 scintigraphy of patients with follicular thyroid cancer was performed during the course of follow-up. The anterior and posterior planar images showed multiple foci of increased radioiodine uptake at the chest region. Lung or rib cage lesions could not be specified (2A). SPECT/CT of the chest region demonstrated multiple areas of increased I-131 uptake, all of which located in the lung parenchyma (2B).
The clinical applications of SPECT/CT in oncology

involve, evaluate the extent of disease or therapeutic response, and it may also help in choosing the appropriate treatment modality for somatostatin receptor positive tumors such as medullary thyroid cancers, pancreatic neuroendocrine tumors, and carcinoid and islet cell tumors. Keidar et al. reported the study of In-111 pentetreotide SPECT/CT for the evaluation of patients with neuroendocrine tumors, and found that SPECT/CT affected the diagnostic interpretation and induced changes in management in 37% and 14% of the patients, respectively.(13)

Neuroblastoma and pheochromocytoma imaging (I-131 and I-123 MIBG)

Pheochromocytoma and neuroblastoma are the most common tumors originating in the adrenergic nervous system. The MIBG scan plays a major role in the early detection of recurrent and relapse disease. SPECT/CT improves accuracy in lesion localization and correlation of CT and MIBG findings, thus increasing diagnostic certainty. It can help characterize the increased uptake in a hyperplastic adrenal gland after prior contralateral adrenalectomy from retroperitoneal recurrence, especially when tumors tend to be bilateral and it may improve the detection of bone and bone marrow involvement, both at diagnosis and follow-up. It may facilitate the detection of recurrent disease close to the heart or liver, with the normal structure showing high MIBG uptake, and also differentiate physiologic bilateral symmetrical upper thoracic activity from scapular or costal bone metastases, or involved supraclavicular lymphadenectomy.(14) Visualization of a mass on CT, with the absence of MIBG-avidity, may exclude residual active disease.

Prostate cancer imaging (In-111 Prostascint)

SPECT/CT allows the detection and exact localization of prostate tumors and sentinel lymph nodes in the pelvis.(15) Its imaging was recently introduced in many institutes as a tumor targeting technique for use in brachytherapy,(16-18) image guided radiation therapy (IGRT), intensity modulated radiation therapy (IMRT) and other conformal therapies for prostate cancer.

Lymphoscintigraphy for sentinel node mapping (Tc-99m rhenium colloid or Tc-99m nanocolloid colloid)

Lymphoscintigraphic planar imaging is a common procedure for sentinel lymph node (SLN) imaging and localization prior to a lymph node biopsy, but it fails to elucidate specific lymphatic drainage. SPECT/CT has the potential to enhance preoperative anatomic orientation and the diagnostic sensitivity of SLN imaging.(19) SPECT/CT SLN mapping provides additional data that are clinically relevant to a sentinel node biopsy in patients with trunk or head and neck melanoma, mucosal head and neck tumors,(20) breast cancer,(21-22) invasive bladder cancer,(23) and prostate cancer.(24)

In patients with head and neck tumors, preoperative lymphoscintigraphy can be used to map lymphatic drainage patterns and identify SNLs. However, it is very difficult to determine the exact locations of head and neck sentinel nodes on preoperative lymphoscintigraphy without the use of anatomic landmarks. In patients with breast cancer, SPECT/CT may improve the preoperative localization of the SLN, detect SLNs missed by planar imaging, exclude non-nodal false positive sites of uptake, and accurately localize axillary and
extra-axillary nodes. In one study, SPECT/CT improved SLN identification in overweight patients and accurately identified SLNs in 75% of patients, in whom the SLNs could not be identified by the intraoperative blue dye technique.\(^{(24)}\)

In summary, SPECT/CT imaging has several benefits in oncology. It improves the quality of the image, fixes the exact location of the lesion through a better CT based attenuation of correction, and provides more accurate localization of the scintigraphic SPECT findings. This leads the an improvement of diagnostic confidence, with potential clinical impact. SPECT/CT also allows the functional characterization of changes or lesions seen on the CT scan, which helps in narrowing the differential diagnosis and decreasing the need of complementary studies.

References


การประยุกต์ใช้ทางคลินิกของ single-photon emission computed tomography and computed tomography (SPECT/CT) ในโรคมะเร็ง

ศิริมงคล นามวงศ์พรหม, ท.บ.
ภาควิชารังสีวิทยา คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่

บทคัดย่อ การวินิจฉัยโรคมะเร็งนั้น การกำหนดระยะของโรคเป็นปัจจัยสำคัญอย่างยิ่งในการพิจารณาเลือกวิธีการรักษา ซึ่งทำให้ผู้ป่วยได้รับการรักษาที่เหมาะสมมากขึ้นไป ในกระบวนการดังกล่าว การตรวจการแพร่กระจายของโรคเพื่อการออกซิเจนในตัวแณกัลต์ การที่คอยตรวจด้วยเอกซเรย์ และการเอกซเรย์ท้องถิ่นวิศวกรรม เพื่อให้ได้ข้อมูลถูกต้องอย่างไรก็ตามเทคโนโลยีในการตรวจที่กล่าวมานี้ มีขีดจำกัดในระดับหนึ่ง โดยการตรวจทางด้านรังสีวินิจฉัยมีความสามารถในการตรวจทางกายภาพได้อย่างแม่นยำ แต่ไม่สามารถตรวจพบเนื้อเยื่อที่มีความไม่ปกติได้ ส่วนการตรวจทางท้องถิ่นวิศวกรรมมีความสามารถในการตรวจความผิดปกติที่ไม่สามารถตรวจพบได้ แต่ไม่สามารถตรวจพบเนื้อเยื่อที่มีความไม่ปกติด้วย เนื่องจากการตรวจด้วย SPECT/CT สามารถทำให้การวินิจฉัยโรคทั้งในกระบวนการต่างๆ สามารถทำให้การกำหนดระยะของโรค ทำได้แม่นยำมากขึ้น เพื่อประโยชน์แก่ผู้ป่วย

บทความนี้จะกล่าวถึงการประยุกต์ใช้ทางคลินิกของ SPECT/CT ในโรคมะเร็ง เชิงทั่วไป 2550;46(4):153-160.

คำสำคัญ: single-photon emission computed tomography (SPECT), เอกซเรย์คอมพิวเตอร์, มะเร็งวิทยา