

Original Article

Pictorial review of SPECT/CT imaging applications in clinical nuclear medicine

Peeyush Bhargava¹, Guocheng He², Amin Samarghandi¹, Ebrahim S Delpassand¹

¹Nuclear Medicine Department, Excel Diagnostics and Nuclear Oncology Center, Houston, TX; ²Nuclear Medicine Department, Baylor College of Medicine, Houston, TX

Received February 10, 2012; accepted March 23, 2012; Epub March 28, 2012; Published April 15, 2012

Abstract: Integrated SPECT/CT scanners are gaining popularity as hybrid molecular imaging devices which can acquire SPECT and CT in a single exam. CT can be a low dose non-contrast enhanced scan for attenuation correction and anatomical localization, or a contrast enhanced diagnostic quality scan for additional anatomical characterization. We present a pictorial review highlighting the usefulness of this emerging technology. We present SPECT/CT images of 13 patients where additional information was provided by the co-registered low dose non-contrast enhanced CT scan. They belong to 12 male and 1 female patients with age ranging from 28 to 76 yrs, who were referred to the Nuclear Medicine Department for various indications. We describe these cases under in the following categories: bone scintigraphy (2), leukocyte scintigraphy (2), nuclear oncology (5), nuclear cardiology (1), and general nuclear medicine (3). Additional information provided by the co-registered low dose CT improves the diagnostic confidence in image interpretation of SPECT imaging.

Keywords: Hybrid SPECT/CT, SPECT, CT

Introduction

Hybrid imaging using SPECT/CT techniques is increasingly being used in clinical nuclear medicine with many institutions now equipped with SPECT/CT cameras. These devices allow acquisition of SPECT and CT in a single examination. The combination of functional data from SPECT acquisition and anatomic characterization on CT images has been shown to improve sensitivity and specificity of scintigraphic techniques [1-4]. Hybrid SPECT/CT devices shorten acquisition time, provide accurate attenuation corrected and co-registered images. The utility of this modality is being extensively evaluated in the areas of oncologic imaging, malignant and benign bone disease, infection imaging, and myocardial perfusion imaging. Various SPECT imaging parameters and CT acquisition techniques are being refined for specific situations. The advantages of complete morphological evaluation with a diagnostic quality CT using contrast is also being studied.

Several SPECT/CT devices are available on the

market with varying capabilities. They primarily fall under two categories depending on the CT capability. The cameras with low dose CT option are optimized for attenuation correction and anatomical localization. Although the CT is not “diagnostic quality” and full morphological characterization is not possible with IV contrast, these scanners are relatively cheaper, have a smaller footprint, and are associated with a lower radiation dose to the patient. At the other end of the spectrum are the top-of-the-line scanners with full CT capability, allowing for CT angiography. The future of SPECT/CT depends on its added value in patient management in various situations, and associated reimbursement. There are currently no CPT codes available to describe SPECT/CT.

The images presented in this pictorial review were acquired on Infinia Hawkeye 4 SPECT/CT. All cases shown highlight the additional value of SPECT/CT in specific clinical settings, using a low dose CT. The CT was used for attenuation correction and anatomical localization and we did not use complete morphological evaluation

with a contrast enhanced CT scan.

Materials and methods

The age of patients ranges from 28 to 76 years old, 12 male, and 1 female. All patients were referred to the Nuclear Medicine Department for various clinical indications. The decision to perform additional SPECT/CT imaging was based primarily on indeterminate findings on planar imaging. All SPECT/CT images were acquired using the Infinia Hawkeye 4.0 camera (GE Healthcare). SPECT images were obtained following low dose CT scan covering the area of interest, acquired without oral or IV contrast, at 140 kVp and 2.5 mA. Both SPECT and CT data were processed using Xeleris workstation (GE Healthcare). Three-dimensional rendering SPECT, CT and SPECT/CT fusion images were displayed in axial, coronal and sagittal planes for viewing and interpretation. Images were correlated to prior imaging studies, and clinical and treatment history available, at the time of interpretation. Most of the images presented in this article are in the standard Xeleris display format with crosshairs highlighting the finding. We describe these cases under in the following categories: Bone Scintigraphy (2), Leukocyte Scintigraphy (2), Nuclear Oncology (5), Nuclear Cardiology (1) and General Nuclear Medicine (3). The SPECT acquisition parameters varied with the energy of tracer and the dose injected. The figures show the additional value of SPECT/CT imaging in specific clinical settings, using a low dose CT.

Results

SPECT/CT in bone scintigraphy

Case 1. 67-year-old, male with a recent diagnosis of prostate adenocarcinoma, Gleason score 4+3 on biopsy. Planar whole body bone scan using ^{99m}Tc -MDP shows multiple foci of increased uptake in the thoracic and lumbar spine. SPECT/CT images localize these foci to degenerative osteophytes and facet joint arthritis. Osteoblastic bone metastases were ruled out (**Figure 1**).

Case 2. A 73-year-old patient with history of prostate cancer was referred for bone scintigraphy because of elevated PSA levels. Foci of increased uptake in the lumbar spine and left ilium were from osteoblastic bone metastasis.

CT images did not show any morphological changes in these foci. Incidental ^{99m}Tc -MDP uptake is seen in unsuspected liver metastasis, found to be from a previously unknown synchronous lung cancer (**Figure 2**).

SPECT/CT in leukocyte scintigraphy

Case 3. A 61 year old male with history of hypertension and diabetes presented with non-healing ulcer in the left heel. Three phase bone scan (using ^{99m}Tc -MDP) shows focal uptake in the left calcaneus positive on all three phases, suspicious for acute osteomyelitis. Planar images from ^{111}In -leukocyte study showed increased uptake in the left heel. SPECT/CT images localized abnormal ^{111}In -leukocyte uptake to the left calcaneus and showed another focus of soft tissue infection in the right leg (**Figure 3**).

Case 4. This patient is a 54-year-old male patient with history of colon cancer and recent left hemicolectomy. He was referred for an ^{111}In -leukocyte study for recurrent MRSA infections. Planar whole body images show abnormal tracer accumulation in left upper quadrant of the abdomen, abutting the spleen, suggestive of an infectious focus. SPECT/CT images localized this focus to an abscess, anterior to the spleen, at the site of prior bowel anastomosis (**Figure 4**).

SPECT/CT in nuclear oncology

Case 5. A 66-year-old female patient presented with hyperparathyroidism was referred for a ^{99m}Tc -sestamibi scan to localize parathyroid adenoma. Planar images show a focus of persistent uptake in the left upper chest. SPECT/CT images localized it to an abnormal soft tissue density in the para-aortic/prevascular region consistent with an ectopic parathyroid adenoma (**Figure 5**).

Case 6. This is a 53-year old male with history of rectal bleeding. A rectal polyp was removed on screening colonoscopy and found to have carcinoid tumor. CT abdomen and pelvis found multiple hypodense lesions in the spleen. ^{111}In -octreotide scan was performed to investigate metastatic disease. A focus of intense uptake in the inferior aspect of the liver was shown on planar images. Subsequent SPECT/CT localized this focal uptake in the gallbladder, a rare physiologic variant. Spleen is enlarged and the hypo-

Applications of SPECT-CT imaging

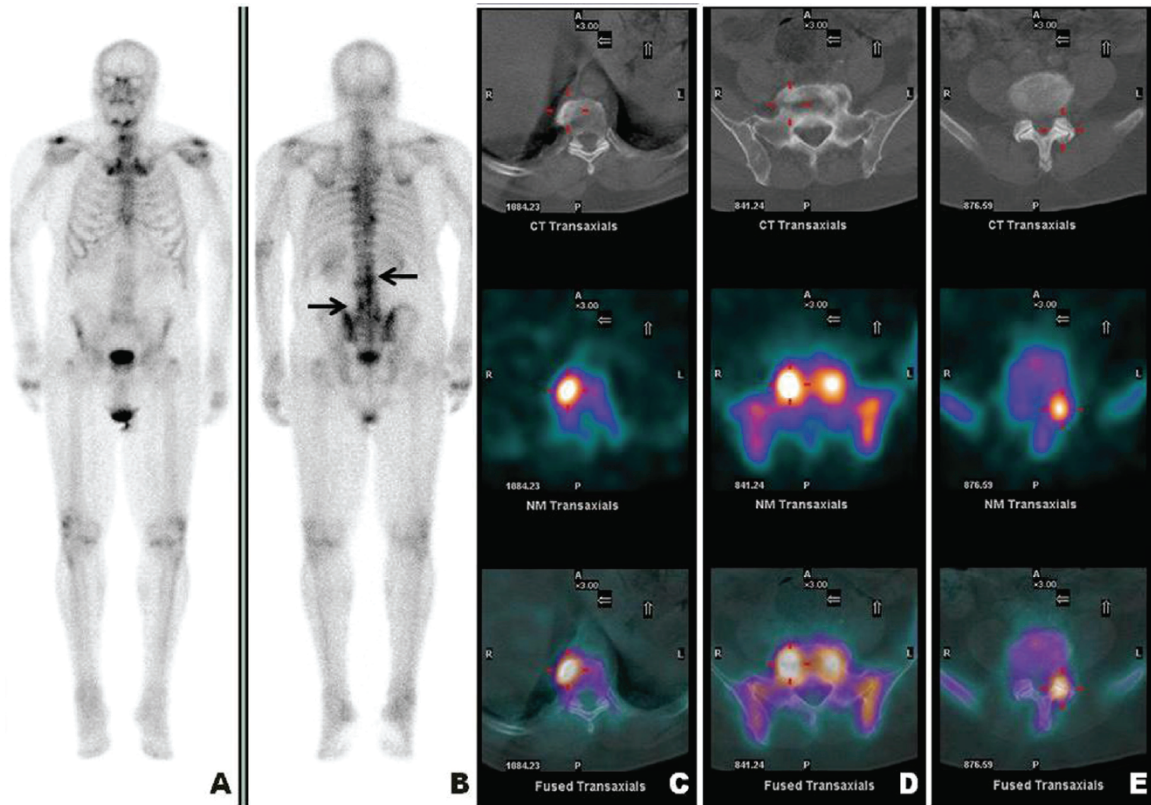


Figure 1. Planar whole body bone scan images (A & B) show foci of uptake in the thoracic and lumbar spine. SPECT/CT localizes foci of increased uptake to degenerative osteophytes (C & D) and facet joint arthritis (E), ruling out osteoblastic bone metastases.

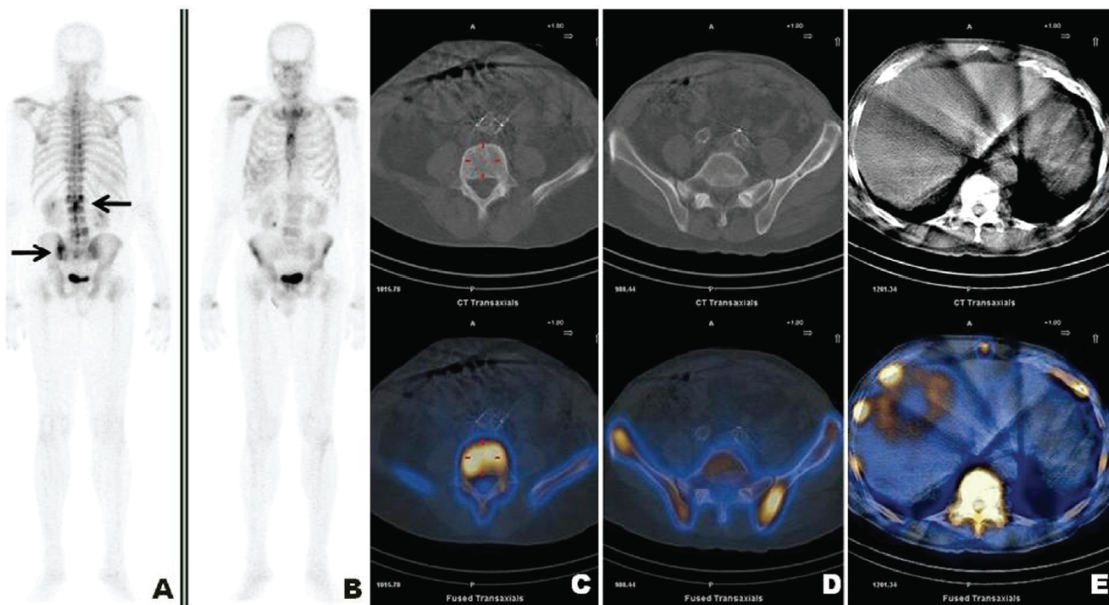


Figure 2. Planar whole body bone scan images (A & B) show bone metastasis in the sternum, L2, L3, left ilium. SPECT/CT localizes bone metastasis (C & D) and finds unsuspected liver metastasis (E) from a previously unknown synchronous lung cancer.

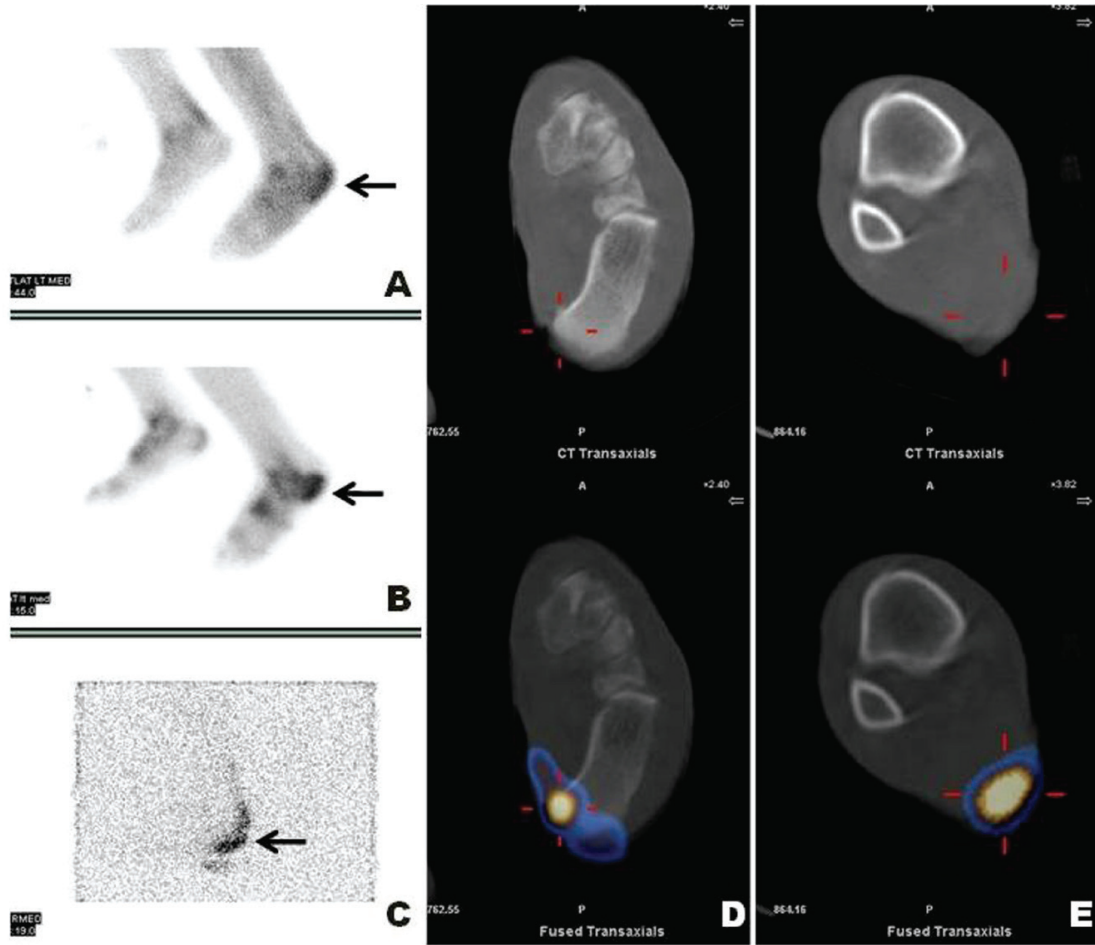
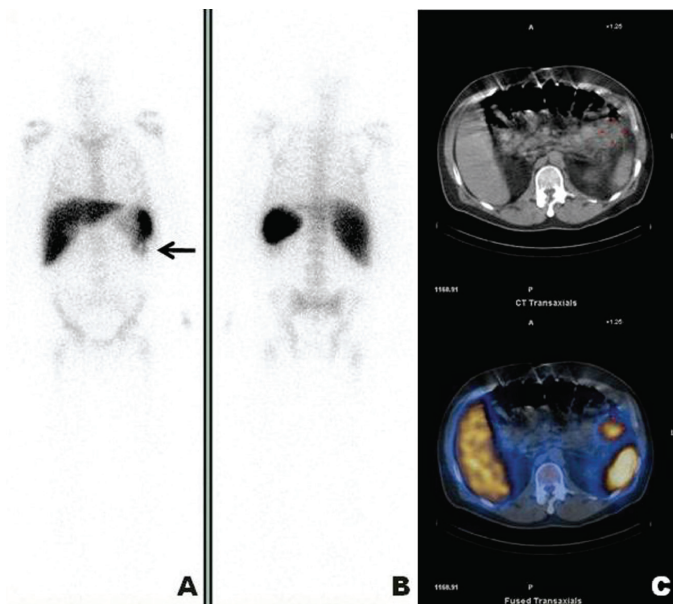


Figure 3. Planar images from a three phase bone scan (A & B) and In-111 leukocyte scan (C) with uptake in the left heel ulcer/calcaeus. ¹¹¹In-leukocyte SPECT/CT images confirm osteomyelitis of the left calcaneus (D) and soft tissue infection in the right leg (E).



dense lesions are photogenic (**Figure 6**).

Case 7. A 64-year-old male was admitted with hypertensive crisis. He had a history of extra adrenal right retroperitoneal pheochromocytoma which was resected 23 year ago. He was found to have elevated urine and plasma catecholamines. ¹²³I-MIBG scan was performed to localize the suspected recurrent tumor. Planar images show intense focal ¹²³I-MIBG uptake in the right upper quadrant of the posterior abdomen. SPECT/CT images demonstrated intense ¹²³I-MIBG uptake

Figure 4. Planar whole body ¹¹¹In-leukocyte images (A & B) show abnormal focus abutting the spleen. Intra-abdominal abscess is localized on SPECT/CT (C).

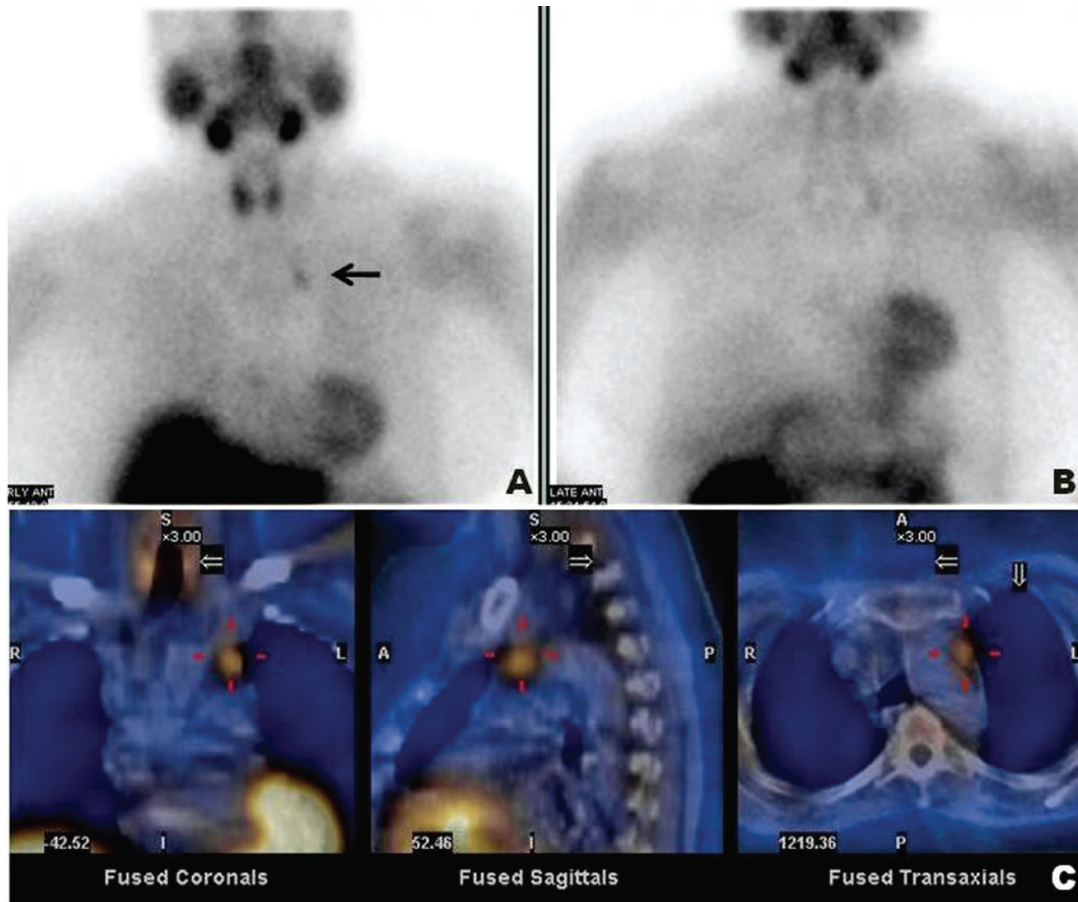
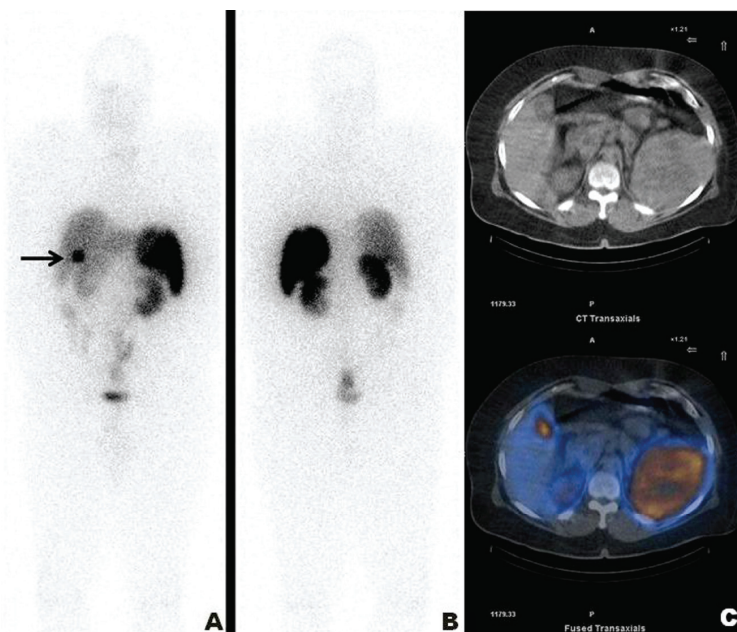


Figure 5. Planar early and delayed ^{99m}Tc -sestamibi images (A & B) show persistent focal uptake in the mediastinum. SPECT/CT localizes ectopic parathyroid adenoma to para-aortic/prevascular region (C).



in a soft tissue mass in the right retroperitoneal paracaval region, consistent with a recurrent extra adrenal pheochromocytoma (paraganglioma) (Figure 7).

Case 8. The patient is 28 year old male with papillary thyroid carcinoma status post total thyroidectomy. He was referred for remnant ablation. Pre-ablation ^{131}I -NaI whole body scan showed three foci of uptake in the neck. SPECT/CT

Figure 6. Planar whole body ^{111}In -pentetreotide images (A & B) show abnormal focus in the inferior aspect of liver. Physiologic gall bladder activity was confirmed on ^{111}In -pentetreotide SPECT/CT imaging (C).

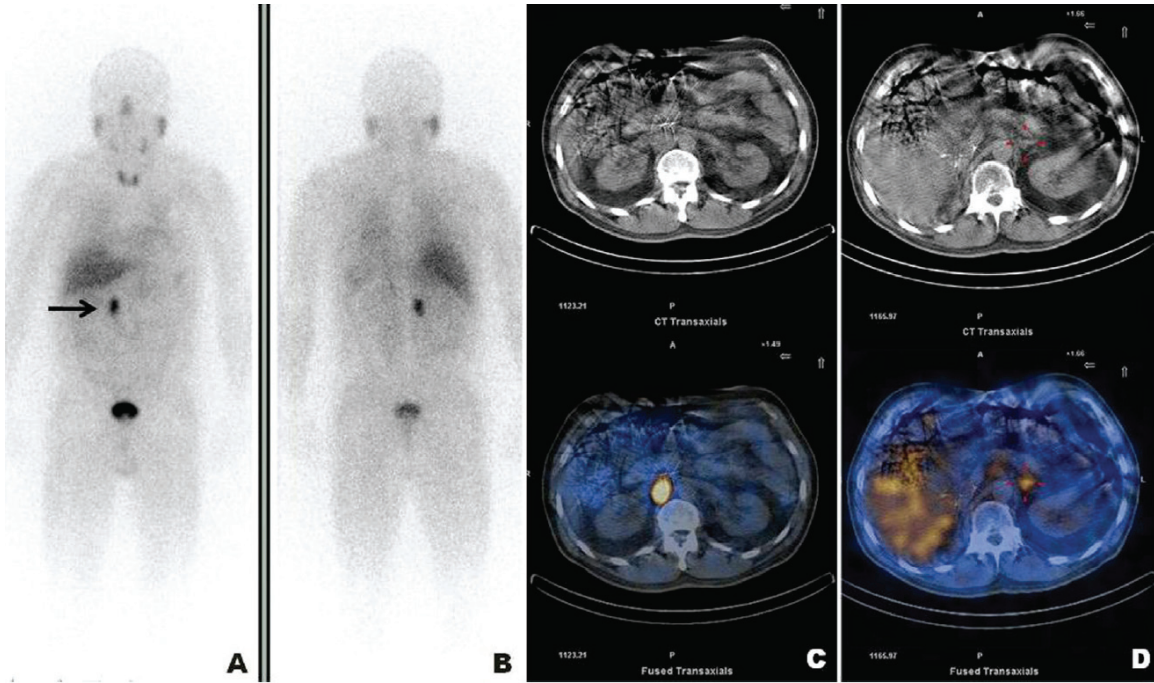


Figure 7. Planar whole body ¹²³I-MIBG images (A & B) show focal uptake in the right midabdomen. SPECT/CT localizes recurrent paraganglioma (C) and shows physiologic uptake in the left adrenal (D).

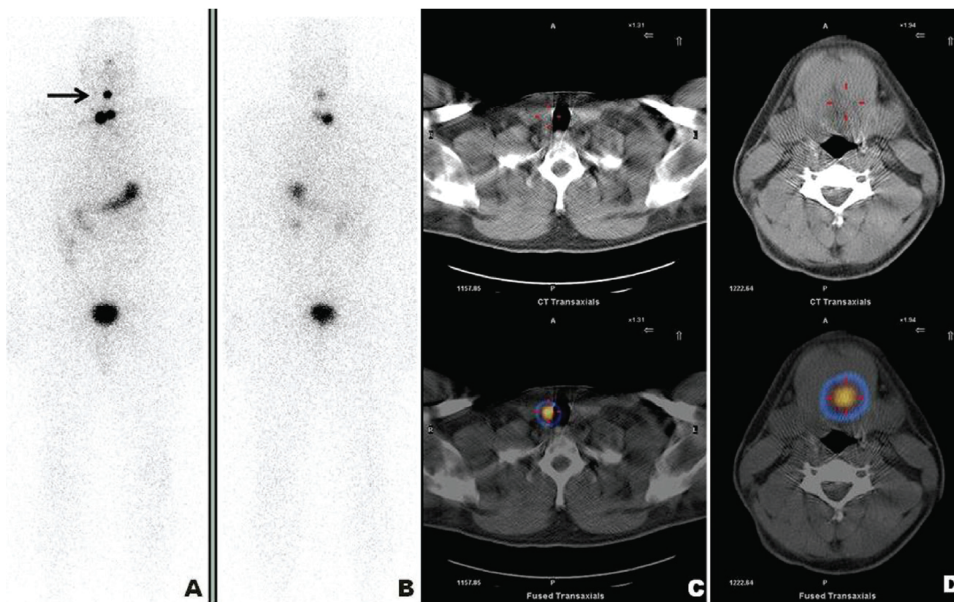


Figure 8. Planar whole body ¹³¹I-Nal images (A & B) show three foci in the neck. Residual thyroid tissue (C) and lingual thyroid tissue (D) localized on SPECT/CT.

localized two foci to the surgical bed consistent with thyroid remnant and one focus to the base of the tongue, the origin of the embryologic thyroglossal duct (foramen cecum), suggestive of lingual thyroid tissue (Figure 8).

Case 9. Patient is a 53 year old male with his-

tory of prostate cancer (Gleason score 4+3), status post radical prostatectomy one year ago, who was referred for a Proscint scan for rising PSA with negative bone scan and CT scan of the abdomen and pelvis. Planar whole body images from ¹¹¹In-capromab pentetide (Proscint) study show increased uptake in

Applications of SPECT-CT imaging

the mid abdomen. SPECT/CT demonstrated multiple foci of increased tracer uptake in the mid abdomen corresponding to sub-centimeter

mesenteric lymph nodes (at the level of superior mesenteric artery), consistent with metastatic disease (**Figure 9**).

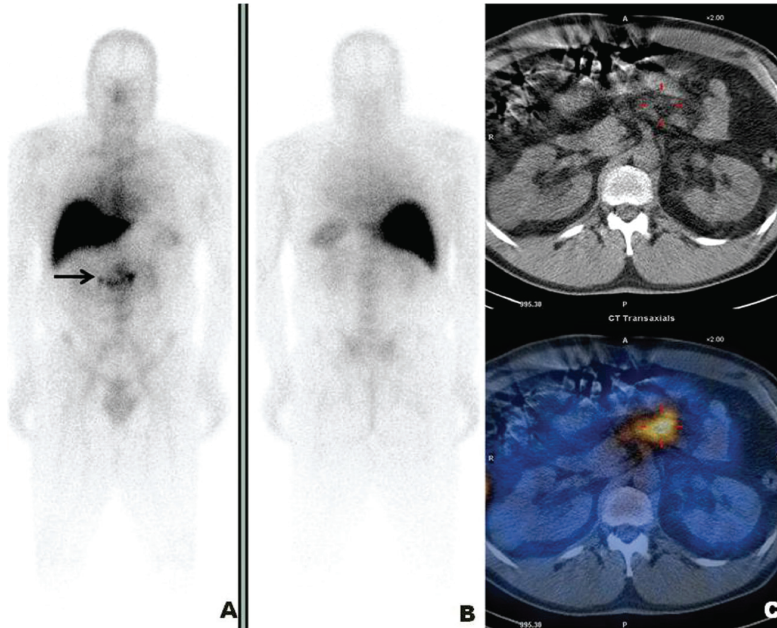


Figure 9. Planar whole body ^{111}In -capromab pendetide (Prostascint) images (A & B) show abnormal focal uptake in the mid abdomen. Metastatic mesenteric lymph nodes confirmed on SPECT/CT (C).

SPECT/CT in nuclear cardiology

Case 10. A pharmacologic stress SPECT myocardial perfusion study was performed in a 76-year-old male with a remote history of CAD, status post MI and CABG about 15 years ago. SPECT images (using $^{99\text{m}}\text{Tc}$ -sestamibi rest and stress one day protocol) without CT attenuation showed a partially reversible inferior wall defect. Attenuation corrected SPECT/CT images showed that the defect was predominantly reversible, consistent with dipyridamole induced myocardial ischemia (**Figure 10**).

SPECT/CT in general nuclear medicine

Case 11. A 67-year-old male was referred for lymphoscintigraphy for recently diagnosed right temple melanoma. Two

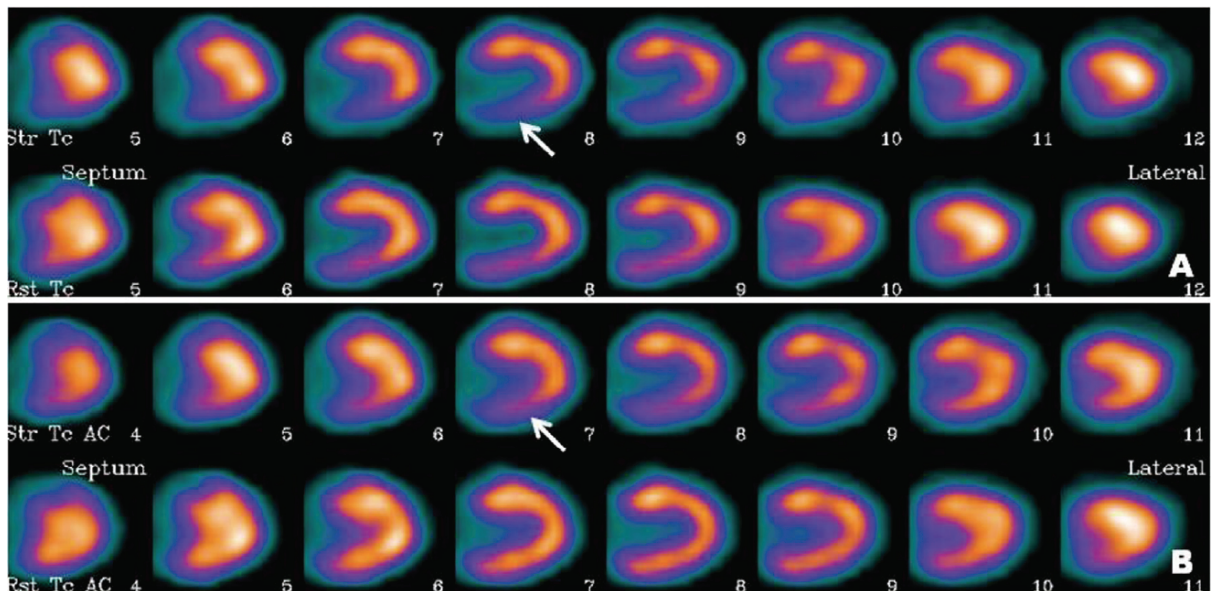


Figure 10. Top two rows (A) of vertical long axis images (non attenuation corrected) from myocardial perfusion imaging show partially reversible inferior wall defect. Bottom two rows (B) of (attenuation corrected) images show the defect to be predominantly reversible.

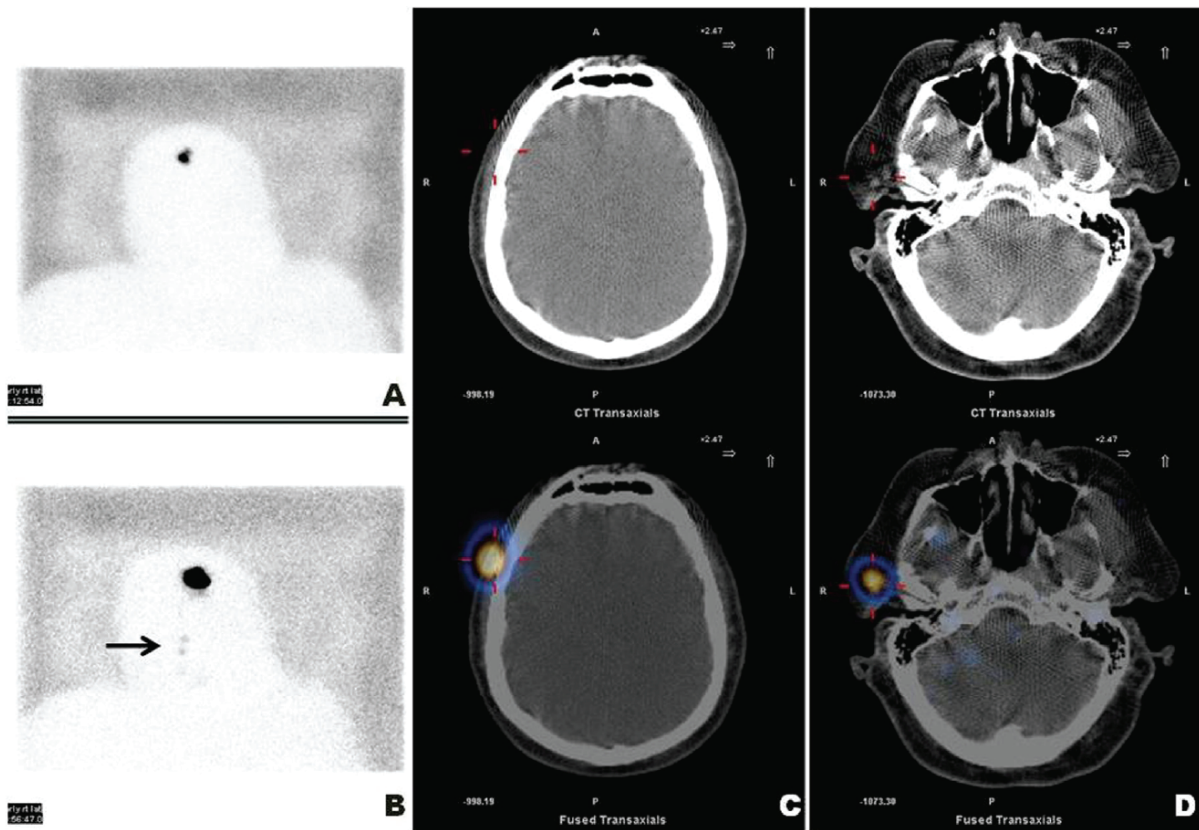


Figure 11. Planar (right lateral) images (A & B) from ^{99m}Tc -sulfur colloid lymphoscintigraphy for a right temple melanoma. Arrow shows focal sentinel node activity. SPECT/CT localizes the site of injection (C), and a pre-auricular lymph node (D).

foci of tracer accumulation consistent with sentinel nodes were shown inferior to the peritumoral injection site of ^{99m}Tc -sulfur colloid on the planar images. SPECT/CT images localize focal uptake to pre-auricular lymph node (Figure 11).

Case 12. Liver and spleen scintigraphy with ^{99m}Tc -sulfur colloid was performed in a 62-year-old male patient with multiple soft tissue nodules in the abdomen and pelvis. SPECT/CT demonstrate 3 foci of tracer accumulation corresponding to the abdominal soft tissue nodules in the left upper quadrant, right mid anterior, and right lower quadrant, consistent with splenosis (Figure 12).

Case 13. A 41 year old male presented with headaches and was found to have chronic subdural hematomas and intracranial hypotension on anatomic imaging studies. CSF leak was suspected and ^{111}In -DTPA cisternography was performed through the lumbar puncture injection.

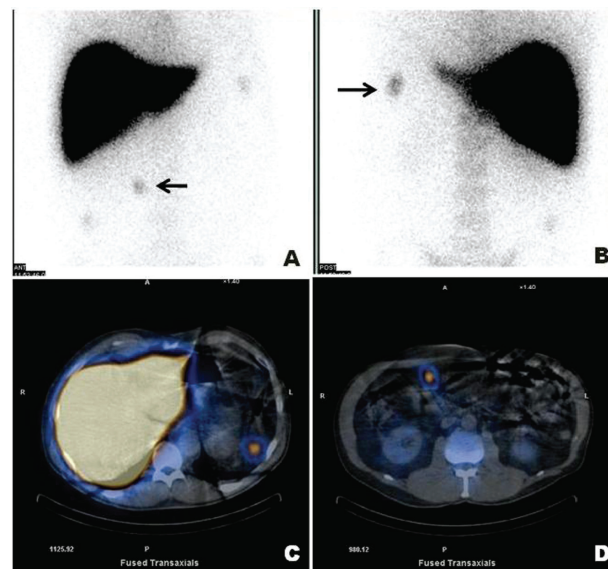


Figure 12. Planar anterior and posterior images (A & B) from ^{99m}Tc -sulfur colloid liver and spleen scan show multiple extrahepatic foci (splenosis). SPECT/CT localizes these foci to soft tissue nodules (C & D).

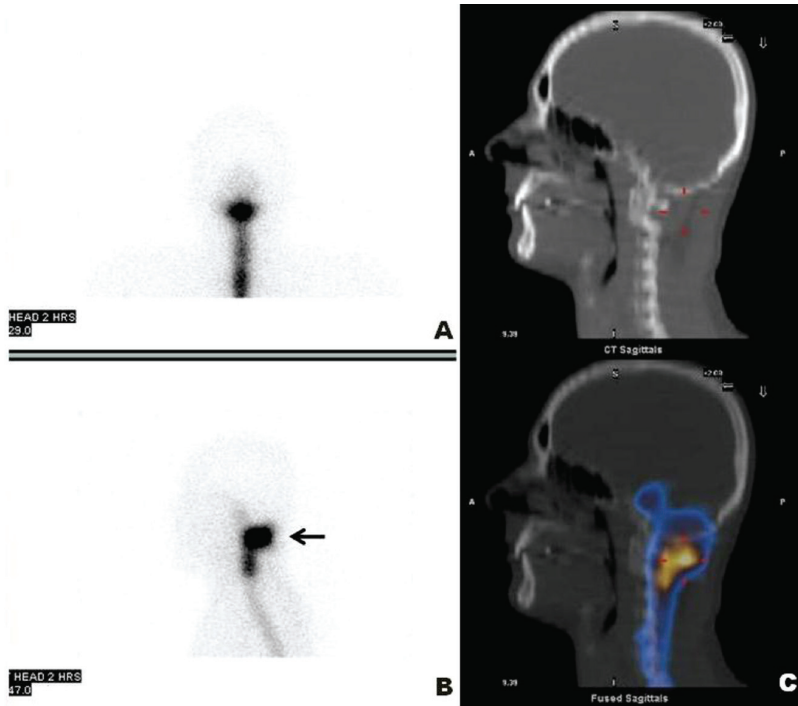


Figure 13. Planar images (A & B) from a cisternogram in anterior and lateral projections show CSF leak at the base of skull. SPECT/CT localizes CSF leak to the soft tissues between C1 and C2 vertebrae (C).

An abnormal focus of intense uptake was seen at the base of the skull on 2 hr and 24 hr planar images, without any discernable basal cistern or lateral ventricle activity or activity around the convexities. SPECT/CT localized the CSF leak to outside the thecal sac in the soft tissues between C1 and C2 towards the left of the midline (Figure 13).

Discussion

In SPECT/CT imaging SPECT and CT are acquired during the same imaging session and the CT data is used for attenuation correction of the SPECT images, and to generate fused SPECT/CT images in the three orthogonal planes for anatomical localization. Contrast enhanced CT scan may also be acquired as a part of SPECT/CT examination. Several recent review articles have described the role of SPECT/CT in clinical nuclear medicine [1-4]. In general, the acquisition of SPECT/CT, in addition to planar imaging, leads to improved sensitivity and specificity of scintigraphic technique due to attenuation correction, anatomical localization, and morphological characterization rendered by the CT por-

tion of the SPECT/CT. Other articles have discussed the benefits of SPECT/CT, as a hybrid imaging modality, along with PET/CT imaging [5-7]. The coming together of functional and anatomical information in one scan is praised as a one stop shop for several indications, such as the evaluation of left ventricle with myocardial perfusion imaging, combined with coronary calcium scoring, and coronary CT angiography. Several researchers have published on the technical aspects of SPECT/CT imaging, including instrumentation, attenuation correction, radiation exposure, and acquisition parameters [8-11].

Bone imaging with ^{99m}Tc labeled phosphonates (MDP or HDP) is an important area of clinical nuclear medicine practice. Additional evaluation with SPECT/CT has been

shown to improve the specificity of a very sensitive radionuclide technique by providing localization information and morphological characterization [12-16]. In the imaging of infection using various radiopharmaceuticals such as Ga^{67} citrate, ^{111}In labeled WBCs or ^{99m}Tc -HMPAO labeled WBCs, SPECT/CT provides additional information on anatomical localization and extent of disease [17-21]. SPECT/CTs role in Nuclear Oncology is rapidly evolving [22-23]. There are several areas where SPECT/CT has proven its utility including: localization of parathyroid adenomas with ^{99m}Tc -sestamibi imaging [24-25], evaluation of thyroid cancer patients with ^{131}I -Nal [26], ^{111}In -pentetate imaging (octreotide scan) and ^{123}I / ^{131}I MIBG imaging for adrenal medullary tumors [27-28]. In ^{111}In -prostascint imaging, SPECT/CT has obviated the need for blood pool imaging and improved sensitivity and specificity in diagnosing recurrent and metastatic prostate cancer [29]. In Nuclear Cardiology hybrid SPECT/CT systems allow for comprehensive anatomic and pathophysiologic evaluation of coronary artery disease. This can not only lead to better risk stratification, but also guide treatment/revascularization. The low

dose CT can be used for coronary calcium scoring and contrast enhanced diagnostic CT can be used for coronary angiography [30-32]. SPECT/CT also aids in the accurate localization of sentinel node before surgical resection [33-36]. The utility of SPECT/CT has been shown in various other general Nuclear Medicine techniques, including ventilation/perfusion scintigraphy [37].

Several SPECT/CT devices are available on the market with varying capabilities. Infinia Hawkeye 4 SPECT/CT from GE Healthcare is a low cost option with 4-slice low dose CT and a dual detector gamma camera mounted on a single slip-ring gantry. The low dose CT (140 kVp and 2.5 mA) provides only attenuation correction and anatomical localization rather than complete morphological evaluation. The Discovery NM/CT 670 from GE Healthcare offers a dual head gamma camera with a 16-slice CT. The Discovery NM/CT 570c, also from GE Healthcare, is a nuclear cardiology camera with cadmium zinc telluride (CZT) solid state detector and can perform a complete cardiac evaluation including myocardial perfusion imaging, attenuation correction, CT angiography, and coronary calcium scoring. The BrightView XCT system from Philips is a dual head gamma camera with a low dose flat-detector X-ray CT. The high end system from Philips, Precedence SPECT/CT combines a dual head gamma camera with a 16-slice CT. The Symbia family of cameras from Siemens offers several CT configurations, combining a dual-detector SPECT with: a 2-slice CT for attenuation Correction and anatomical localization (Symbia T), a 2-slice diagnostic CT (Symbia T2), a 6-slice diagnostic CT (Symbia T6), or a 16-slice diagnostic CT (Symbia T16).

We have presented a collection of cases representative of common clinical situations encountered in Clinical Nuclear Medicine practice, where SPECT/CT provides additional information useful in patient management. Since the images were acquired on Infinia Hawkeye 4 SPECT/CT camera with a low dose CT, the quality of CT images is limited. CT was used for attenuation correction and anatomical localization and we did not use complete morphological evaluation with a contrast enhanced CT scan. The additional value of SPECT/CT in these cases was predominantly related to anatomical localization of SPECT findings on CT (**Figures 1, 3, 5, 7, 8, 9, 11, and 13**). Improved sensitivity

of SPECT over planar imaging (**Figures 2, 4, and 12**); confirmation of physiologic uptake (**Figure 6**); and value of CT based attenuation correction (**Figure 10**) was also noted. We hope that as more data is available on the utility of SPECT/CT, its role is established in various clinical situations, evidence based protocols are put together for CT utilization (with or without contrast) and coding guidance is made available for this exciting hybrid imaging technology.

Conclusions

SPECT/CT has emerged as an indispensable modality in clinical nuclear medicine practice. It provides additional information over conventional planar imaging in a wide variety of scintigraphic procedures, enhancing the diagnostic confidence in image interpretation and leading to better patient management.

Address correspondence to: Dr. Peeyush Bhargava, Excel Diagnostics and Nuclear Oncology Center, 9701 Richmond Ave, Houston, TX, 77042 Tel: 713-781-6200; Fax: 713-781-6206; E-mail: pbhargava@exceldiagnostics.com

References

- [1] Mariani G, Bruselli L, Kuwert T, Kim EE, Flotats A, Israel O, Dondi M, Watanabe N. A review on the clinical uses of SPECT/CT. *Eur J Nucl Med Mol Imaging* 2010; 37: 1959-1985.
- [2] Buck AK, Nekolla S, Ziegler S, Beer A, Krause BJ, Herrmann K, Scheidhauer K, Wester HJ, Rummeny EJ, Schwaiger M, Drzezga A. SPECT/CT. *J Nucl Med* 2008; 49: 1305-1319.
- [3] Bybel B, Brunken RC, DiFilippo FP, Neumann DR, Wu G, Cerqueira MD. SPECT/CT imaging: clinical utility of an emerging technology. *Radiographics* 2008; 28: 1097-1113.
- [4] Patel CN, Chowdhury FU, Scarsbrook AF. Hybrid SPECT/CT: the end of "unclear" medicine. *Postgrad Med J* 2009; 85: 606-613.
- [5] Delbeke D, Schöder H, Martin WH, Wahl RL. Hybrid imaging (SPECT/CT and PET/CT): improving therapeutic decisions. *Semin Nucl Med* 2009; 39: 308-340.
- [6] Even-Sapir E, Keidar Z, Bar-Shalom R. Hybrid imaging (SPECT/CT and PET/CT)-improving the diagnostic accuracy of functional/metabolic and anatomic imaging. *Semin Nucl Med* 2009; 39: 264-275.
- [7] Bockisch A, Freudenberg LS, Schmidt D, Kuwert T. Hybrid imaging by SPECT/CT and PET/CT: proven outcomes in cancer imaging. *Semin Nucl Med* 2009; 39: 276-289.
- [8] Núñez R, Erwin WD, Wendt RE 3rd, Stachowiak A, Mar M, Stevens D, Madewell JE, Yeung HW,

Applications of SPECT-CT imaging

- Macapinlac HA. Acquisition parameters for oncologic imaging with a new SPECT/multislice CT scanner. *Mol Imaging Biol* 2010; 12: 110-138.
- [9] Seo Y, Mari C, Hasegawa BH. Technological development and advances in single-photon emission computed tomography/computed tomography. *Semin Nucl Med* 2008; 38: 177-198.
- [10] Patton JA, Turkington TG. SPECT/CT physical principles and attenuation correction. *J Nucl Med Technol* 2008; 36: 1-10.
- [11] O'Connor MK, Kemp BJ. Single-photon emission computed tomography/computed tomography: basic instrumentation and innovations. *Semin Nucl Med* 2006; 36: 258-266.
- [12] Gnanasegaran G, Barwick T, Adamson K, Mohan H, Sharp D, Fogelman I. Multislice SPECT/CT in benign and malignant bone disease: when the ordinary turns into the extraordinary. *Semin Nucl Med* 2009; 39: 431-442.
- [13] Gnanasegaran G, Cook G, Adamson K, Fogelman I. Patterns, variants, artifacts, and pitfalls in conventional radionuclide bone imaging and SPECT/CT. *Semin Nucl Med* 2009; 39: 380-395.
- [14] Papathanassiou D, Bruna-Muraille C, Jouannaud C, Fogelman I. Single-photon emission computed tomography combined with computed tomography (SPECT/CT) in bone diseases. *Joint Bone Spine* 2009; 76: 474-480.
- [15] Scharf S. SPECT/CT imaging in general orthopedic practice. *Semin Nucl Med* 2009; 39: 293-307.
- [16] Horger M, Bares R. The role of single-photon emission computed tomography/computed tomography in benign and malignant bone disease. *Semin Nucl Med* 2006; 36: 286-294.
- [17] Filippi L, Schillaci O. SPECT/CT with a hybrid camera: a new imaging modality for the functional anatomical mapping of infections. *Expert Rev Med Devices* 2006; 3: 699-703.
- [18] Lou L, Alibhai KN, Winkelaar GB, Turnbull RG, Hoskinson ME, Warshawski R, Jen H, Abele JT. ^{99m}Tc-WBC scintigraphy with SPECT/CT in the evaluation of arterial graft infection. *Nucl Med Commun* 2010; 31: 411-416.
- [19] Filippi L, Uccioli L, Giurato L, Schillaci O. Diabetic foot infection: usefulness of SPECT/CT for ^{99m}Tc-HMPAO-labeled leukocyte imaging. *J Nucl Med* 2009; 50: 1042-1046.
- [20] Filippi L, Schillaci O. Usefulness of hybrid SPECT/CT in ^{99m}Tc-HMPAO-labeled leukocyte scintigraphy for bone and joint infections. *J Nucl Med* 2006; 47: 1908-1913.
- [21] Bar-Shalom R, Yefremov N, Guralnik L, Keidar Z, Engel A, Nitecki S, Israel O. SPECT/CT using ⁶⁷Ga and ¹¹¹In-labeled leukocyte scintigraphy for diagnosis of infection. *J Nucl Med* 2006; 47: 587-594.
- [22] Brandon D, Alazraki A, Halkar RK, Alazraki NP. The role of single-photon emission computed tomography and SPECT/computed tomography in oncologic imaging. *Semin Oncol* 2011; 38: 87-108.
- [23] Chowdhury FU, Scarsbrook AF. The role of hybrid SPECT-CT in oncology: current and emerging clinical applications. *Clin Radiol* 2008; 63: 241-251.
- [24] Levine DS, Belzberg AS, Wiseman SM. Hybrid SPECT/CT imaging for primary hyperparathyroidism: case reports and pictorial review. *Clin Nucl Med* 2009; 34: 779-784.
- [25] Eslamy HK, Ziessman HA. Parathyroid scintigraphy in patients with primary hyperparathyroidism: ^{99m}Tc sestamibi SPECT and SPECT/CT. *Radiographics* 2008; 28: 1461-1476.
- [26] Wong KK, Zazhevsky N, Cahill JM, Frey KA, Avram AM. Hybrid SPECT-CT and PET-CT imaging of differentiated thyroid carcinoma. *Br J Radiol* 2009; 82: 860-876.
- [27] Gross MD, Djekidel M, Hay RV, Rubello D. Scintigraphic localization of adrenal tumors. *Minerva Endocrinol* 2009; 34: 171-184.
- [28] Rozovsky K, Koplewitz BZ, Krausz Y, Revel-Vilk S, Weintraub M, Chisin R, Klein M. Added value of SPECT/CT for correlation of MIBG scintigraphy and diagnostic CT in neuroblastoma and pheochromocytoma. *AJR Am J Roentgenol* 2008; 190: 1085-1090.
- [29] Beer AJ, Eiber M, Souvatzoglou M, Schwaiger M, Krause BJ. Radionuclide and hybrid imaging of recurrent prostate cancer. *Lancet Oncol* 2011; 12: 181-191.
- [30] Mahmarian JJ. Hybrid SPECT-CT: integration of CT coronary artery calcium scoring and angiography with myocardial perfusion. *Curr Cardiol Rep* 2007; 9: 129-135.
- [31] Kaufmann PA, Di Carli MF. Hybrid SPECT/CT and PET/CT imaging: the next step in noninvasive cardiac imaging. *Semin Nucl Med* 2009; 39: 341-347.
- [32] Kaufmann PA. Cardiac hybrid imaging: state-of-the-art. *Ann Nucl Med* 2009; 23: 325-331.
- [33] Vermeeren L, van der Ploeg IM, Olmos RA, Meinhardt W, Klop WM, Kroon BB, Nieweg OE. SPECT/CT for preoperative sentinel node localization. *J Surg Oncol* 2010; 101: 184-190.
- [34] Van der Ploeg IM, Valdés Olmos RA, Kroon BB, Nieweg OE. The Hybrid SPECT/CT as an additional lymphatic mapping tool in patients with breast cancer. *World J Surg* 2008; 32: 1930-1934.
- [35] Mar MV, Miller SA, Kim EE, Macapinlac HA. Evaluation and localization of lymphatic drainage and sentinel lymph nodes in patients with head and neck melanomas by hybrid SPECT/CT lymphoscintigraphic imaging. *J Nucl Med Technol* 2007; 35: 10-16.
- [36] Husarik DB, Steinert HC. Single-photon emission computed tomography/computed tomography for sentinel node mapping in breast cancer. *Semin Nucl Med* 2007; 37: 29-33.
- [37] Roach PJ, Gradinscak DJ, Schembri GP, Bailey EA, Willowson KP, Bailey DL. SPECT/CT in V/Q scanning. *Semin Nucl Med* 2010; 40: 455-466.