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ORIGINAL ARTICLE

CME

The Incremental Value of Single-photon Emission Computed Tomography / Computed Tomography in Post-thyroidectomy Iodine-131 Scanning of Differentiated Thyroid Carcinoma. Part I: Retrospective Analysis of 26 Cases

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ABSTRACT

Objective: *This study investigated whether single-photon emission computed tomography (SPECT) with integrated low-dose computed tomography (CT) may have additional value over whole-body scintigraphy in determining the presence and location of tumour uptake in patients with differentiated thyroid carcinoma.*

Methods: *Between 1 January and 31 December 2011, planar imaging was performed on 79 patients after total or nearly total thyroidectomy for differentiated thyroid carcinoma. Of these patients, 26 also underwent SPECT/CT (using an integrated system) because the planar findings were inconclusive. Fusion images were considered to have incremental value over planar images when they better localised sites of increased iodine-131 uptake. The final diagnosis was supplemented by other imaging modalities, serological correlation, and clinical follow-up. The impact of SPECT/CT results on therapeutic strategy was assessed.*

Results: *SPECT/CT had an incremental value over planar imaging in all of the 26 patients who underwent fusion imaging, by exclusion of distant metastases (42%), differentiation of pathological versus physiological uptake (38%), more accurate localisation of equivocal uptake (50%), discrimination between normal remnants and lymph node metastases in the neck (12%), and identification of occult lesions in the skeleton unsuspected on planar imaging (12%). SPECT/CT led to modified therapeutic management in nine (35%) of the 26 patients studied.*

Conclusion: *The use of SPECT/CT fusion imaging offered incremental value over whole-body scintigraphy in increasing diagnostic accuracy, improving the interpretation of equivocal uptake, and modifying therapeutic strategies.*

Key Words: *Image processing, computer-assisted; Iodine radioisotopes; Thyroid neoplasms; Tomography, emission-computed, single-photon*

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中文摘要

分化型甲狀腺癌患者甲狀腺切除術後使用SPECT/CT 掃描偵測放射性碘（I-131）的優勢：第一部份：26個病例回顧分析

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目的：探討為分化型甲狀腺癌患者檢測腫瘤性濃聚灶的存在及其位置時，單光子發射電腦斷層攝影（SPECT）配合低劑量電腦斷層攝影（CT）是否比全身顯像更有優勢。

方法：2011年1月1日至12月31日期間，接受甲狀腺全切除或近全切除的79名分化型甲狀腺癌患者進行平面顯像。其中26人因其平面顯像結果屬非結論性，所以亦透過一個集成系統接受SPECT/CT掃描。如果融合圖像對I-131濃聚灶定位更佳，便顯示SPECT/CT掃描相對平面顯像較有優勢。然後輔以其他影像學檢查、相關的血清學、和臨床隨訪來作最終診斷。同時評估SPECT/CT掃描結果對於治療策略的影響。

結果：26名病人的結果顯示其SPECT/CT融合圖像比平面顯像更有優勢，因融合圖像有助排除遠處轉移腫瘤的可能性（42%）、能區分病理性濃聚及生理性濃聚（38%）、對可疑濃聚灶有更準確的定位（50%）、能分辨頸部術後殘留的正常淋巴結與轉移淋巴結（12%），以及能夠識別平面顯像漏診的骨組織隱匿病灶（12%）。26名病人中，9人（35%）的SPECT/CT掃描結果改變了醫生的治療策略。

結論：與全身顯像比較，SPECT/CT融合圖像較有優勢，這技術增加了診斷的準確性，改善了對可疑濃聚灶的解釋，及改變了治療策略。

INTRODUCTION

Thyroid carcinoma is one of the few cancers associated with an excellent prognosis and low mortality rate. Over 90% are differentiated thyroid carcinomas (DTC), either papillary thyroid carcinoma or follicular thyroid carcinoma, both of which retain morphological and functional characteristics of follicular epithelium. Despite their favourable prognosis, patients with thyroid carcinoma require life-long monitoring as the disease can recur locally or with distant metastases even decades after initial therapy.

A multitude of imaging modalities have been used for follow-up, including ultrasound of the neck and functional evaluation using different radiotracers such as technetium-99m (^{99m}Tc)-tetrofosmin, ^{99m}Tc-sestamibi, and ^{18}F-fluorodeoxyglucose (^{18}F-FDG).[1] However, conventional planar iodine-131 (^{131}I) whole-body scintigraphy, in association with serum thyroglobulin (Tg) measurement, is still considered the routine diagnostic procedure for thyroid carcinoma.[2] Sensitivity of 70 to 80% and specificity of 90 to 100% have been reported for diagnostic planar ^{131}I whole-body imaging in detecting recurrences or metastases from DTC.[1] However, there are multiple factors that limit performance of this procedure. Planar imaging, with its lack of anatomic landmarks, can sometimes fail to precisely localise pathological focal uptake, hence affecting correct disease classification and therapeutic management. In addition, the presence of multiple areas of physiological uptake are not always easily differentiable from pathological uptake and may lead to false-positive results.[3,4] However, the γ camera used for planar acquisitions only provides limited resolution, together with increased noise in images obtained when using radionuclides such as ^{131}I and small lesions may be missed leading to false-negative results. False-negative results can also occur in poorly differentiated thyroid carcinoma, which shows a reduced or absent uptake but high Tg secretion. In these types of tumours, other than conventional imaging methods such as ultrasound, computed tomography (CT), and magnetic resonance imaging, radioisotope procedures such as ^{18}F-FDG positron emission tomography/CT have been shown to be useful.[5]

Single-photon emission computed tomography (SPECT) can overcome the limitations of planar ^{131}I whole-body imaging. Although SPECT can provide cross-sectional scintigraphic images with higher sensitivity and

improved contrast resolution than planar acquisitions, the precise anatomic evaluation of certain lesions remains difficult. The performance of SPECT may be further improved by fusing SPECT and CT images; this was previously achieved by using external or internal markers to co-register the two examinations performed in two different sessions.[6] More recently, and in the current study, an integrated SPECT/CT system permits simultaneous anatomic mapping and functional imaging in a single imaging session without moving the patient from the imaging table.[7] This method greatly improves upon previous technical difficulties, including misregistration of two separate sets of images, often acquired at different points in time, compounded by shifting internal organ movement and peristalsis. An integrated SPECT/CT system can determine the exact anatomical site of uptake, more accurately characterising equivocal foci on planar imaging, thus limiting false-positive results.[6]

This study investigated the additional value of SPECT with low-dose CT over conventional planar ^{131}I whole-body imaging in detecting and characterising residual disease, and local and distant metastases in thyroidectomised DTC patients and whether its findings significantly modified the therapeutic strategy.

METHODS

Patient Population

The study population comprised 79 patients who had undergone thyroidectomy for thyroid carcinoma over a period of 12 months from 1 January to 31 December 2011. All 79 patients underwent planar ^{131}I whole-body scintigraphy, of whom 26 also underwent ^{131}I-SPECT/CT study. All ^{131}I-SPECT/CT studies were performed with an integrated system to evaluate foci of increased uptake detected on planar whole body images.

Of the 26 patients undergoing SPECT/CT, there were eight men and 18 women with an age range of 18 to 88 years. The histological type of the tumours was papillary thyroid cancer in 24 patients, and follicular thyroid cancer in two patients. At initial presentation, six patients had localised intrathyroidal disease, 17 patients had regional lymph node metastases, and three patients had metastatic disease in distant sites. Distant metastases were initially diagnosed using conventional imaging techniques, including CT and plain radiographs. In 15 patients, the ^{131}I-SPECT/CT study was performed in conjunction with the first postoperative ^{131}I scan (after the ablation dose of ^{131}I) while, in the other 11 patients, it was performed as part of the follow-up imaging evaluation.

Before scintigraphy, patients ate a low iodine diet for 2 weeks and were advised to abstain from thyroxine replacement for at least 3 weeks, and had a confirmed serum sensitive thyroid stimulating hormone level of >30 mIU/l at the time of scanning.

Scintigraphy Protocol

Planar ^{131}I whole-body imaging was performed in both anterior and posterior projections using two variable-angle dual-head γ cameras, the Infinia Hawkeye 4 (GE Healthcare Israel Ltd, Tirat Hacarmel, Israel), and the Infinia Hawkeye 1 (GE Healthcare Israel Ltd). High-energy parallel-hole collimators were used at a table speed of 8 cm/min. The imaging was completed with a spot view of selected body areas in anterior, posterior, and lateral projections at the discretion of the radiologists.

The γ cameras are part of a hybrid system equipped with an integrated X-ray transmission system (low-dose CT) to provide anatomic maps for attenuation correction and image fusion. The CT apparatus has a fixed-anode oil-cooled X-ray tube installed on the slip-ring gantry of the γ camera and operates at 140 keV and up to 2.5 mA. The hybrid system was used to perform SPECT/CT during the same session as planar whole-body imaging, with the patient in the same position and focusing on suspected areas of increased uptake seen on planar ^{131}I whole-body images.

First, emission SPECT images were acquired over 360° (180° per head) at the 364-keV photo peak ± 10% energy window, with the patient in the supine position. A 64 x 64 matrix was used, with a 6° angular step, an acquisition time of 60 seconds per frame, and a zoom factor of 1.33. The SPECT examination was followed by CT. In both systems, the X-ray tube and detector array rotate together in fixed geometry. Multiple CT slices were obtained in the helical mode when using the Infinia Hawkeye 4 (4 x5-mm thick slices obtained simultaneously with a beam coverage of 2 cm in each gantry rotation) and in the transaxial mode when using the Infinia Hawkeye 1 (2 x 5-mm thick slices obtained simultaneously with a beam coverage of 1 cm in each gantry rotation). All images were reconstructed online to a 512 x 512 image matrix.

SPECT images were reconstructed by using the ordered

subset expectation maximisation method (Table 1) and fused with CT images by using a dedicated software package (Xeleris functional imaging workstation [GE Healthcare, Chalfont St Giles, UK]) with use of both a linear grey scale and a continuous linear rainbow colour scale with varying degrees of background subtraction. The planar and SPECT/CT images were interpreted by one or two radiologists, and always one with substantial experience in nuclear medicine.

RESULTS

SPECT/CT had incremental value over planar imaging in 11 (42%) patients by excluding distant metastases, in 10 (38%) patients by differentiating pathological from physiological uptake, in 13 (50%) patients by more accurately localising equivocal uptake on planar imaging, in 3 (12%) patients by discriminating normal remnants from lymph node metastases in the neck, and in 3 (12%) patients by identifying occult metastatic lesions in the skeleton unsuspected on planar imaging. Overall SPECT/CT provided additional information in one or more of the above aspects in all 26 patients reviewed.

Globally, planar imaging and SPECT/CT findings were concordantly negative in six (23%) patients who were considered disease-free, confirmed by low Tg levels and negative findings on conventional imaging (such as ultrasound of the neck). Findings were concordantly positive in 20 (77%) patients, with SPECT/CT detecting more foci in five (19%) patients than planar scintigraphy alone. Of these five patients, SPECT/CT demonstrated occult skeletal metastases in three patients, and visualised foci of neck nodal metastases in two patients; all of which were not apparent on planar scintigraphy alone.

SPECT/CT led to modified therapeutic management in nine (35%) of the 26 patients studied, with subsequent surgical intervention in two patients (both received radiosurgery for brain metastases), external radiotherapy in two patients (1 each to the thorax and cervical spine), and selection of a more appropriate therapeutic radioiodine dose in seven patients.

Table 1. Reconstruction parameters.

Reconstruction type	OSEM
Prefilter type	Hamming
Filter parameter 1	0.9
Filter parameter 2	0.0
3D postfilter type	Hann
3D postfilter type parameter 1	0.9
3D postfilter type parameter 2	10.0
No. of OSEM iterations	2
Maximum No. of OSEM subsets	10

Abbreviations: 3D = 3-dimensional; OSEM = ordered subset expectation maximisation.

Case Reports

Twelve representative patients were selected from the study population to illustrate the value of ^{131}I-SPECT/CT fusion imaging. The details of imaging data are listed in Table 2. In this study, physiological uptake in the salivary glands, gastric mucosa, gut, nasal mucosa, urinary tract, and liver were considered to be normal.

Allowing the Confident Exclusion of Distant Metastasis

Two patients (patients 1 and 2) who had undergone total thyroidectomy for papillary carcinoma underwent post-therapeutic ^{131}I whole-body planar scintigraphy with targeted SPECT/CT imaging 4 days after administration of an ablative dose of ^{131}I (3 GBq). These patients demonstrated residual malignancy in the thyroid bed. However, confident exclusion of distant metastases in the thorax, abdomen, and pelvis was achieved through the use of ^{131}I-SPECT/CT fusion imaging.

Differentiating Pathological Versus Physiological Uptake

Two patients had similar findings of increased uptake in the right lower quadrant of the abdomen on ^{131}I whole-body planar scintigraphy, illustrating the utility of ^{131}I-SPECT/CT fusion imaging in differentiating physiological uptake from genuine pathology, avoiding misinterpretation and possible unnecessary treatment.

Patient 3 had a history of follicular carcinoma with complete thyroidectomy done; a post-ablation ^{131}I scan was performed during subsequent follow-up four days after administration of ^{131}I (3 GBq). The biplanar whole-body images showed residual malignancy in the neck, along with suspicious metastasis in the skull and equivocal uptake in the right lower quadrant of the abdomen. ^{131}I-SPECT/CT fusion images over the pelvis were able to confirm that the uptake was due to distant bony metastasis to the right posterior ilium rather than physiological activity in the bowel lumen, leading to a subsequent change in the therapeutic strategy.

Patient 4 had a history of papillary carcinoma post-thyroidectomy and underwent post-ablation ^{131}I (3 GBq) scan during subsequent follow-up. The biplanar whole-

Table 2. Data for 12 patients with additional information provided by ^{131}I-SPECT/CT.

Patient No.	Sex	Age (years)	Histological type	Tg (μg/l)	Region of tumour	Planar finding	^{131}I-SPECT/CT characterisation	Additional information from ^{131}I-SPECT/CT	Change of therapeutic strategy
1	F	43	Papillary	15	Neck Chest	Thyroid remnant Equivocal	Thyroid remnant Normal	Exclusion of distant metastasis	No
2	M	59	Papillary	<0.5	Neck Abdomen	Thyroid remnant Equivocal	Thyroid remnant Physiological uptake	Localisation of physiological uptake	No
3	F	30	Follicular	5230	Neck Head Abdomen	Thyroid remnant Skull metastasis Equivocal	Thyroid remnant Skull metastasis Right iliac metastasis	Detection of occult bone involvement	Yes
4	F	18	Papillary	0.7	Pelvis	Equivocal	Bowel activity	Localisation of physiological uptake	Yes
5	F	88	Follicular	5570	Chest Abdomen	Lung metastasis Equivocal	Rib/sternal metastasis Liver metastasis	Localisation of lesion	Yes
6	M	79	Papillary	2	Neck Chest	Thyroid remnant Equivocal	Thyroid remnant Mediastinal/ oesophageal uptake	Localisation of lesion	Yes
7	M	54	Papillary	126	Neck Chest	Thyroid remnant Lung metastasis	Thyroid remnant Left supraclavicular fossanodal metastases Miliary mets	Localisation of lesion	Yes
8	F	35	Papillary	2184	Head Chest Spine Extremities	Skull/brain metastasis Equivocal Equivocal Bone metastasis	– Rib/lung metastasis Vertebral metastasis –	Localisation of lesion Detection of occult vertebral involvement	Yes
9	M	63	Papillary	1873	Head Neck Chest	Equivocal Equivocal Lung metastasis	Brain metastasis Mandibular bone metastasis –	Localisation of lesion Detection of occult bone involvement	Yes
10	F	58	Papillary	8	Neck	Thyroid remnant/neck lymph node metastasis Abdomen	– Liver metastasis Stomach activity	Localisation of lesion Localisation of physiological uptake	No
11	F	54	Papillary	<0.9	Neck Pelvis	Thyroid remnant Equivocal	– Tubal clips	Detection of artefactual uptake	No
12	F	24	Papillary	21	Neck	Equivocal	Nodal metastasis Hair contamination	Localisation of lesion Detection of artefactual uptake	No

Abbreviations: ^{131}I-SPECT/CT = iodine-131 single-photon emission computed tomography/computed tomography; Tg = serum thyroglobulin (post-total thyroidectomy ≤2 μg/l).

body images showed residual malignancy in the neck, and equivocal intense uptake in the right lower quadrant, similar to patient 3. ^{131}I-SPECT/CT fusion imaging was not performed at that time due to X-ray tube failure. However, correlation with a plain radiograph of the pelvis showed an ill-defined sclerotic lesion in the right iliac bone, and this lesion was considered to be bony metastasis. At subsequent follow-up 6 months later, a low-dose diagnostic scan was performed 48 hours after administration of ^{131}I (1.1 MBq) and SPECT/CT of the pelvis was done to further delineate the nature of the right lower quadrant uptake. The planar whole-body image revealed resolution of the previous uptake in the neck, but persistent uptake in the right lower quadrant of the abdomen. However, the ^{131}I-SPECT/CT fusion images revealed only pelvic bowel activity, without genuine iliac bone metastasis. With these findings, the patient was treated as having complete remission without any need for further radioiodine treatment.

Improving Specificity and Diagnostic Accuracy of Pathological Uptake

^{131}I-SPECT/CT fusion imaging allowed precise localisation of ^{131}I uptake in patients 5 to 10 with differentiated thyroid carcinoma, thus improving the diagnostic accuracy of image interpretation based on planar images alone.

Identifying Artefacts That May Mimic Pathological Uptake

Patients 11 and 12 illustrate how ^{131}I-SPECT/CT fusion images can easily define equivocal findings subsequent

to unusual artefactual uptake that may otherwise lead to false conclusions.

DISCUSSION

In the current management protocols for differentiated thyroid cancer, most patients (except those with all the favourable prognostic factors, such as intra-thyroidal microcarcinoma in a young woman) would receive an ablation dose of radioactive iodine soon after total thyroidectomy for eradication of the minimal residual thyroid remnants (to facilitate Tg follow-up, and to reduce the risk of recurrence). A radioactive iodine scan would be performed within 1 week after the ablation dose to document the sites of ^{131}I uptake. During subsequent follow-up, radioactive iodine scans are also performed if residual cancer is suspected, as suggested by an elevated serum Tg level and / or abnormal uptake on the initial ablation scan. In these situations, a low diagnostic dose (e.g. 1.1 MBq) is used if abnormal uptake was shown on the preceding scan, and a high dose (e.g. 3 GBq) is used for higher diagnostic sensitivity if the serum Tg is elevated in the absence of abnormal uptake on the preceding scan. Abnormal uptake refers to uptake outside the thyroid bed on the first ablative scan and to any non-physiological uptake in subsequent scans.

The use of anatomic and functional image fusion is increasing in nuclear medicine, particularly in oncology, to aid diagnosis, allow accurate tumour localisation, and improve treatment outcome.[8,9] However, despite the higher sensitivity of scintigraphic procedures, often neither planar nor SPECT acquisitions are able to accurately delineate the site of lesions due to the absence of readily identifiable anatomical structures. The differentiation of pathological from physiological uptake is sometimes equally problematic, as whole-body scans may reveal foci of ^{131}I uptake owing to a plethora of other causes, such as ectopic foci of normal thyroid tissue, contamination, ectopic gastric mucosa, gastrointestinal or urinary tract abnormalities, inflammation and infection, mammary abnormalities, and non-thyroid neoplasms.[4]

Recent technology that combines functional and anatomic SPECT/CT images has improved the ability of planar ^{131}I imaging to detect iodine-avid foci. Previous methods required the placement of external markers at specific positions on the patient's body to co-register SPECT and diagnostic multi-slice CT scans acquired in two different sessions. However, some artefacts are unavoidable due to minimal differences in positioning between the two sessions. Another technical problem is that the external markers are manually defined.[6] By acquiring SPECT and CT images on a hybrid system in the same session and with the patient in the same position immediately after planar ^{131}I whole-body imaging, as in the current study, positioning problems previously encountered are partially solved. This reduces registration artefacts due to physiological uptake and improves anatomical delineation.[10]

The hybrid systems (Infinia Hawkeye 1 and Infinia Hawkeye 4) were used in this study. The results enabled more precise anatomic localisation in different regions, such as the neck (patients 7 and 12), thorax (patients 5, 6, and 8), abdomen/pelvis (patients 2 and 10), and skeleton (patients 3, 8, and 9). The system also improved image interpretation and more correctly differentiated malignant lesions from sites of physiological uptake such as in the gastrointestinal tract (patients 2, 4, and 10). Using this method, some authors have found fusion images to have an incremental diagnostic value over planar imaging in 57% of patients, leading to an impact on management in 41% of patients,[10] while other authors found additional value over planar imaging in 67.8% of patients and changing the therapeutic strategy in 35.6%.[11] In this study, SPECT/CT had an incremental value over planar imaging in one or more of the aspects discussed in all of the patients evaluated, along with modification of the therapeutic management in 35% of the patients. In some patients, the disease could be reclassified and the most appropriate therapeutic strategy selected. For example, localisation of foci of uptake to cervical lymph nodes versus the thyroid bed (patient 12) could impact on management by leading to alteration of the dose of ^{131}I to be administered or further referral for surgical neck dissection. Identification of distant metastases and unsuspected neoplastic lesions in bone that had not been shown or characterised on planar imaging (patients 3, 8, and 9) has a potential impact on management by warranting an increase in the dose of ^{131}I administered for therapy and / or the addition of surgery or external radiotherapy.

SPECT/CT also improved the specificity of planar images, which may be impaired by artefacts, anatomical variants, and tracer uptake due to non-thyroidal diseases (patients 11 and 12).[4] Although in the absence of elevated Tg levels, ^{131}I-avid foci were likely to be related to physiological uptake, integrated SPECT/CT images increased confidence in differentiating pathological

^{131}I uptake from physiological activity.[6] This was even more important when the benign lesion or physiological uptake identified on SPECT/CT represented the only area of uptake (patient 4) as unnecessary treatment could be avoided. In this study, because some patients also had low or borderline Tg levels (patients 2, 4, and 11), physiological uptake could have been suspected and tumour excluded. However, SPECT/CT may still be considered a determinant of the diagnosis because, although most true positives for metastases on SPECT/CT corresponded to high Tg serum levels, in some patients with metastases the Tg levels were only slightly elevated or borderline.

The SPECT/CT system used in this study provided low-dose non–contrast-enhanced CT images that lack the resolution of a diagnostic CT, and does not preclude the need for a high-resolution diagnostic CT scan with intravenous contrast administration in settings that make the evaluation of extent of disease and the relationship of lesions to vascular structures clinically significant, such as in surgical candidates.[11] In these patients, SPECT/CT data should be used to guide selection of the appropriate field of view for performing a diagnostic quality CT scan for better anatomical delineation. However, a diagnostic CT scan with contrast administration is contraindicated in the follow-up of patients in whom radioiodine therapy is contemplated within 2 months after the SPECT/CT study.[10]

In this study, the major limitation was the retrospective nature, which resulted in heterogeneity of the study population with regard to stage of disease. In addition, choosing the field of view for low-dose CT scanning was based on ^{131}I planar images and not on SPECT images, which might have led to missed lesions. Finally, most patients in this study underwent SPECT/CT imaging following administration of a therapeutic dose of ^{131}I. The sensitivity of radioiodine imaging depends on the administered radioactivity; therefore, low-activity (1.1 MBq) diagnostic ^{131}I whole-body scans have a lower detection rate than high-activity (3.0-4.4 GBq, as used in this study) post-therapy scans.[12] Consequently, after administration of a therapeutic dose, the SPECT image quality is theoretically superior to that after administration of a lower dose for a diagnostic study. Despite this limitation, it has been reported that foci of uptake in the neck, as well as elsewhere in the body, could be localised in a similar percentage of patients who underwent a diagnostic scan (65%) as in the total patient population (57%).[10]

CONCLUSION

^{131}I-SPECT/CT fusion imaging improves the interpretation of planar ^{131}I whole-body images, precisely localising and characterising local residual disease and iodine-avid metastases, differentiating them from areas of physiological uptake and reducing false-positive results on planar imaging, thus identifying tumours more accurately. SPECT/CT can correctly modify the disease classification defined by planar imaging alone and influence decisions in therapeutic management in terms of administering further therapeutic doses of radioiodine and guiding surgical planning.

REFERENCES

1. Unal S, Menda Y, Adalet I, Boztepe H, Ozbey N, Alagöl F, et al. Thallium-201, technetium-99m-tetrofosmin and iodine-131 in detecting differentiated thyroid carcinoma metastases. J Nucl Med. 1998;39:1897-902.
2. Sherman SI. Thyroid carcinoma. Lancet. 2003;361:501-11.
3. Mitchell G, Pratt BE, Vini L, McCready VR, Harmer CL. False positive 131I whole body scans in thyroid cancer. Br J Radiol. 2000;73:627-35.
4. Shapiro B, Rufini V, Jarwan A, Geatti O, Kearfott KJ, Fig LM, et al. Artifacts, anatomical and physiological variants, and unrelated diseases that might cause false-positive whole-body 131-I scans in patients with thyroid cancer. Semin Nucl Med. 2000;30:115-32.
5. Zoller M, Kohlfuerst S, Igerc I, Kresnik E, Gallowitsch HJ, Gomez I, et al. Combined PET/CT in the follow-up of differentiated thyroid carcinoma: what is the impact of each modality? Eur J Nucl Med Mol Imaging. 2007;34:487-95.
6. Yamamoto Y, Nishiyama Y, Monden T, Matsumura Y, Satoh K, Ohkawa M. Clinical usefulness of fusion of 131I SPECT and CT images in patients with differentiated thyroid carcinoma. J Nucl Med. 2003;44:1905-10.
7. Bocher M, Balan A, Krausz Y, Shrem Y, Lonn A, Wilk M, et al. Gamma camera-mounted anatomical X-ray tomography: technology, system characteristics and first images. Eur J Nucl Med. 2000;27:619-27.
8. Townsend DW, Cherry SR. Combining anatomy and function: the path to true image fusion. Eur Radiol. 2001;11:1968-74.
9. Beyer T, Townsend DW, Brun T, Kinahan PE, Charron M, Roddy R, et al. A combined PET/CT scanner for clinical oncology. J Nucl Med. 2000;41:1369-79.
10. Tharp K, Israel O, Hausmann J, Bettman L, Martin WH, Daitzchman M, et al. Impact of 131I-SPECT/CT images obtained with an integrated system in the follow-up of patients with thyroid carcinoma. Eur J Nucl Med Mol Imaging. 2004;31:1435-42.
11. Spanu A, Solinas M, Chessa F, Sanna D, Nuvoli S, Madeddu G. 131I SPECT/CT in the follow-up of differentiated thyroid carcinoma: incremental value versus planar imaging. J Nucl Med. 2009;50:184-90.
12. Chen L, Luo Q, Shen Y, Yu Y, Yuan Z, Lu H, et al. Incremental value of 131I SPECT/CT in the management of patients with differentiated thyroid carcinoma. J Nucl Med. 2008;49:1952-7.