Pediatr Radiol (2011) 41:1008–1012
DOI 10.1007/s00247-011-2039-x

ORIGINAL ARTICLE

SPECT/CT imaging in children with papillary thyroid carcinoma

Hwa-Young Kim · Michael J. Gelfand · Susan E. Sharp

Received: 4 October 2010 / Revised: 18 January 2011 / Accepted: 3 February 2011 / Published online: 24 May 2011

Abstract
Background SPECT/CT improves localization of single photon-emitting radiopharmaceuticals.
Objective To determine the utility of SPECT/CT in children with papillary thyroid carcinoma.
Materials and methods 20 SPECT/CT and planar studies were reviewed in 13 children with papillary thyroid carcinoma after total thyroidectomy. Seven studies used I-123 and 13 used I-131, after elevating TSH by T4 deprivation or intramuscular thyrotropin alfa. Eight children had one study and five children had two to four studies. Studies were performed at initial post-total thyroidectomy evaluation, follow-up and after I-131 treatment doses. SPECT/CT was performed with a diagnostic-quality CT unit in 13 studies and a localization-only CT unit in 7. Stimulated thyroglobulin was measured (except in 2 cases with anti-thyroglobulin antibodies).
Results In 13 studies, neck activity was present but poorly localized on planar imaging; all foci of uptake were precisely localized by SPECT/CT. Two additional foci of neck uptake were found on SPECT/CT. SPECT/CT differentiated high neck uptake from facial activity. In six studies (four children), neck uptake was identified as benign by SPECT/CT (three thyroglossal duct remnants, one skin contamination, two by precise anatomical CT localization). In two children, SPECT/CT supported a decision not to treat with I-131. When SPECT/CT was unable to identify focal uptake as benign, stimulated thyroglobulin measurements were valuable. In three of 13 studies with neck uptake, SPECT/CT provided no useful additional information.
Conclusion SPECT/CT precisely localizes neck iodine uptake. In small numbers of patients, treatment is affected. SPECT/CT should be used when available in thyroid carcinoma patients.

Keywords Thyroid cancer · Radioactive iodine · SPECT/CT · Neck imaging · Pediatrics

Introduction

PET/CT and more recently single-photon emission computed tomography co-registered to CT (SPECT/CT) have been accepted as important diagnostic tools in oncology. Fusion of functional and anatomical images improves diagnostic accuracy by placing abnormalities, detected by functional imaging, in a precise anatomical context [1]. Hybrid thyroid imaging, in particular SPECT/CT, has been shown to be a useful modality in the evaluation of adults after total thyroidectomy and after therapy for thyroid carcinoma [2–7]. Traditionally, a whole-body scan has been performed to localize I-131 uptake and detect residual or recurrent disease as well as distant metastases. However, precise anatomical localization of foci of increased uptake is difficult on planar images because of the lack of anatomical landmarks. Differentiation between physiological uptake in residual thyroid tissue and pathological uptake in neoplastic thyroid tissue is often very difficult. Lymph node metastases in the neck might be confused with remnant thyroid tissue. In the chest, lung uptake adjacent to the mediastinum is sometimes confused with mediastinal metastasis. By precisely localizing radioiodine uptake, SPECT/CT might improve the

H.-Y. Kim · M. J. Gelfand (✉) · S. E. Sharp
Department of Radiology, Cincinnati Children's Hospital,
3333 Burnet Ave.,
Cincinnati, OH 45229, USA
e-mail: michael.gelfand@cchmc.org

diagnostic accuracy of radioiodine scanning and affect patient management [2–8].

The purpose of this study is to evaluate SPECT/CT in a group of pediatric and adolescent patients with papillary carcinoma of thyroid.

Materials and methods

Twenty SPECT/CT studies were retrospectively reviewed in 13 children. Approval to conduct this study was granted by the Institutional Review Board of Cincinnati Children's Hospital. Patients ranged in age from 6 to 17 years at the time of imaging; only one child was younger than 11 years. The histological type of thyroid carcinoma was papillary in all 13 children; seven of these children had the follicular variant of papillary thyroid carcinoma and one had the diffuse sclerosing variant. All children had total or near-total thyroidectomy prior to imaging. Seven children had lymph node metastases at diagnosis: 3 had fewer than 10 metastases, 3 had 10–20 metastases and 1 had more than 20 metastases. One child had lung metastases at presentation that were no longer radioiodine-avid at the time of the follow-up imaging examination included in this study.

Seven studies were performed with [I-123]sodium iodide and 13 with [I-131]sodium iodide. Diagnostic administered activities of I-131 ranged from 1.6 mCi to 2.3 mCi (59–85 MBq), with a median dose of 2.0 mCi (74 MBq). Diagnostic administered activities of I-123 ranged from 0.47 mCi to 2.2 mCi (17–81 MBq) with a median dose of 1.2 mCi (44 MBq). A 6-year-old girl received the smallest dose, at 0.47 mCi (17 MBq). Stimulation from elevated TSH was achieved using T4 deprivation or intramuscular injections of thyrotropin alfa. Eight children had one study while five children had two to four studies. Seven studies were performed at i\nitial evaluation after total or near-total

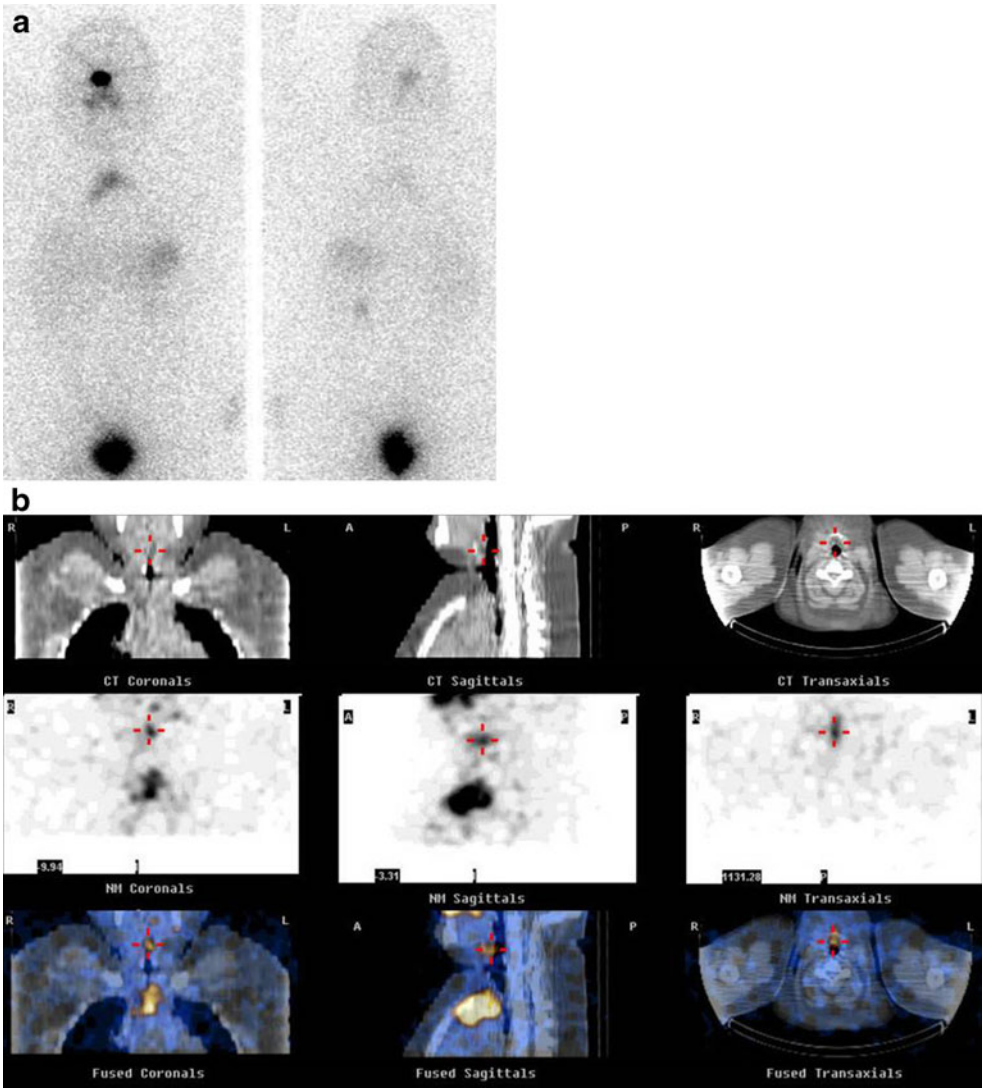

Fig. 1 A post-I-131 therapy scan at discharge is illustrated in an obese adolescent boy. The boy had papillary carcinoma follicular variant and 11 positive nodes at initial surgery and underwent subsequent surgery for local relapse. Thyroglobulin (*Tg*) was 4.5 ng/mL at TSH 199 μIU/mL. **a** Poorly defined neck activity and probable thymus activity is seen on whole-body images. **b** Tomographic I-131 SPECT/CT images—*top row* localization CT; *middle row* SPECT images; *bottom row* fused co-registered images. Uptake is present in the thymus gland in the anterior mediastinum and in a thyroglossal duct remnant

thyroidectomy, eight studies at follow-up after prior I-131 treatment, three studies at follow-up without I-131 treatment, and two were performed in conjunction with I-131 therapy using I-131 treatment doses of 92 mCi and 265 mCi (3.4–9.8 GBq). All studies included routine whole-body and spot planar imaging. Planar imaging was followed with SPECT imaging with co-registered localization CT performed at reduced exposure settings, with dose modulation. For I-123 doses, imaging was obtained at 24 h. For diagnostic I-131 doses, imaging was performed at 48 h, with additional images in some patients at 24 or 72 h. For therapeutic I-131 doses, imaging was obtained at 5 or 7 days. Seven of 20 SPECT/CT studies were performed using a General Electric Infinia Hawkeye camera (GE Healthcare, Milwaukee, WI, USA) with a localization CT unit and 13 of 20 studies used a Siemens Symbia T2 camera (Siemens Medical Solutions, Erlangen, Germany) with an integrated diagnostic-quality CT unit. Effective dose was calculated for a 60-kg 15-year-old girl using the ImPACT Dose Calculator (ImPACT, London, UK) [9]. The calculated effective radiation dose for localization CT using the SPECT camera with the diagnostic CT unit was 0.33 mSv.

Eleven of the 13 children had stimulated thyroglobulin measurements; the other two had anti-thyroglobulin antibodies.

Results

In seven studies, no neck activity was seen on planar imaging, and SPECT images were not useful. In 13 studies, neck activity was clearly present on planar imaging; in every case, anatomical localization of neck uptake on planar imaging was very limited. Foci of uptake in the neck were all precisely localized on co-registered SPECT and CT and on fused SPECT/CT images; SPECT/CT allowed localization of foci of uptake to within 0.4–0.5 cm on the co-registered CT images. Two additional foci of uptake were seen in the neck in two children by SPECT/CT only. When it was difficult to differentiate high

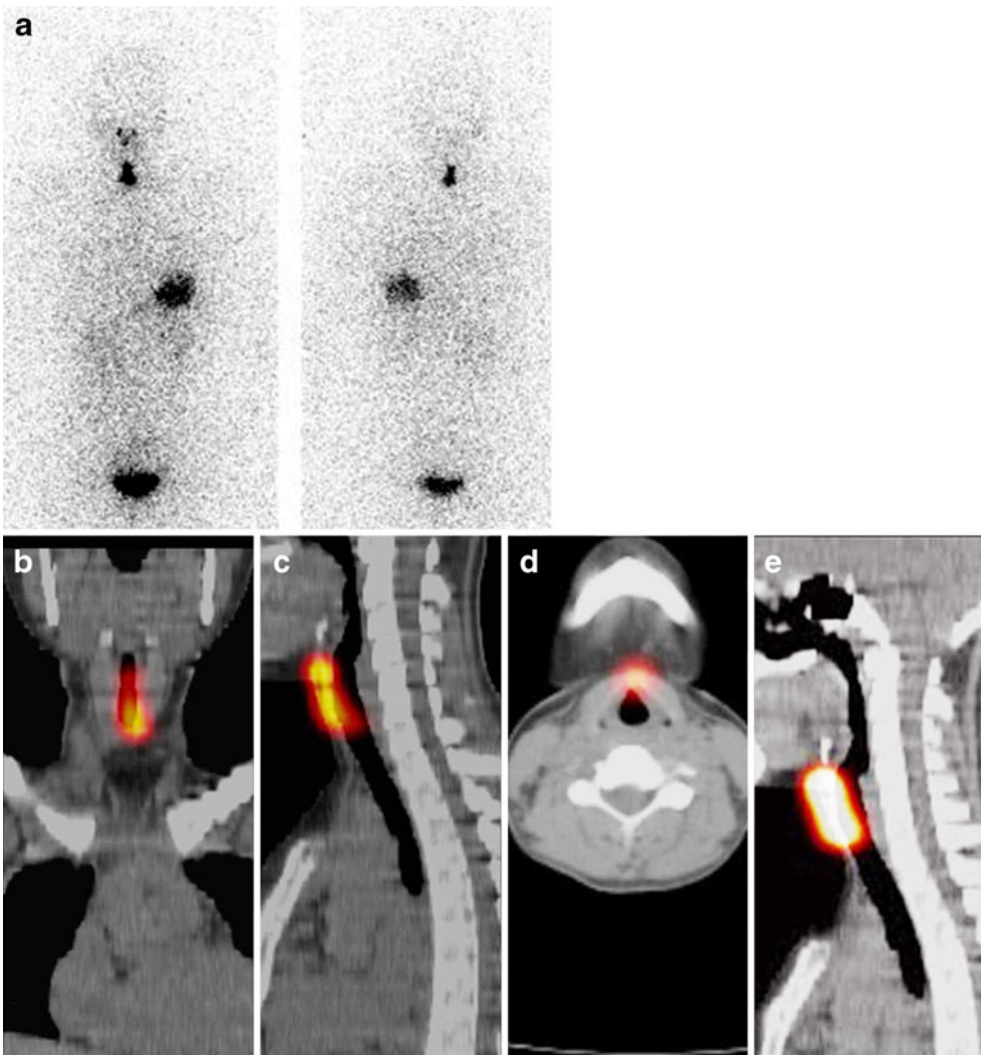

Fig. 2 Images in an adolescent girl with papillary carcinoma follicular variant and no positive nodes at initial surgery. The tumor was 3.5×2.4×2.4 cm with one small area of minimal vascular invasion. I-131 therapy was refused. **a** I-123 scan of the torso demonstrates vertical linear uptake in the neck. **b–d** I-123 SPECT/CT, coronal, sagittal and axial views after initial surgery. **e** I-131 SPECT/CT sagittal views at 6-month follow-up. There is uptake in a thyroglossal duct remnant. Shortly after surgery Tg was 3.1 at TSH 27. Six months later Tg was 1.7 at TSH 107

neck from salivary gland, oral and facial activity on planar images, SPECT/CT provided precise localization. In one child, thymic uptake of radioiodine was confirmed (Fig. 1).

In six studies in four children, foci of neck uptake were identified as benign by SPECT/CT (three thyroglossal duct remnants [Figs. 1 and 2], one skin contamination, two by precise anatomical CT localization). In the other studies, distinction between uptake in thyroid remnant tissue and uptake in tiny tumor deposits could not be made with adequate certainty. In one study, a large area of uptake on planar images was resolved into three discrete foci by SPECT/CT. In one study, absence of iodine uptake was clearly demonstrated in a lymph node that was suspicious on MRI (Fig. 3). In two children who were followed without I-131 therapy, SPECT/CT supported a decision not to treat with I-131. In 3 of 13 studies with activity in the neck on planar imaging, SPECT/CT did not provide useful additional information.

In children where small foci of uptake on SPECT/CT could not be identified as benign with reasonable certainty by SPECT/CT, stimulated thyroglobulin measurements were valuable in making a decision about I-131 therapy.

Discussion

Thyroid cancer is an uncommon malignancy in children. Some reports suggest that the incidence of thyroid cancer is increasing in the pediatric population, but this is not confirmed by others [10]. Papillary thyroid carcinoma is the most common histology (74%) [10]. Pediatric differentiated thyroid cancer patients tend to present with highly radiosensitive, bulky and widespread tumor [10].

SPECT/CT imaging has been shown to be of incremental value over whole-body planar imaging, increasing diagnostic accuracy and modifying therapeutic strategies in individual patients [3, 4, 6]. When SPECT/CT is added to whole-body planar imaging, there are fewer indeterminate studies; lesions are precisely localized and more accurately characterized. Treatment is changed in a significant minority of patients who undergo SPECT/CT, 24% in one report [8]. Wong et al. [4] reported that 4 of 130 neck foci were characterized as thyroglossal duct remnants in adults on SPECT/CT, but in another study using pinhole imaging, thyroglossal duct remnants concentrating radioiodine were noted in one-third of patients [11]. In our study, 3 of 13 foci of uptake were demonstrated to be thyroglossal duct remnants, with anterior midline uptake at the level of the hyoid bone.

Papillary thyroid carcinomas frequently metastasize to cervical lymph nodes. Even after a thyroidectomy that is meant to be total, a variable amount of normal thyroid parenchyma persists in the patient's neck. On post-therapeutic radioiodine scans, activity contained in this residual thyroid parenchymal tissue can hamper cervical nodal staging in many cases. With SPECT/CT, nodal staging in the neck is improved in many patients. Schmidt et al. [8] performed SPECT/CT in 57 patients at the first radioablative therapy after thyroid surgery. They demonstrated a gain in information on nodal stage in 35% of these patients. Kohlfuerst et al. [7] reported that SPECT/CT changed the nodal status of staging in 36% of patients and had an impact on the metastatic status in 21% of patients. Distant metastases are uncommon and were not encountered on any of the scans in this study; a patient with lung metastases had been treated prior to SPECT/CT imaging, and the metastases were no longer iodine-positive on the

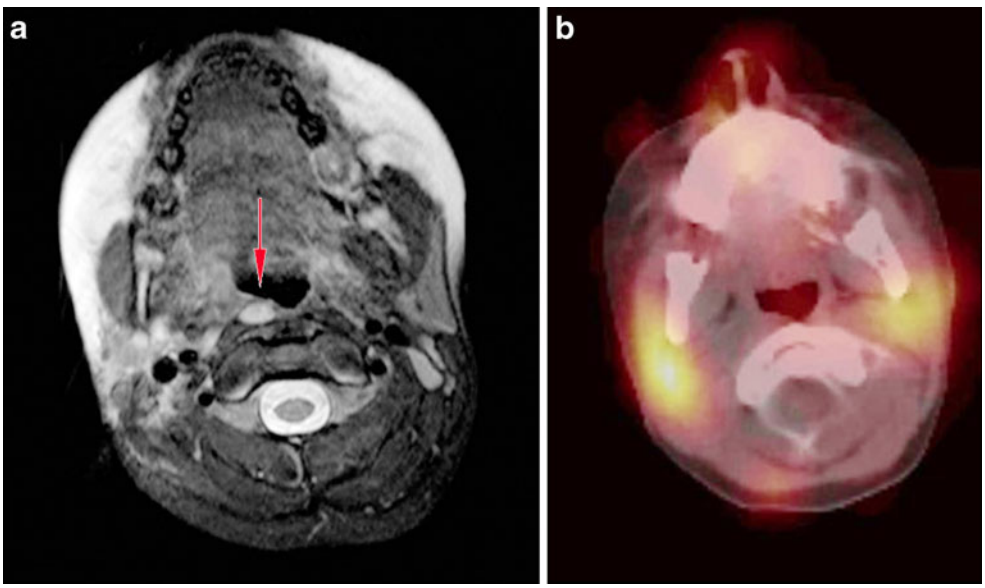

Fig. 3 Images in a school-age girl with papillary carcinoma, diffuse sclerosing variant and 24 positive nodes at initial surgery. Positive anti-Tg antibodies. **a** At initial imaging, T2-W MRI demonstrates increased signal in a retropharyngeal node. **b** I-123 SPECT fused with localization CT at the same evaluation permits identification of the same anatomical location and demonstrates no radioiodine uptake. The girl subsequently received I-131 therapy

follow-up scan included in this study. SPECT/CT has provided better spatial localization and demarcation of lesions than planar scintigraphy alone [7, 12].

Hybrid imaging has also been reported in children, using PET/CT and the positron emitter I-124. Using I-124, adult dosimetry studies have been reported. Freudenberg et al. reported that an I-124 PET/CT dosimetry protocol is safe and provides useful dosimetry information in pediatric differentiated thyroid cancer patients [13–15]. 18F-FDG might also be used in children when there is concern about the presence of differentiated thyroid carcinoma that does not concentrate radioiodine. Detection of 18F-FDG-avid metastases is enhanced when patients are studied at high TSH levels [16–18].

Conclusion

Localization of foci of radioiodine uptake by planar I-123 and I-131 imaging is done in the absence of accurate spatial references. Co-registered SPECT/CT allows precise anatomical localization. Thyroglossal duct remnants are easily identified. Other foci of radioiodine uptake are more accurately classified in some cases. When combined with other clinical data, SPECT/CT might affect therapeutic decisions.

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