Clinical experience following implementation of routine SPECT-CT imaging following 131-iodine administration for thyroid cancer

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Abstract

Background: Planar scintigraphy has long been indicated in patients receiving I-131 therapy for thyroid cancer to determine the anatomic location of metastases. We studied our experience upon implementing additional single-photon emission (SPECT)-CT scanning in these patients.

Method: We performed a retrospective study of consecutive adult patients with newly diagnosed thyroid cancer treated with I-131 between 2011 and 2017. Radiologic findings detected with planar scintigraphy alone vs those identified with SPECT-CT scanning were primary endpoints.

Result: In this study, 212 consecutive patients with thyroid cancer were analyzed in two separate cohorts (107 planar scintigraphy alone and 105 planar scintigraphy with SPECT-CT). The addition of SPECT-CT resulted in more findings, both thyroid-related and incidental. However, we identified only 3 of 21 cases in which SPECT-CT provided an unequivocal additional benefit by changing clinical management beyond planar scintigraphy alone. No difference in the detection of distant metastatic disease or outcome was identified between cohorts.

Conclusion: Synergistic SPECT-CT imaging in addition to planar nuclear scintigraphy adds limited clinical value to thyroid cancer patients harboring a low risk of distant metastases, while frequently identifying clinically insignificant findings. These data from a typical cohort of patients receiving standard thyroid cancer care provide insight into the routine use of SPECT-CT in such patients.

Key Words
- SPECT-CT imaging
- 131-iodine treatment
- planar scintigraphy
- thyroid cancer

Introduction

The past two decades have witnessed a dramatic rise in the incidence of newly diagnosed thyroid cancer (1), primarily attributable to the detection of incidental or small-volume disease. Simultaneous to this, practitioners have also increasingly individualized their approach to thyroid cancer care. While near-total thyroidectomy was historically the operative norm for well-differentiated thyroid carcinoma, data now confirm that many are adequately treated with hemithyroidectomy (2, 3). In parallel, uniform administration of adjunctive radioactive iodine (I-131) has been abandoned as data demonstrate limited or no benefit to those with low-risk diseases (4, 5, 6). Critical to this evolution of thyroid cancer care has been the ability to personalize care decisions based upon individualized risk assessment. This occurs through improving the specificity and sensitivity of data received,
specifically radiologic and imaging findings, as well as a cutting-edge molecular understanding of the disease.

In patients receiving I-131 therapy for well-differentiated thyroid carcinoma, a post-treatment nuclear medicine scintigraphy scan is recommended 3–7 days following isotope administration (7). This radiologic procedure provides planar imaging of the whole body, specifically determining the anatomic location of remnant thyroid tissue or metastatic thyroid cancer. While anterior neck uptake is most commonly seen, the distant metastatic disease can also be confirmed. With the use of post-treatment scintigraphy scanning, the staging of thyroid cancer can be finalized, while also documenting areas of concern for spread or persistent disease.

However, nuclear scintigraphy scanning affords only a modest resolution in comparison to other means of anatomic imaging. This detriment led to the development and use of single-photon emission CT (SPECT) with integrated CT, as a means of improving the three-dimensional characterization of post-treatment findings. Over the past several years, the integrated use of SPECT-CT scanning together with planar nuclear scintigraphy has gained widespread adoption as part of the radiiodine therapy protocol for patients with thyroid cancer. Several studies have supported the apparent incremental diagnostic value that accompanies SPECT-CT in this setting (8, 9, 10, 11, 12).

Yet, routine use of SPECT-CT leads to increased exposure to ionizing radiation, as well as additive cost. Greater use of cross-sectional imaging also increases the chance of incidental findings and their downstream ramifications. Thus, in totality, there are both perceived benefits as well as detriments to this additional imaging process. To date, no investigation has fully examined such endpoints in a real-world setting, allowing a broader understanding of the overall utility of SPECT-CT in the treatment of a typical group of thyroid cancer patients. Beginning in 2014, our institution gradually increased the use of SPECT-CT in the setting of post-treatment radiiodine imaging, culminating in near-universal use from 2016 onward. This afforded us a unique ability to perform a retrospective clinical utility study investigating both the benefits and detriments in comparison to planar scintigraphy alone.

Methods

We performed an investigation of consecutive cohorts of comparable patients with well-differentiated thyroid cancer, all receiving adjunctive I-131 therapy. The two cohorts were separated only by time, with the control population consisting of patients treated between 2009 and 2015 who received only post-treatment planar scintigraphy following radiiodine administration. In contrast, the comparison cohort received post-treatment SPECT-CT in addition to planar scintigraphy between the years 2011 and 2017. The use of SPECT-CT was phased in over several years, thus explaining the overlap of the above groups. To avoid selection bias, this study enrolled all consecutive patients evaluated at Brigham and Women’s Hospital for thyroid cancer care between 2009 and 2017 (13).

Our thyroid nodule and cancer center represent a single point of care for all nodule and cancer evaluation within our healthcare system, thus further reducing sampling or selection bias. For the purposes of this analysis, we only studied consecutive patients from 2009 to 2017 who were newly diagnosed with well-differentiated thyroid cancer. All patients were recommended by a thyroid specialist to receive I-131 treatment. Typically, I-131 doses ranged from 30 to 150 mCi at the discretion of the provider based upon applicable guideline recommendations for the time (7, 14). Preparation for I-131 therapy was either by thyroid hormone withdrawal or by rh-TSH injection. A low-iodine diet was administered for 1 week prior to treatment in all cases. Planar scintigraphy and SPECT-CT were performed 5–7 days after radioactive iodine treatment. All patients receiving I-131 therapy had undergone near-total thyroidectomy as the primary treatment of the disease. Imaging was performed on the Siemens Inc. Symbia Intevo imaging system in all cases.

Demographic data were collected including sex and age at the time of I-131 treatment. Thyroid cancer staging was profiled using the AJCC 7th or 8th edition (concurrent to the current period). We also collected histopathology, response to therapy at 6–12 months following initial treatment, and final outcome. A patient’s response to therapy was defined per the American Thyroid Association (ATA) clinical guidelines (7).

We reviewed all post-treatment scintigraphy reports, as well as available concurrent SPECT-CT reports for each patient. Primary endpoints included detection of local or distant metastatic disease identified by either modality, as well as detection of incidental non-thyroidal findings on SPECT-CT. This was defined as any finding reported by the radiologist in his/her impression that was not thyroid or thyroid cancer-related. From this, we sought answers to three principal study questions: Did SPECT-CT improve the detection of thyroid cancer-related findings beyond that obtained with planar scintigraphy? How did any improved specificity from SPECT-CT scanning impact the...
care of patients? And, what non-thyroid cancer-related (incidental) findings were detected on SPECT-CT, leading to unintended but necessarily follow-up or further testing?

This investigation was evaluated and approved by the Mass General Brigham Investigational Review Board. Statistical comparisons were performed using chi-square analysis for categorical data and using the Mann–Whitney U test for continuous data. P-values < 0.05 were considered significant. Descriptive data are shown using absolute numbers and percentages of the total study population.

Results

We studied 212 patients with thyroid cancer consecutively treated with I-131 therapy between 2009 and 2017. The median age was 47.2 years in the planar scintigraphy cohort and 46.2 years in the SPECT-CT cohort, while 77 and 75% were female, respectively. Here, 195 patients (91.1%) were diagnosed with papillary thyroid carcinoma, while 16 (7.5%), and 1 (0.5%) were diagnosed with follicular thyroid carcinoma/Hurthle cell carcinoma and poorly differentiated thyroid carcinoma, respectively. The distribution of AJCC staging was comparable between cohorts (P = 0.25). The study population demographics are shown in Table 1.

In the entire study population (n = 212), post-I-131 radiologic findings questioning local or metastatic disease were identified in 16 (7.5%) patients, with more noted in the SPECT-CT cohort (5 of 107 (5%) planar scintigraphy cohort vs 11 of 105 (10.5%) SPECT-CT cohort). In the planar scintigraphy cohort, four (3.7%) of findings were of suspected local metastatic disease confirmed with ultrasound and one (0.9%) suspected distant metastases, while in the ‘SPECT-CT cohort’, five (4.6%) findings on planar scintigraphy demonstrated suspected local disease, while six (5.7%) were of suspected distant metastatic disease. In summary, SPECT-CT combined with planar scintigraphy identified a greater percentage of abnormal findings following I-131 therapy.

However, of these 11 abnormal findings in the SPECT-CT cohort, only 3 led to a change in clinical management. In five separate cases, SPECT-CT scanning provided more precise data than that obtained with planar scintigraphy alone (e.g. such as size measurement or precise location), though led to no change in clinical management or new unique identification. SPECT-CT scanning did identify three additional new findings reported as a local disease not identified on planar scintigraphy scanning. However, all three cases (100%) were either false-positive findings or proved clinically insignificant and did not modify care. In summary, SPECT-CT scanning, in addition to planar scintigraphy, resulted in three cases of clinical benefit, five cases of greater precision though no change in clinical management, and three cases of false or clinically insignificant findings. Details explaining the impact on clinical management are provided in Table 2. In the planar scintigraphy cohort, stimulated thyroglobulin (Tg) was available in 43 (40%) patients (mean Tg = 15.8, s.d. 9.4), while 51 (47%) patients had positive thyroglobulin antibodies. In the SPECT-CT cohort, stimulated thyroglobulin was available in 63 (60%) patients (mean 9.1, s.d. 16.5), while 21 (20%) had positive TG antibodies.

Comparing study cohorts, there was no significant detection of distant metastatic disease or detection of thyroid cancer-related findings using SPECT-CT scanning compared to planar scintigraphy alone. Similarly, at a mean follow-up of 3.4 years in SPECT-CT group and 5.7 years in planar scintigraphy group, there was no difference in final outcome between cohorts (P = 0.07, Table 3).

Table 1  Study population (P = 0.25).

| Planar scintigraphy alone (n = 107) | Planar scintigraphy plus SPECT-CT (n = 105) |
|-----------------------------------|--------------------------------------------|
| **Female (n):** 77 (72%)         | Female: 75 (71%)                            |
| Age (mean, range): 47.2 years (19–82) | Age: 46.2 years (18–79)                     |
| RAI dosage (mean, range): 59.8 mCi (30–200) | RAI dosage: 66.5 mCi (30–150)                |
| **Type of thyroid cancer**        | **Classical variant:** 50 (47.6%)           |
| Papillary carcinoma               |  **Follicular variant:** 17 (16.1%)         |
| Papillary carcinoma               |  **Tall-cell variant:** 13 (12.4%)          |
| Classical variant: 56 (52%)       | Classical w/ tall cell features: 9 (8.6%)  |
| Follicular variant: 24 (22.4%)    | Other PTCa: 4 (3.8%)                        |
| Tall-cell variant: 7 (6.5%)       | Follicular/Hurthle thyroid carcinoma: 11 (10.5%) |
| Classical w/ tall cell features: 10 (9.3%) |  **PDTC:** 1 (1%)                           |
| Other PTCa: 5 (4.7%)              |                                            |
| Follicular thyroid carcinoma: 5 (4.7%) |                                            |

*Warthin-like, oncocytic variant PTC and PTC with high-grade features. aSolid variant, sclerosing variant, columnar variant. 
FVPTC, follicular variant of PTC; PTC, papillary thyroid carcinoma; RAI, radioactive iodine treatment; TCVPTC, tall-cell variant of PTC.
Table 2  Detailed descriptions of 11 cases in which additional SPECT-CT findings were noted separate from planar scintigraphy alone. Results are categorized as being false-positives, showing improved precision but without modifying care or as improving management.

| Case [years] M/F | Pathology                                                                 | SPECT-CT findings                                                                 | Final outcome                                                                 |
|------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 56 M             | 6.0 cm PTC, tall-cell variant; +gross ETE; +LVI; +N1a, largest LN 0.9 cm  | SPECT-CT identified an additional level 2 lymph node suspected to be metastases  | Follow-up ultrasound identified no suspicious findings. No recurrent disease confirmed. Patient with excellent response to treatment. Presumed false-positive finding. |
|                  |                                                                           |                                                                                  | Follow-up ultrasound identified no suspicious findings. No recurrent disease confirmed. Patient with excellent response to treatment. Presumed false-positive finding. |
| 21 F             | 2.5 cm PTC, multifocal, +vascular invasion; +LN involvement, largest 4.2 cm N1b | SPECT-CT identified an 8 mm lymph node in the left neck and 7 mm lymph node in the right supraclavicular area suspected to be metastases | Follow-up ultrasound identified no suspicious findings. No recurrent disease confirmed. Patient with excellent response to treatment. Presumed false-positive finding. |
| 54 F             | 1.6 cm PTC with tall-cell features, no ETE, no LVI; no LN involvement    | SPECT-CT identified a 5 mm cervical lymph node suspected to be metastases         | Follow-up ultrasound identified no suspicious findings. No recurrent disease identified. Patient with excellent response to treatment. Presumed false-positive finding. |
| 35 F             | 2.3 cm PTC, follicular variant; encapsulated; no LN involvement          | SPECT-CT identified an area of concerning uptake corresponding to a 9 mm soft tissue in the post-surgical thyroid bed | Patient with delayed RAI treatment 4 years after surgery. SPECT-CT clarified area of uptake was soft tissue/remnant thyroid and not metastatic LN. Patient with excellent response to treatment. |
| 19 F             | 3.4 cm classic PTC, focal capsular but extensive vascular invasion; minimal ETE; no LN involvement | SPECT-CT confirmed intense uptake in right lateral neck corresponding to lymph node | SPECT-CT improved localization, though no additional treatment was required. Patient with excellent response to therapy. |
| 55 M             | 4.8 cm PTC, follicular variant; encapsulated; no capsular or vascular invasion; no LN involvement | SPECT-CT identified focal uptake in right posterior pharyngeal wall, questioned as lymph node metastases | SPECT-CT finding proved to be a false-positive finding. Patient with excellent response to treatment. |
| 30 F             | Multifocal, diffuse sclerosing variant PTC, extensive LVI, +ETE, N1b, with largest LN 1.2 cm | Iodine avid focus seen in the right upper neck, SPECT-CT identified this an enlarged submental lymph node | SPECT-CT finding proved to be a false-positive finding. Subsequent recurrence identified on left neck and removed surgically. Patient with excellent response to treatment. |
| 56 F             | 2.1 cm PTC, macroscopic ETE, extensive LVI, +ETE, N1b with largest lymph node 1.0 cm | Planar scintigraphy confirmed area of radiotracer uptake in right neck, SPECT-CT reported suspicious supraclavicular lymph node | SPECT-CT helped with localization. Without further treatment, neck ultrasound 6 months thereafter was negative. Patient with excellent response to therapy. |
| 33 F             | 1.2 cm PTC, multifocal w/4 foci; no ETE                                   | Planar scintigraphy identified abnormal pelvic uptake suggesting bone metastases | SPECT-CT helped management, clarifying that pelvic uptake was a false-positive finding. No further treatment provided. Patient with excellent response to therapy and no evidence of disease during follow-up. |
| 44 F             | Multifocal PTC, largest 1.5 cm                                            | Planar scintigraphy identified abnormal uptake in the skull                       | SPECT-CT helped management clarifying that skull uptake was false-positive. |
| 49 F             | 1.2 cm FVPTC                                                              | Planar scintigraphy identified liver uptake concerning for liver metastases       | SPECT-CT helped management clarifying that it was false-positive. |

ENE, extra-nodal extension; ETE, extra-thyroidal extension; F, female; FVPTC, follicular variant papillary thyroid carcinoma; HT, Hashimoto’s thyroiditis; LN, lymph node; LVI, lymphovascular invasion; M, male; PTC, papillary thyroid carcinoma; RAI, radioactive iodine treatment; TCVPTC, tall-cell variant papillary thyroid carcinoma; Tg, thyroglobulin.
Separately, a total of 28 of 105 patients (26.7%) in the SPECT-CT cohort were found to have at least one incidental SPECT-CT finding that was non-thyroid-related, as shown in Table 4. All findings led to follow-up recommendations, though none impacted thyroid cancer care.

In total, routine SPECT-CT imaging, in addition to planar scintigraphy led to 3 (2.8%) findings beneficial to thyroid cancer care, 5 (4.8%) findings in which greater precision was provided though did not change management, 28 (26.7%) findings that were incidental, and 3 (2.8%) false-positive findings.

Discussion

The utility and benefits of synergistic SPECT-CT when applied to baseline planar scintigraphy following I-131 therapy have been proposed by many (8, 9, 15, 16), but few data have provided evidence of the broad clinical utility (e.g. risks and benefits) in the real-world setting of thyroid cancer care. Our study provides evaluation of such clinical utility, comparing two consecutive and comparable cohorts differing primarily by the year of their treatment following the institution of routine SPECT-CT imaging from 2015 onward. We confirmed three cases (2.8%) where synergistic SPECT-CT proved beneficial and five (4.8%) where greater precision was obtained. However, SPECT-CT detected 21 non-thyroid-related incidental findings. Together, these data provide insight into the benefits as well as the predicted complexities of implementing such testing into routine practice. These data may allow clinicians to thoughtfully choose which imaging modality if favored in low-risk populations of thyroid cancer patients post-I-131 therapy.

Our data parallels and yet differs from other analyses. In a retrospective analysis of 94 patients with thyroid cancer, Wang reported that SPECT-CT changed the precise localization in 14 of 65 patients with neck uptake, 2 of 31 patients with lung uptake, and 4 of 17 patients with bone uptake. Notable to this article is the extent of advanced disease, as the author also reported that SPECT-CT was not required in 85% of 564 subjects as the whole-body scan was able to determine the extent of local residual disease and metastases in nearly all such patients (18). Similarly, Jeong et al. reported that SPECT-CT provided additional information in only 8.6% of patients with neck uptake using planar scintigraphy (19). Finally, Avram et al. found that pre-ablation SPECT-CT could impact TNM staging (10) as well as initial ATA risk stratification (11). Our data are among the first to investigate the important endpoints of final outcome as well as change in clinical care based on results. Neither were significantly impacted by use of SPECT-CT scanning.

Separate factors associated with SPECT-CT, such as cost and additional radiation exposure, should also be considered in the management of such patients.

Table 4 21 Incidental non-thyroid cancer-related findings reported on SPECT-CT scanning in 28 separate patients following I-131 administration.

| Renal cyst | Mild dilatation of mid to distal appendix | T3 bone island | Atelectasis | Sinusitis | Calcification of aortic valve | Sub-centimeter lung nodule | Nephrolithiasis | Hiatal hernia | Cholelithiasis | Hepatic steatosis | Renal angiomyolipoma | Reactive mediastinal lymph node | Sinus polyp vs cyst | Gynecomastia | Atherosclerosis | Odontogenic disease | Sialoadenitis | Thymic hyperplasia | Emphysema | Congenital rib abnormality |
|-----------|-----------------------------------------|----------------|------------|----------|----------------------------|--------------------------|-----------------|-------------|-------------|----------------|------------------------|-----------------------------|-------------------|----------------|-------------------|----------------|----------------|-------|-------------------|
| **Final outcome** | **No evidence of disease** | **Persistent disease** | **P** |
| Scintigraphy alone | 96 | 11 | 0.07 |
| Scintigraphy plus SPECT-CT | 85 | 20 | |

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considered, especially for an illness where analyses have correlated a high cost of thyroid cancer treatment even without SPECT-CT itself (20, 21). The cancer-related financial burden has been reported to be associated with lower quality of life and even increased mortality (22, 23, 24, 25). Notably, in a large study of nearly 500,000 patients with thyroid cancer, psychological financial burden experienced by patients appears greater than for other types of cancers (12). Thus, for many patients with low-risk diseases, it may be reasonable and cost-effective to avoid further intervention or advanced imaging.

We acknowledge several limitations to this study. First, we note that this is a retrospective cohort assessment. However, the two cohorts nonetheless appear logically separated by time as SPECT-CT was implemented. We separately acknowledge that the use of I-131 for thyroid cancer during this decade trended toward application to higher-risk disease. Thus, outside the setting of a randomized controlled trial, precise comparisons between cohorts cannot be assumed based on extent of disease. Nonetheless, AJCC staging was not significantly different between the two cohorts in our study.

In conclusion, performing routine post-therapy SPECT-CT scanning in conjunction with planar nuclear scintigraphy offers some benefit, yet also significant burden of incidental findings, in a typical cohort of thyroid cancer patients with low risk of distant metastases receiving radioactive iodine therapy. SPECT-CT imaging led to some additional findings that were beneficial to thyroid cancer care while also detecting a significant proportion of false and incidental findings usually not impacting an individual’s thyroid cancer care.

Declaration of interest
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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Statement of ethics
This investigation was evaluated and approved by the Mass General Brigham Investigational Review Board.

Author contribution statement
All authors listed in this manuscript contributed to the design of the work and the acquisition and interpretation of data for the work. They all reviewed the manuscript, helped with revision and approved the final version to be published. All authors agree to be accountable of the work. Sara Ahmadi MD and Erik Alexander contributed to data collection and analysis.

References

1. Morris LG, Tuttle RM & Davies L. Changing trends in the incidence of thyroid cancer in the United States. JAMA Otolaryngology: Head and Neck Surgery 2016 142 709–711. (https://doi.org/10.1001/jamaoto.2016.0230)
2. Matsuoka K, Sugino K, Masudo K, Nagahama M, Kitagawa W, Shibuya H, Ohkuwa K, Urano T, Suzuki A, Magoshi S, et al. Thyroid lobectomy for papillary thyroid cancer: long-term follow-up study of 1088 cases. World Journal of Surgery 2014 38 68–79. (https://doi.org/10.1007/s00268-013-2224-1)
3. Nixon JJ, Ganly I, Patel SG, Palmer FL, Whiticher MM, Tuttle RM, Shah A & Shah JP. Thyroid lobectomy for treatment of well differentiated intrathyroid malignancy. Surgery 2012 151 S71–S79. (https://doi.org/10.1016/j.surg.2011.08.016)
4. Jonklaas J, Cooper DS, Ain KB, Bigos T, Brierley JD, Haugen BR, Ladenson PW, Magner J, Ross DS, Skarulis MC, et al. Radioiodine therapy in patients with stage I differentiated thyroid cancer. Thyroid 2010 20 1423–1424. (https://doi.org/10.1089/thy.2010.0308)
5. Sacks W, Fung CH, Chang JT, Waxman A & Braunstein GD. The effectiveness of radioactive iodine for treatment of low-risk thyroid cancer: a systematic analysis of the peer-reviewed literature from 1966 to April 2008. Thyroid 2010 20 1235–1245. (https://doi.org/10.1089/thy.2009.0455)
6. Lamartina L, Durante C, Filetti S & Cooper DS. Low-risk differentiated thyroid cancer and radioiodine remnant ablation: a systematic review of the literature. Journal of Clinical Endocrinology and Metabolism 2015 100 1748–1761. (https://doi.org/10.1210/jc.2014-3882)
7. Haugen BR, Alexander EK, Bible KC, Doherty GM, Mandel SJ, Nikiforov YE, Pacini F, Randolph GW, Sawka AM, Schlumberger M, et al. 2015 American Thyroid Association management guidelines for adult patients with thyroid nodules and differentiated thyroid cancer: the American Thyroid Association guidelines task force on thyroid nodules and differentiated thyroid cancer. Thyroid 2016 26 1–133. (https://doi.org/10.1089/thy.2015.0020)
8. Schmidt D, Szikszai A, Unke R, Bautz W & Kuerer T. Impact of 131I SPECT/spiral CT on nodal staging of differentiated thyroid carcinoma at the first radioablation. Journal of Nuclear Medicine 2009 50 18–23. (https://doi.org/10.2967/jnumed.10.052746)
9. Spanu A, Solinas ME, Chessa F, Sanna D, Nuvoli S & Madeddu G. 131I SPECT/CT in the follow-up of differentiated thyroid carcinoma: incremental value versus planar imaging. Journal of Nuclear Medicine 2009 50 184–190. (https://doi.org/10.2967/jnumed.10.056572)
10. Avram AM, Fig LM, Frey KA, Gross MD & Wong KK. Preablation 131-I scans with SPECT/CT in postoperative thyroid cancer patients: what is the impact on staging? Journal of Clinical Endocrinology and Metabolism 2013 98 1163–1171. (https://doi.org/10.1210/jc.2012-3630)
11. Avram AM, Esfandiari NH & Wong KK. Preablation 131-I scans with SPECT/CT contribute to thyroid cancer risk stratification and 131-I therapy planning. Journal of Clinical Endocrinology and Metabolism 2015 100 1895–1902. (https://doi.org/10.1210/jc.2014-4043)
12. Barrows CE, Belle JM, Fleishman A, Lubitz CC & James BC. Financial burden of thyroid cancer in the United States: an estimate of economic and psychological hardship among thyroid cancer survivors. Surgery 2020 167 378–384. (https://doi.org/10.1016/j.surg.2019.09.010)
13. Angell TE, Maurer R, Wang Z, Kim MI, Alexander CA, Barletta JA, Benson CB, Cibas ES, Cho NL, Doherty GM, et al. A cohort analysis of clinical and ultrasound variables predicting cancer risk in 20,001 consecutive thyroid nodules. Journal of Clinical Endocrinology and Metabolism 2019 104 5665–5672. (https://doi.org/10.1210/jc.2019-00664)
14. Cooper DS, Doherty GM, Haugen BR, Kloos RT, Lee SL, Mandel SJ, Mazzaferri EL, McIver B, Pacini F, Schlumberger M, et al. Revised American Thyroid Association management guidelines for patients with thyroid nodules and differentiated thyroid cancer: Thyroid 2009 19 1167–1214. (https://doi.org/10.1089/thy.2009.0110)

https://ec.bioscientifica.com
https://doi.org/10.1530/EC-21-0371

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15 Malamitsi JV, Koutsikos JT, Giourgouli SI, Zachaki SE, Pipikos TA, Vlachou FJ & Prassopoulos VK. I-131 postablation SPECT/CT predicts relapse of papillary thyroid carcinoma more accurately than whole body scan. *In Vivo* 2019 **33** 2255–2263. (https://doi.org/10.21873/invivo.11731)

16 Zilioli V, Peli A, Panarotto MB, Magri G, Alkraisheh A, Wiefels C, Rodella C & Giubbini R. Differentiated thyroid carcinoma: incremental diagnostic value of (131)I SPECT/CT over planar whole body scan after radioiodine therapy. *Endocrine* 2017 **56** 551–559. (https://doi.org/10.1007/s12020-016-1086-3)

17 Wang H, Fu HL, Li JN, Zou RJ, Gu ZH & Wu JC. The role of single-photon emission computed tomography/computed tomography for precise localization of metastases in patients with differentiated thyroid cancer. *Clinical Imaging* 2009 **33** 49–54. (https://doi.org/10.1016/j.clinimag.2008.06.024)

18 Garger YB, Winfeld M, Friedman K & Blum M. In thyroidectomized thyroid cancer patients, false-positive I-131 whole body scans are often caused by inflammation rather than thyroid cancer. *Journal of Investigative Medicine High Impact Case Reports* 2016 **4** 2324709661633715. (https://doi.org/10.1177/2324709661633715)

19 Jeong SY, Lee SW, Kim HW, Song BI, Ahn BC & Lee J. Clinical applications of SPECT/CT after first I-131 ablation in patients with differentiated thyroid cancer. *Clinical Endocrinology* 2014 **81** 445–451. (https://doi.org/10.1111/cen.12460)

20 Boltz MM, Hollenbeak CS, Schaefer E, Goldenberg D & Saunders BD. Attributable costs of differentiated thyroid cancer in the elderly medicare population. *Surgery* 2013 **154** 1363–1369; discussion 9–70. (https://doi.org/10.1016/j.surg.2013.06.042)

21 Wang LY, Roman BR, Migliacci JC, Palmer FL, Tuttle RM, Shaha AR, Shah J; Patel SG & Ganly I. Cost-effectiveness analysis of papillary thyroid cancer surveillance. *Cancer* 2015 **121** 4132–4140. (https://doi.org/10.1002/cncr.29631)

22 Kale HP & Carroll NV. Self-reported financial burden of cancer care and its effect on physical and mental health-related quality of life among US cancer survivors. *Cancer* 2016 **122** 283–289. (https://doi.org/10.1002/cncr.29808)

23 Altice CK, Banegas MJ, Tucker-Seeley RD & Yabroff KR. Financial hardships experienced by cancer survivors: a systematic review. *Journal of the National Cancer Institute* 2017 **109** djw205. (https://doi.org/10.1093/jnci/djw205)

24 Ramsey SD, Bansal A, Fedorensko CR, Blough DK, Overstreet KA, Shankaran V & Newcomb P. Financial insolvency as a risk factor for early mortality among patients with cancer. *Journal of Clinical Oncology* 2016 **34** 980–986. (https://doi.org/10.1200/JCO.2015.64.6620)

25 Fenn KM, Evans SB, McCorkle R, DiGianna MW, Pusztai L, Sanft T, Hofstatter EW, Killelea BK, Knobf MT, Lannin DR, et al. Impact of financial burden of cancer on survivors’ quality of life. *Journal of Oncology Practice* 2014 **10** 332–338. (https://doi.org/10.1200/JOP.2013.001322)

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