CLINICAL STUDY

Sodium–iodide symporter (NIS) gene expression in lymph-node metastases of papillary thyroid carcinomas

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Abstract

Objective: To investigate the molecular mechanisms underlying the influence of alteration of iodine trapping on the prognosis of metastatic papillary thyroid carcinomas, focusing on the expression of the Na\(^+\)/I\(^-\) symporter (NIS).

Design: We evaluated the expression of the NIS gene in a series of 11 enlarged neck lymph-node metastases of papillary thyroid carcinomas, including four patients in whom an enlarged lymph node represented the first sign of the tumoral disease. Nine lymph nodes, either reactive or metastatic for non-thyroid tumors, were also investigated.

Methods: Expression of the NIS gene was evaluated by RT-PCR in material obtained by fine-needle aspiration biopsy.

Results: The NIS gene was expressed in eight (73%) of 11 differentiated thyroid cancer metastatic lymph nodes examined. Five of these metastatic lymph nodes were positive at the post-treatment total-body iodine-131 scan; in the other three, the total-body scan showed no uptake in the metastatic tissues, indicating an alteration downstream to the NIS mRNA synthesis causing the loss of iodide uptake. As expected, when the NIS mRNA expression was absent, total-body 131I scan showed no uptake in the metastatic lymph nodes.

Conclusions: Our study demonstrates that NIS gene expression may be absent in metastatic differentiated thyroid carcinomas and that different mechanisms, other than loss of NIS transcription, may also be involved in the loss of iodide uptake in metastatic thyroid cells. Study of NIS gene expression in the metastatic lymph nodes, therefore, may provide useful information in the management of patients with thyroid carcinoma.
slices, as assessed by immunohistochemistry (9, 14). In contrast, no data are available about the presence of the NIS transcript in thyroid tumor metastases.

In the present study, we analyzed the expression of the NIS gene in a series of enlarged neck lymph-node metastases of papillary thyroid carcinomas. It is noteworthy that, in four patients of our series, the enlarged cervical lymph node represented the first sign of disease, so that the evaluation of NIS mRNA expression was not affected by the pharmacological suppression of TSH concentrations.

Patients and methods

Patients

Twenty enlarged cervical lymph nodes were investigated: seven patients were in follow-up for papillary thyroid carcinomas, 13 patients had one single enlarged node of unknown origin. All patients underwent fine-needle aspiration biopsy under ultrasound guidance; an aspirate aliquot was smeared for cytological examination and another was frozen for subsequent PCR (15). Histopathological diagnosis in multiple sections of excised lymph nodes was assumed to reflect a correct diagnosis. On histological examination, the 20 lymph nodes examined yielded diagnoses of 11 papillary thyroid carcinomas and nine enlarged lymph nodes, either reactive or metastatic from non-thyroid tumors. Therefore, in four of 11 papillary thyroid carcinoma metastases the enlarged cervical lymph nodes represented the first clinical sign of a differentiated thyroid cancer (Table 1).

RNA extraction and RT-PCR

Messenger RNA was extracted from the biopsy material with an mRNA Puriﬁcation Kit (Amersham Pharmacia Biotech, Milan, Italy) following the manufacturer’s instructions, as previously described (16). cDNA was synthesized according to the procedure of the manufacturer (Roche Diagnostics SpA, Monza, Italy). The mixture was incubated at 25°C for 10 min, at 42°C for 60 min, heated to 99°C for 5 min, and then stored at –20°C. PCR amplification was performed using 5 μl cDNA (of 20 μl mixture), as previously reported (16). Briefly, samples were subjected to 40 cycles of amplification and PCR conditions for the NIS gene were as follows: denaturation at 94°C for 1 min, annealing at 62°C for 1 min and extension at 72°C for 1 min. The last cycle was 72°C for 7 min (one cycle). Ten microliters of the 50 μl of the amplification products were then run on 1.5% Tris–borate–EDTA (TBE) agarose gel containing ethidium bromide, and analyzed to confirm a positive or negative outcome.

Primers oligonucleotides for the NIS gene were: 5’ primer, 5’-TCTCTCGAGATCGCTCT-3’ and 3’ primer, 5’-ATCCAGATGCACTCCTT-3’. The amplification yielded a 299 base pair DNA product corresponding to fragment 1801–2099 according to the published sequence of the NIS gene (6).

Expression of the transcripts of thyrotropin receptor (TSH-R), thyroglobulin (Tg) and glyceraldehyde-3-phosphate dehydrogenase (GAPDH), a control gene ubiquitously expressed, was also analysed, as previously described (16).

The primers for the NIS, Tg and the TSH-R genes spanned exon–intron junctions of the genes, to exclude possibility of genomic DNA contamination. All primers were from Life-Technologies (Milan, Italy).

In the negative samples, we performed a radiolabeled PCR by adding 1 μl α-32P-dNTP (3000 Ci/mm, Amersham Pharmacia Biotech) to the PCR mixture. The samples were then subjected to 40 cycles of amplification, using the same conditions previously described, and 10 μl of the 50 μl of PCR products were run on 10% TBE polyacrylamide electrophoresis gel (BioRad Laboratories Srl, Milan, Italy). The gel was dried

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex/age (yr)</th>
<th>Age at diagnosis (yr)</th>
<th>Tumor diameter (mm)</th>
<th>Lymph-node metastases</th>
<th>NIS gene expression</th>
<th>131I Uptake</th>
<th>Thyroglobulin serum concns† (ng/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/73</td>
<td>71</td>
<td>22 × 15</td>
<td>Recurrent right</td>
<td>+</td>
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<td>18</td>
</tr>
<tr>
<td>2</td>
<td>F/31</td>
<td>30</td>
<td>18 × 24</td>
<td>Lower right jugular</td>
<td>+</td>
<td>Positive</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>F/49</td>
<td>47</td>
<td>19 × 15</td>
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<td>–</td>
<td>Negative</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>M/38</td>
<td>35</td>
<td>32 × 23</td>
<td>Lower left spinal accessory</td>
<td>+</td>
<td>Negative</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>F/58</td>
<td>54</td>
<td>17 × 15</td>
<td>Lower right jugular</td>
<td>+</td>
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<td>35</td>
</tr>
<tr>
<td>6</td>
<td>M/77</td>
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<td>43</td>
<td>15 × 10</td>
<td>Paratracheal right</td>
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<td>NA</td>
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<td>8*</td>
<td>M/21</td>
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<td>12 × 9</td>
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<td>+</td>
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<tr>
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<td>F/18</td>
<td>18</td>
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<td>+</td>
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<td>NA</td>
</tr>
<tr>
<td>10*</td>
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<td>29</td>
<td>21 × 18</td>
<td>Lower right spinal accessory</td>
<td>–</td>
<td>Negative</td>
<td>NA</td>
</tr>
<tr>
<td>11</td>
<td>F/44</td>
<td>42</td>
<td>26 × 20</td>
<td>Upper left jugular</td>
<td>+</td>
<td>Positive</td>
<td>NA</td>
</tr>
</tbody>
</table>

* In these four patients the lymph-node metastasis represented the first clinical sign of papillary thyroid carcinomas; at the time of biopsy sampling, the thyroid was present and the serum thyrotropin was in normal range. † Serum thyroglobulin measured at the time of 131I total-body scan after 6 weeks of thyroid hormone withdrawal (normal value <1 ng/ml). NA, not available.

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at 60 °C and subsequently exposed to radiographic film to confirm a positive or negative outcome.

**Results**

All the tumoral specimens presented the GAPDH transcript, indicating the integrity of the mRNA and the cDNA (data not shown).

The NIS gene was expressed in eight (73%) of 11 differentiated thyroid cancer metastatic lymph nodes examined (Fig. 1). Five of eight metastatic lymph nodes positive for NIS mRNA expression were also positive at the post-treatment total-body iodine-131 scan (Nos 1, 2, 6, 8 and 11; Table 1); in the other three, the total-body scan showed no uptake in the metastatic tissues (Nos 4, 5 and 9; Table 1). Three of 11 (27%) thyroid cancer metastatic tissues did not express the NIS transcript (Fig. 1). To exclude the presence of false-negative results, we performed a radiolabeled PCR (see Methods), a more sensitive method for detection of the mRNA expression, which confirmed the results obtained with non-radiolabeled PCR (data not shown). In these three patients, the total-body scan showed no uptake in the metastatic lymph nodes (Nos 3, 7 and 10; Table 1). The expression of NIS mRNA was also examined in two of the three primary thyroid carcinomas in which the metastatic tissue was negative for expression of the NIS transcript (Nos 3 and 10; Table 1); in both we found expression of the NIS transcript. In the other patient (No. 7) a micro (occult) carcinoma was found at pathological examination and no tissue specimen was available for genetic examination.

All samples from differentiated thyroid carcinoma metastases were positive for Tg and TSH-R transcripts (data not shown). In contrast, the nine reactive and non-thyroid metastatic lymph nodes did not express any of the thyroid-specific genes examined (data not shown).

**Discussion**

Use of radiiodine is the most powerful tool in the management of differentiated thyroid carcinomas, for both diagnostic and therapeutical purposes, in either primary or metastatic disease. Indeed, differentiated thyroid carcinomas generally retain many of the differentiated features of normal thyroid cells, including the ability to concentrate iodine. However, impairment of iodine metabolism, together with variable degrees of reduction in thyroid-specific transcripts, have frequently been observed in neoplastic thyroid tissues (12, 17). Thirty-five to sixty percent of differentiated thyroid carcinoma metastases do not take up 131I (18, 19) and in some patients with increased serum Tg concentrations, total-body iodine-131 scan, even when performed with a high dose of radiiodine, is also negative (20), necessitating the use of alternative tools of detection, such as octreoscan, positron emission tomography scan or conventional imaging modalities, but with a poorer prognosis for the patient (2, 3).

Several studies have investigated the levels of NIS mRNA in thyroid tumors, showing a reduction or loss of NIS gene expression in most differentiated thyroid carcinomas (6–12); only in one study has an increased expression of the NIS gene in papillary thyroid carcinomas been demonstrated (13).

In a previous study, using a non-quantitative detection system, we found loss of NIS mRNA in thyroid tumors, showing a reduction or loss of NIS gene expression in most differentiated thyroid carcinomas (6–12); only in one study has an increased expression of the NIS gene in papillary thyroid carcinomas been demonstrated (13).

In a further study, using a quantitative PCR method, NIS gene expression was found to be
decreased in 40 of 43 thyroid carcinomas and more advanced tumor stages were associated with lower expression of the NIS gene (12).

In the present study, we examined the expression of the NIS mRNA in a series of 11 enlarged neck lymph-node metastases of papillary thyroid carcinomas, including four patients in whom the enlarged lymph node represented the first sign of the tumoral disease. We found loss of NIS transcript expression in three of 11 thyroid lymph-node metastases examined. The absence of NIS expression correlated with a negative total-body iodine-131 scan. Also, we examined the expression of NIS mRNA in two of the three patients with primary thyroid carcinomas whose metastatic tissue was negative for NIS transcript expression and, in both, we found the presence of NIS transcript. This observation confirms our previous finding (8) that loss of NIS gene expression in metastatic tumors may be the result of a dedifferentiation process occurring during the development of metastasis.

In contrast, three patients were negative on 131I scan, even though the NIS transcript was expressed in the metastatic tissue. Thyroglobulin concentrations at the time of the 131I total-body scan was increased in all metastatic tissue. Thyroglobulin concentrations were negative for NIS even though the NIS mRNA was collected for examination. Our data show that, even in the absence of suppressive therapy, the expression of TSH-dependent transcripts is the current gold standard for the diagnosis of differentiated thyroid carcinoma (18). However, the expression of TSH-dependent transcripts in metastatic tumors may be the result of a dedifferentiation process occurring during the development of metastasis.

In conclusion, as the iodide symporter system plays a critical role in thyroid tumorigenesis, analysis of the expression of its mRNA may offer useful information for the management of and the therapeutic approach to patients with differentiated thyroid carcinoma, especially in the presence of metastases.

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