Clinical Study

The analysis of quantitative expression of somatostatin and dopamine receptors in gastro-entero-pancreatic tumours opens new therapeutic strategies

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Abstract

Objective: Somatostatin (sst) are present in the majority of gastro-entero-pancreatic (GEP) tumours. Effects of somatostatin receptor (sst) analogues are partial and of limited duration. Cell lines derived from GEP express dopaminergic receptors D2. New chimeric analogues simultaneously recognising sst2 and sst5 or sst2 and D2 have additive effects in inhibition of GH and prolactin secretion in pituitary adenomas. Our aim was to quantify the expression of sst and D2 mRNA in human GEP tumours.

Design and methods: mRNA expression of sst1, sst2, sst3 and sst5 as well as D2, was analysed using real-time PCR (TaqMan probe) in a series of 35 patients with GEP tumours (pancreas (n = 19) and intestinal (n = 16)). Levels of expression were compared with a group of 13 somatotroph adenomas.

Results: All GEP tumours express sst1, sst2 and D2. Expression of sst3 and sst5 was observed in 89 and 76% of tumours respectively with highly variable levels. sst2 mRNA expression was higher in non-functional tumours (P < 0.009) and sst5 was higher in pancreatic than in intestinal tumours (P < 0.02). Whereas sst2 levels were similar between GEP and somatotroph tumours, levels of sst3 and D2 were higher in the former (394.9 ± 156.1 × 10⁻² vs 69.7 ± 19.5 × 10⁻² copy/copy β-Gus (P < 0.0036) and 519.6 ± 121.2 × 10⁻² vs 50.0 ± 21.6 × 10⁻² copy/copy β-Gus (P < 0.0001) respectively). In small tumours (< 30 mm), sst2 density appeared as a crucial parameter in somatostatin receptor scintigraphy results, whereas in big tumours, a consistent bias in SRS results was introduced by the size. In pancreatic GEP, high-level sst2 expression was found in tumours with more active angiogenesis (higher microvessel density and vascular endothelial growth factor expression (P < 0.03)).

Conclusions: GEP tumours co-express sst2 and D2 in 100% of cases and sst5 in 89% thus supporting the testing of bi-specific agonists (sst2/sst5 or sst2/D2) in these tumours.

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Introduction

Somatostatin receptor (sst) subtype status has been characterised using various techniques in gastro-entero-pancreatic (GEP) tumours, however, results are heterogeneous and depend on tumour types (1–4). Relatively, few data are available concerning semi-quantitative sst expression from studies using densitometry from autoradiography, immunohistochemistry and RT-PCR analysis (3, 5, 6). Differential expression of sst subtypes, but especially sst3, appears important in predicting results of somatostatin receptor scintigraphy (SRS) and therapeutic response to cold somatostatin analogues (7–13). A good correlation has been found to exist between RT-PCR and immunohistochemistry in GEP tumours indicating that the former method may indeed be sufficiently accurate in detecting sst subtypes (5). Real-time PCR adds a quantitative dimension to receptor mRNA detection.

Therapy using standard somatostatin analogues (either daily octreotide or slow-release depot preparations; Octreotide LAR and SR-Lanreotide, sst2 agonist) in patients with functional GEP is not universally efficacious and the effects of treatment wane with time (14). Ligands with enhanced receptor binding or those recognising several receptor subtypes may improve clinical outcome and perhaps offer an effective anti-tumoural benefit. BIM-23244, a somatostatin receptor subtypes 2 and 5...
selective analogue was found to have enhanced efficacy in suppressing growth hormone from octreotide-resistant human growth hormone-secreting pituitary adenomas (15). Recently, a multivalent ligand, SOM230, capable of binding to sst1, sst2, sst3 and sst5, has been developed with promising results in treatment of patients with acromegaly (16, 17) and trials are on-going in patients with symptomatic GEP tumours resistant to standard somatostatin analogue therapy. Better knowledge of sst receptor status in these patients may allow for a tailored approach using such compounds and indeed, quantitative receptor expression may correlate with clinical outcome. A further interesting concept stemmed from combined receptor targeting as demonstrated by the enhanced potency of a chimeric somatostatin–dopamine molecule, BIM-23A387, in suppressing growth hormone and prolactin secretion from human pituitary somatotroph adenoma cells in vitro (18, 19). Here, the chimeric compound was far more potent than standard somatostatin or dopamine analogues alone (18). Although D2 receptors (D2) have been found in the neuroendocrine tumour cell lines, SCAT and BON-1 (20), no data are available in patients with GEP tumours.

The purpose of this study was to quantify sst and D2 receptors mRNA using real-time PCR in a group of patients with GEP tumours originating from the pancreas and small intestine with detailed clinical data available for comparative analysis. The results were compared with a group of patients with somatotroph adenomas.

Subjects and methods

The study was carried out in 35 patients with GEP tumours (19 men and 16 women), aged 51 ± 14.7 years. The present study was approved by the ethics committee of the university and was undertaken after informed consent was obtained from each patient and all participants. The analysis involved only the primary tumour, which had been surgically resected and detailed clinical and pathological characteristics were available in all patients. After surgery, a portion of each tumour tissue was analysed in terms of the quantitative expression of mRNA for the D2 and for sst1, sst2, sst3 and sst5 receptor subtypes. The primary tumour location included: pancreas (n = 19) and intestine (n = 16): ileum: 13; jejunum, 2 and duodenum, 1. The following tumour characteristics were recorded: size (largest perpendicular diameter), functional status (presence or absence of symptoms from hormonal overproduction), SRS results, histological differentiation and WHO status (21). General clinical and tumour characteristics of patients are summarised in Table 1.

Quantitative expression of mRNA for receptors targeted by actual somatostatin and dopamine agonists (sst2 and sst5 and D2) were compared in patients with GEP tumours to a group of 13 patients with somatotroph adenomas, characterised by immunocytochemistry.

VEGF and microvascular density estimation

The vascular endothelial growth factor (VEGF) protein was detected by the murine MAB VG1 (22) in pancreatic tumours using a methodology described recently (23) PBS was substituted for primary antibody as the negative control. Positive controls consisted of serum in blood vessels and of islets (detected with strong intensity) in non-tumoural pancreas (adjacent to the tumours). All sections were performed in the same run. The specimens were scanned at a low optical power (×40) to study the tissue distribution of staining and at a high optical power (×250) to study the cellular staining patterns. The percentage of cells with positive reactivity was scored. A cytoplasmic score was calculated by multiplication of the percentage of cytoplasmic-stained cells by their staining intensity (negative scored as 0, weak scored as 1, moderate scored as 2 and strong scored as 3) (23) Microvessel counting was also only available for pancreatic tumours.

Table 1 Patient’s and tumour characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Pancreatic</th>
<th>Intestinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of cases</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Gender, male/female</td>
<td>10/9</td>
<td>9/7</td>
</tr>
<tr>
<td>Age, median years</td>
<td>49</td>
<td>59</td>
</tr>
<tr>
<td>Tumour size, mean (range) (mm)</td>
<td>45.9 (9–160)</td>
<td>30 (10–60)</td>
</tr>
<tr>
<td>Tumour location</td>
<td>Body/tail: 11 head: 8</td>
<td>Ileum: 13 Jejunum: 2 Duodenum: 1</td>
</tr>
<tr>
<td>Functional status</td>
<td>Glucagon (2), VIP (1), gastrin (1), non-functional (15)</td>
<td>Serotonin-secreting (13), gastrin (1), non-functional (2)</td>
</tr>
<tr>
<td>Histology classification (WHO) (21)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Well-differentiated tumour</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Well-differentiated tumour of ‘uncertain’ behaviour</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Poorly differentiated carcinoma</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>SRS (Octreoscan)</td>
<td>Positive: 13, negative: 6</td>
<td>Positive: 14, negative: 1, not done: 1</td>
</tr>
</tbody>
</table>

VIP, vasoactive intestinal peptide.
and was performed on ×200 fields (area of a ×200 field: 0.442/mm²) after CD34 staining. Two areas of high vascularisation were chosen for microvessel counting at a low optical power (×40). The final microvessel density (MVD) was the mean value of 3 appraised fields in each area (total area: 2.65/mm²). Vessels with a clearly defined lumen or well-defined linear vessel shape were taken into consideration for counting. In addition, the cellular proliferation index, Ki-67 (%), was calculated using a murine monoclonal MIB-1 antibody (DAKO, Trappes, France) as described previously (23).

Detection of somatostatin receptor and D2 mRNAs

Total RNA was extracted from 30 to 60 mg tissue from each tumour using the RNAeasy isolation system (QIAGEN). Tissue sampling was carefully evaluated at microscopy to ensure that sampling was from tumoural tissue and not from adjacent tissues. One microgram of total RNA prepared from tumoural tissues was used for cDNA synthesis with 200 U Superscript II reverse transcriptase (Life Technologies, Inc.) primed with 300 ng random primer (18).

The 5’ exonuclease (TaqMan) assay, which produces a direct proportional readout for the progression of PCR, was used. Amplification of cDNA derived from 50 to 150 ng total RNA was performed in a 25 µl reaction volume with 300 nM of each primer, 200 nM probe and 12.5 µl MasterMix (PE Applied Biosystems, Paris, France). The synthetic sst1, sst2, sst3, sst5 and D2 primers and TaqMan probes used in the PCR were described previously (18, 24) and were follows (forward (F), reverse (R) primers and probe (P)):


Forty cycles of two-step PCR- annealing extension were performed on an ABI Prism 7700 sequence detection apparatus (PE Applied Biosystems, Paris, France). The sst and D2 mRNA levels were normalised to the β-Gus mRNA levels obtained in the same reaction. The β-Gus primers and probe were purchased from PE Applied Biosystems (18). For each measurement, three independent RT-PCR analyses were performed. To produce standard curves for sst, D2 and β-Gus mRNA, cDNA constructs were produced for each parameter and verified by sequencing. The results were expressed as copy of sst or D2/copy of β-Gus.

Statistical analysis

The results are presented as the mean ± S.E.M. Statistical significance between two unpaired groups was determined by the Mann–Whitney U test. A P value less than 0.05 was considered significant for all tests.

Results

sst and D2 mRNA expression in GEP tumours

All GEP tumours had constant but variable expression of sst1, sst2 and D2 (Fig. 1; Table 2). Somatostatin receptor subtypes sst3 and sst5 were expressed in 76 and 89% of GEP tumours respectively (Table 2). mRNA level expression of sst5 was higher in pancreatic than in intestinal tumours (P < 0.02); mRNA level expression of sst2 was also higher in pancreatic than in intestinal GEP; however, this did not achieve statistical significance (Table 2; Fig. 2).

The level of mRNA sst2 expression was significantly higher in patients with non-functional tumours (n = 19) compared with functional tumours (n = 16, 91.7 ± 37.4 × 10⁻² vs 39.9 ± 19.7 × 10⁻² copy/copy β-Gus, P < 0.009).

Comparison with somatotroph adenomas

Somatostatin receptor subtypes sst2, sst5 and D2 mRNA levels were compared with a group of 13 somatotroph adenomas (Fig. 3). Levels of sst5 and D2 mRNA were significantly higher in pituitary adenomas compared with GEP tumours (P < 0.0036 and P < 0.0001 respectively), whereas sst2 mRNA levels were similar. Levels of sst5 and D2 mRNA were in the range of those observed in somatotroph adenomas in 43 and 17% of GEP tumours respectively.

Figure 1 sst, sst2, sst3, sst5 and D2 mRNA levels in 35 GEP tumours (19 pancreatic and 16 intestinal). The quantification was performed by real-time PCR. Measurements were reported to the level of β-Gus.
**sst expression compared with tumour stage and SRS status**

Level of mRNA for sst2 and sst3 was significantly higher in WHO stages 1–2 compared with stage 3 (115 ± 48 × 10^{-2} vs 60 ± 22 × 10^{-2}, P < 0.03) and 17 ± 7 × 10^{-2} vs 4 ± 2.4 × 10^{-2}, (P < 0.00673) copy/copy β-Gus respectively). However, as the majority of intestinal tumours tested were stage 3, this analysis may be biased by the tumour type. These differences were not apparent when pancreatic tumours were considered alone (n = 8, 115 ± 48 × 10^{-2} vs n = 9, 91 ± 43 × 10^{-2} copy/copy β-Gus) thus confirming that these effects may be attributable to tumour type alone.

mRNA levels of sst2 and sst3 were also compared with SRS results (available in 34 patients). Table 1: sst2 levels were higher in SRS-positive (n = 27) than in SRS-negative (n = 7) tumours (87.1 ± 26.3 × 10^{-2} and 28.4 ± 10.6 × 10^{-2} copy/copy β-Gus) without achieving statistical significance. However, when small tumours were considered (< 30 mm; n = 16) receptor density clearly influenced SRS results: ten SRS-positive patients had a mean sst2 density of 128.3 ± 48.6 × 10^{-2} vs 31.2 ± 12.1 × 10^{-2} copy/copy β-Gus (P < 0.05) in six SRS-negative tumours (Fig. 4). Expression of other receptor subtypes had no influence on SRS results, in fact, mean sst3 receptor levels were higher in SRS-negative than in SRS-positive tumours (109.9 ± 65.9 × 10^{-2} vs 59.4 ± 19.0 × 10^{-2} copy/copy β-Gus) however, not statistically significant.

**sst and D2 expression compared with vascular markers and Ki-67 in pancreatic tumours**

sst2 and D2 were then analysed with respect to vascular markers, MVD and VEGF, in pancreatic tumours (Table 3). The MVD ranged from 80 to 674 vessels/mm² (329 ± 44). The VEGF score ranged from 0 to 180 (58.4 ± 14.3). No correlations were found between MVD and VEGF in relation to sst1, sst2, sst3 and D2 receptors. When pancreatic tumours were classified into two groups expressing high-level sst3 (n = 7, 24 ± 5 × 10^{-2} copy/copy β-Gus) and tumours not expressing or expressing low-level sst3 (n = 12, 0.6 ± 0.3 × 10^{-2} copy/copy β-Gus), MVD and VEGF expression were significantly higher in the high-level sst3 group (428 ± 70 vs 236 ± 41 vessels/mm² and 94 ± 25.8 vs 24.5 ± 7.4 respectively, P < 0.03; Fig. 5), although general low sst3 expression.

When tumours were classified into two groups according to the Ki-67 level above 3% (n = 9, 7.2 ± 0.6) or below 3% (n = 8, 2.6 ± 0.3), sst5 levels were found to be higher in first group compared with the second group (25 ± 11.8 × 10^{-2} vs 206 ± 62 × 10^{-2} copy/copy β-Gus, P < 0.005; Fig. 6).

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**Table 2** Expression levels of sst1, sst2, sst3, sst5 and D2 in GEP tumours and in pituitary adenomas.

<table>
<thead>
<tr>
<th>Receptor subtype</th>
<th>Pancreatic</th>
<th>Mid gut</th>
<th>GEP</th>
<th>Somatotroph adenomas (n=13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sst1</td>
<td>6.6 ± 2.5 (100%)</td>
<td>7.3 ± 1.1 (100%)</td>
<td>7.0 ± 1.4 (100%)</td>
<td>ND</td>
</tr>
<tr>
<td>sst2</td>
<td>102.4 ± 33.8 (100%)</td>
<td>39 ± 18.7 (100%)</td>
<td>73.8 ± 20.7 (100%)</td>
<td>115.9 ± 32.0 (100%)</td>
</tr>
<tr>
<td>sst3</td>
<td>11.1 ± 3.6 (84%)</td>
<td>1.2 ± 0.1 (63%)</td>
<td>6.8 ± 2.3 (76%)</td>
<td>ND</td>
</tr>
<tr>
<td>sst5</td>
<td>128.5 ± 39.8 (79%)</td>
<td>31.8 ± 9.6 (100%)</td>
<td>69.7 ± 19.5 (89%)</td>
<td>394.9 ± 156.1 (100%)</td>
</tr>
<tr>
<td>D2</td>
<td>65.9 ± 37.8 (100%)</td>
<td>31 ± 14.7 (100%)</td>
<td>50.0 ± 21.6 (100%)</td>
<td>519.6 ± 121.2 (100%)</td>
</tr>
</tbody>
</table>

The percentages of tumours expressing a subtype receptor are indicated in parenthesis. ND, not done.

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**Figure 2** Comparison of mRNA expression levels of sst2, sst3 and D2 mRNA between 19 pancreatic and 16 intestinal tumours. The quantification was performed by real-time PCR. Measurements were reported to the level of β-Gus. *P < 0.02.

**Figure 3** Comparison of mRNA expression level of sst2, sst3 and D2 mRNA between 35 GEP tumours and 13 somatotroph adenomas (GH). Quantification was performed by real-time PCR. Measurements were reported to the level of β-Gus. *P < 0.0036; †P < 0.0001.
Discussion

Somatostatin analogues are widely used in the treatment of GEP tumours and SRS is a useful tool in diagnosis. The general use of SRIF agonists is justified by the presence in these tumours of SRIF receptors detected by qualitative mRNA and protein methods. For the first time, using real-time PCR, we systematically quantified not only sst subtypes but also D2 mRNA, in a large series of human GEP tumours. All GEP tumours expressed sst1, sst2 and D2 while only 76 and 89% of tumours expressed sst3 and sst5 respectively. These results are close to those of Papotti et al using semi-quantitative PCR and immunohistochemistry with a good correlation between these two techniques (5). In our series, the expression levels were higher for sst2 and sst5 and markedly lower for sst1 and sst3. Note that non-functioning GEP tumours had a significantly higher level of sst2 than functional ones ($P<0.009$); however, the significance of this remains to be determined. Similar results concerning sst2 and sst5 were also previously observed in 38 patients with GEP (mostly pancreatic) using semi-quantitative PCR, although sst1 and sst3 were less frequently observed (66 and 50% respectively) (3). Compared with a group of pituitary tumours, the level of sst5 mRNA expression was less while sst2 expression levels were almost similar (Table 2). In a group of 27 ileal carcinoids, Reubi and Wasser (6) found sst2 to have the highest density (5.4 d.p.m./mg tissue) followed by sst1, sst5, sst3 and sst4 (3.4, 2.4, 1.6 and 1.5 d.p.m./mg tissue respectively). However, comparison of techniques using ligand binding and mRNA detection is difficult. Indeed, techniques focused on protein detection may reflect more accurate levels of sst receptors, whereas PCR may have overestimated quantities expressed. Moreover, the use of PCR does not allow for analysis of the percentage of cells expressing different receptor subtypes which requires in situ hybridisation or immunohistochemistry; indeed, the heterogeneity of sst expression has been previously described (5).

Although the dopamine receptors and the transmembrane dopamine transporter are known to play an important role in gastrointestinal physiology (25), they

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**Table 3** Expression levels of sst1, sst2, sst3, sst5 and D2 receptors according to the microvascular density (MVD) as measured by microscopy using CD34 staining (vessels/mm$^2$), vascular endothelial growth factor (VEGF, measured as a score by multiplication of the percentage of stained cells by their staining intensity 0) by immunohistochemistry and cellular proliferation index (Ki-67) in 19 pancreatic tumours.

<table>
<thead>
<tr>
<th>Tumour</th>
<th>VEGF score</th>
<th>MVD (vessels/mm$^2$)</th>
<th>Ki-67 (%)</th>
<th>sst1</th>
<th>sst2</th>
<th>sst3</th>
<th>sst5</th>
<th>D2</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>180</td>
<td>496</td>
<td>7</td>
<td>4.3</td>
<td>175.0</td>
<td>49.0</td>
<td>7.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C2</td>
<td>10</td>
<td>95</td>
<td>3</td>
<td>0.9</td>
<td>7.0</td>
<td>0.3</td>
<td>236.0</td>
<td>4.0</td>
</tr>
<tr>
<td>C3</td>
<td>180</td>
<td>400</td>
<td>9</td>
<td>1.2</td>
<td>9.0</td>
<td>0.3</td>
<td>7.0</td>
<td>3.0</td>
</tr>
<tr>
<td>C4</td>
<td>50</td>
<td>209</td>
<td>2</td>
<td>0.7</td>
<td>6.0</td>
<td>0.3</td>
<td>414.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C5</td>
<td>20</td>
<td>173</td>
<td>3</td>
<td>27.1</td>
<td>13.0</td>
<td>0.3</td>
<td>306.0</td>
<td>39.0</td>
</tr>
<tr>
<td>C6</td>
<td>50</td>
<td>674</td>
<td>5</td>
<td>1.3</td>
<td>31.0</td>
<td>27.3</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C7</td>
<td>150</td>
<td>417</td>
<td>3</td>
<td>3.5</td>
<td>38.0</td>
<td>25.2</td>
<td>12.0</td>
<td>4.0</td>
</tr>
<tr>
<td>C8</td>
<td>160</td>
<td>100</td>
<td>6</td>
<td>3.4</td>
<td>79.0</td>
<td>15.2</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C9</td>
<td>0</td>
<td>102</td>
<td>3</td>
<td>0.2</td>
<td>20.0</td>
<td>3.9</td>
<td>70.0</td>
<td>6.0</td>
</tr>
<tr>
<td>C10</td>
<td>40</td>
<td>276</td>
<td>4</td>
<td>0.6</td>
<td>135.0</td>
<td>0.0</td>
<td>127.0</td>
<td>110.0</td>
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<tr>
<td>C11</td>
<td>60</td>
<td>652</td>
<td>7</td>
<td>1.6</td>
<td>15.0</td>
<td>1.0</td>
<td>40.0</td>
<td>2.0</td>
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<tr>
<td>C12</td>
<td>0</td>
<td>337</td>
<td>5</td>
<td>41.6</td>
<td>35.0</td>
<td>0.1</td>
<td>0.0</td>
<td>576.0</td>
</tr>
<tr>
<td>C13</td>
<td>30</td>
<td>464</td>
<td>4</td>
<td>7.4</td>
<td>461.0</td>
<td>0.0</td>
<td>466.0</td>
<td>9.0</td>
</tr>
<tr>
<td>C14</td>
<td>60</td>
<td>563</td>
<td>1</td>
<td>4.5</td>
<td>38.0</td>
<td>15.5</td>
<td>19.0</td>
<td>3.0</td>
</tr>
<tr>
<td>C15</td>
<td>60</td>
<td>442</td>
<td>6</td>
<td>7.3</td>
<td>230.0</td>
<td>8.4</td>
<td>129.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C16</td>
<td>0</td>
<td>307</td>
<td>9</td>
<td>2.7</td>
<td>59.0</td>
<td>29.7</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C17</td>
<td>0</td>
<td>80</td>
<td>10</td>
<td>9.2</td>
<td>504.0</td>
<td>0.3</td>
<td>39.0</td>
<td>477.0</td>
</tr>
<tr>
<td>C18</td>
<td>0</td>
<td>357</td>
<td>4</td>
<td>1.9</td>
<td>87.0</td>
<td>0.5</td>
<td>6.0</td>
<td>11.0</td>
</tr>
<tr>
<td>C19</td>
<td>60</td>
<td>112</td>
<td>9</td>
<td>ND</td>
<td>4.0</td>
<td>0.3</td>
<td>50.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Mean ± s.d. 58.4 ± 14.3 329 ± 44 5.3 (1–10) 6.6 ± 2.5 102 ± 33 11 ± 3.6 129 ± 40 65 ± 37
have not been investigated in neuroendocrine gastrointestinal tumours. Interestingly, Lemmer et al. have showed the presence of D2 in two cell lines, STC1 murine neuroendocrine gut tumours and BON human pancreatic neuroendocrine tumours (20). Here, we showed for the first time the presence of D2 mRNA in all human GEP tumours. Moreover, the quantitative analysis showed that D2 expression level was in the range of those observed in somatotroph adenomas in 17% of GEP tumours. The identification of D2 in all GEP tumours of both intestinal and pancreatic origin opens the possibility of examining new chimeric analogues which simultaneously recognise sst2 and D2, such as BIM-23A387 or BIM-23A370, which have been shown to enhance the suppression of growth hormone and prolactin in pituitary adenomas compared with sst2 and D2 analogues used alone (18, 26). A direct antiproliferative effect of the somatostatin/dopamine chimeras, BIM-23A387 and BIM-23A370, was found in the lung carcinoma cell line (Calu-6) possible via sst/D2 dimerisation (27). In addition, other analogues capable of recognising both sst2 and sst5 (BIM-23A44) or the multivalent agonist SOM230 (recognising sst1, sst2, sst3 and sst5) offer the possibility of increasing therapeutic efficacy by acting via more than one receptor. Although D2 was found in all tumours, low levels were expressed in about 80% inferring that D2 receptor targeting may only be relevant to subset of patients with GEP tumours. Moreover, cellular distribution of sst and D2 receptors should also be an important parameter involved in the efficacy of such treatment. Examining the potential effect on tumour secretion or even proliferation in GEP tumours will require functional studies.

Somatostatin receptor scintigraphy is performed not only for tumoural localisation but also for predicting the efficacy of somatostatin agonist or modified radiopharmaceutical analogues (28–31). However, in some case, SRS results were not correlated with results of treatments (32–34). Actual SRS using 111In-pentetreotide recognises mostly sst2 subtype. Pentetreotide had tenfold higher affinity for sst2 than for sst5 or sst3 (6). Globally, SRS is positive in approximately 80% of all patients with GEP tumours (35). Previously, semi-quantitative RT-PCR revealed most prominently sst2 expression in scintigraphic positive tumours (36). Using sst2 knockout mice, Holland and collaborators confirmed the crucial role of sst2 in determining the uptake of [111In-DTPA-D-Phe1]octreotide (28). In the present study, we confirm sst2 as the most important receptor subtype in case of positive SRS uptake as the levels of sst2 in 27 SRS-positive tumours was markedly higher as compared with seven SRS-negative tumours. Levels of other sst did not differ between SRS-positive and SRS-negative tumours thus confirming that other sst have less influence on SRS outcome (36). Jais et al previously observed no difference in sst receptor distribution and SRS results although again numbers were small (17 positive SRS vs 4 negative) (3). In the present study, when only small tumours (<30 mm) were examined, sst2 mRNA level expression was significantly higher in SRS-positive tumours than in SRS-negative ones (Fig. 4), thus confirming the crucial role of sst2 receptor alone on scintigraphic results for small tumours. Moreover, compared with SRS-negative tumours, SRS-positive tumours were larger (44 ± 7 vs 21 ± 2.7 mm, P < 0.01, data not shown) confirming the role of tumour size itself on scintigraphic results for the large tumours. Among all SRS-positive tumours, sst2 mRNA levels were significantly higher in the group of small versus big tumours (128 ± 48×10^−2 vs 73 ± 48×10^−2 copy/β-Gus copy, P < 0.05, data not shown) confirming the bias introduced by the size in SRS results.
sst level expression and in particular sst2 may predict clinical response to somatostatin receptor analogues and could thus help in tailoring targeted therapy as shown in somatotroph adenomas (37, 24). As in patients with breast cancer where oestrogen receptor status and levels help in predicting therapeutic responses, quantitative receptor measurements may help in determining responses to cold and radiolabelled somatostatin (or somatostatin–dopamine) analogues to be used in treatment according to analogues binding characteristics (38, 39).

As well as being involved in regulation of hormonal release, sst are known to have direct and indirect effects on angiogenesis and cellular proliferation (review: (40)). Interestingly, sst3 was higher in pancreatic than in intestinal tumours (Table 2). Thus, when pancreatic tumours were separated into high and low sst3 level groups, a positive correlation was observed with both microvessel density and VEGF score (P < 0.03) was observed (Fig. 5). MVD and VEGF expression have been found to be increased in benign pancreatic tumours and their expression decreases as tumours dedifferentiate (23). sst3 has previously been found to be the predominant somatostatin receptor subtype in endothelial cells (41). sst3 may be expressed also in the microvessels of the tumours of our series. Nevertheless, the observation of co-expression of angiogenic factors with sst1 is important as underlined by the recent observation that somatostatin inhibition of tumour angiogenesis in a Kaposis’s sarcoma cell xenograft model occurred via sst1-mediated inhibition of both nitric oxide synthetase and MAPK activities (42). In endothelial cells-expressing sst3, addition of the sst3 antagonist, BN81658, significantly reversed the anti-angiogenic effects of somatostatin (42). VEGF and somatostatin were also recently found to be co-expressed in the same tissue compartments in ovarian cancer suggesting a major role for somatostatin in angiogenesis (43).

Finally, low sst5 mRNA expression was present in pancreatic tumours with high Ki-67 level. Overall, few data are available comparing sst receptors with cellular markers of proliferation. Interestingly, our results were contradictory to recent data in a series of 16 insulinomas, where sst5 was positively correlated with aggressive tumour behaviours, such as large tumour size, tumours of uncertain behaviour and presence of nuclear atypia (44). In brain tumours (astrocytomas and meningiomas), no relation existed between Ki-67 and sst subclasses in two series (45, 46). In contrast, in breast cancer, sst2 mRNA expression was significantly higher in low-proliferating (as measured using Ki-67) breast cancers (47). Note that in an endothelial cell line model (HUVEC) sst other than sst2 and sst3 appears important in controlling proliferation as demonstrated by the ability of the multivalent ligand SOM230, but not octreotide, to inhibit proliferation and this did not appear to be mediated via sst1 as only sst1, sst2 and sst3 were detected using RT-PCR and western blotting (48). SOM230 or other specific sst2–sst5 or sst3–D2 agonists may thus represent suitable candidates as potential anti-angiogenic and anti-proliferating drugs.

In conclusion, GEP tumours were found to co-express sst2 and D2 in all cases and sst5 in 89%. SRS results were strongly correlated to the sst2 mRNA expression level in small tumours (<30 mm), but were consistently distorted by the size in large tumours explaining some discordance between SRS and somatostatin treatment results. While mean level of receptor expression for sst5 and D2 is lower in GEP than in pituitary adenomas, comparative levels are observed in almost a half and a fifth of tumours respectively. These results argue for testing of bi-specific agonists (sst2/sst5 or sst3/D2) in the treatment of GEP tumours not only for inhibiting secretion but also angiogenesis and cell proliferation.

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