Abstract

Objective: The aim of this study was to examine pituitary adenomas in a series of postmortem pituitaries by use of modern technologies of immunostaining, to classify the adenomas according to the current WHO classification and to analyse the possible associations to the available clinical data.

Methods: In this study, pituitaries of 3048 autopsy cases obtained from autopsy series of the years 1991–2004 were examined.

Results: A total of 334 pituitary adenomas were found in 316 pituitaries. One hundred and thirty-two sparsely granulated prolactin cell adenomas (39.5%), 75 null cell adenomas (22.5%) and 31 oncocytomas were diagnosed. Forty-six ACTH cell adenomas (13.8%, 27 densely granulated, 19 sparsely granulated) and one adenoma composed of Crooke’s cells were detected. Twenty-two gonadotroph cell adenomas (6.6%), seven GH cell adenomas (four sparsely granulated, three densely granulated), one mixed GH cell–PRL cell adenoma, two TSH cell adenomas, five plurihormonal adenoma type I, four plurihormonal adenoma type II and two α-subunit-only adenomas were seen. Six adenomas remained unclassified because the tissue was not contained in all sections for immunohistochemistry. Seventeen pituitaries included multiple tumours. The overall tumour size ranged from 0.1 to 20 mm in diameter. Among 76 adenomas (22.7%), which had a tumour size of ≥3 mm, only three tumours were macroadenomas corresponding to a tumour size of more than 10 mm. The evaluation of the available clinical data showed 99 cases of hypertension, 65 cases of diabetes mellitus, six patients with hyper-thyroidism and four with hypothyroidism. No symptoms of adenohypophysyal hormone hypersecretion were reported. The statistical correlations to clinical data were discussed.

Conclusions: Adenomas in postmortem pituitaries differ from those in surgical series in proportion of adenoma types and biological behaviour.
primary antibodies were used: anti-growth hormone (GH)-monoclonal (BioGenex, San Ramon, USA) diluted 1:200; anti-prolactin (PRL)-monoclonal (Immunotech, Marseille, France) diluted 1:400; anti-adrenocorticotrophic hormone (ACTH)-monoclonal (Novocastra, Newcastle, UK) diluted 1:400; anti-thyroid-stimulating hormone (TSH)-monoclonal (Immunotech) diluted 1:5000; anti-β follicle-stimulating hormone (βFSH)-monoclonal (Immunotech) diluted 1:40 000; anti-β lutetinizing hormone (βLH)-monoclonal (Immunotech) diluted 1:5000; anti-α subunit-monoclonal (Immunotech) diluted 1:1500; anti-S-100 protein (DAKO) diluted 1:1500; and ki-67 (MiB-1) (Zytomed, Berlin, Germany) diluted 1:150.

We identified the adenomas by their architecture which was sinusoidal, diffuse or solid in contrast to the alveolar basic structure of the normal pituitary and by their nearly or completely monocellular composition. Focal hyperplasias were not encountered in this study. They were differentiated from the adenomas by their nearly intact alveolar basic structure.

The available clinical data were rescreened from the files for any information about hypertension, diabetes mellitus, hypo- and hyper-thyroidism and any other endocrinological disorders.

### Statistical analysis

For statistical analysis, Mann–Whitney test and Fisher’s exact test were used for comparing tumour size, gender, adenoma type and clinical data. Statistical significance was established at the level of $P < 0.05$.

### Results

A total of 334 pituitary adenomas in 316 of 3048 pituitaries (10.4%) were found. The cases included 157 male and 159 female patients in the age range of 28–97 years (mean 73 years).

The most frequently detected tumours were sparsely granulated PRL cell adenomas (132 cases, 39.5%). The results of the morphological tumour type are summarized in Table 1. A total of 17 pituitaries comprised multiple tumours, 16 cases included two tumours and one case three adenomas (Table 2).

### GH cell adenomas

In seven cases, tumour cells exhibited immunopositivity for GH. Tumour size varied from 0.75 to 8.8 mm (median 2.3 mm, Table 3). Four sparsely granulated GH cell adenomas were composed of monomorphic medium-sized tumour cells with chromophobic or weakly acidophilic cytoplasm. Fibrous bodies were demonstrated by globular expression of Pankeratin KL 1. Three densely granulated tumours exhibited a distinct acidophilic cytoplasm.

### Table 1

<table>
<thead>
<tr>
<th>Adenoma type</th>
<th>Number of tumours</th>
<th>Included cases with multiple tumours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>GH cell adenoma, sparsely granulated</td>
<td>4</td>
<td>–</td>
<td>1.2</td>
</tr>
<tr>
<td>GH cell adenoma, densely granulated</td>
<td>3</td>
<td>–</td>
<td>0.9</td>
</tr>
<tr>
<td>PRL cell adenoma, sparsely granulated</td>
<td>132</td>
<td>12</td>
<td>39.5</td>
</tr>
<tr>
<td>Mixed GH cell–PRL cell adenoma</td>
<td>1</td>
<td>–</td>
<td>0.3</td>
</tr>
<tr>
<td>Plurihormonal adenoma type I</td>
<td>5</td>
<td>–</td>
<td>1.5</td>
</tr>
<tr>
<td>TSHoma</td>
<td>2</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td>ACTH cell adenoma, densely granulated</td>
<td>27</td>
<td>3</td>
<td>8.1</td>
</tr>
<tr>
<td>ACTH cell adenoma, sparsely granulated</td>
<td>19</td>
<td>1</td>
<td>5.7</td>
</tr>
<tr>
<td>Crooke’s cell adenoma</td>
<td>1</td>
<td>–</td>
<td>0.3</td>
</tr>
<tr>
<td>Gonadotroph cell adenoma</td>
<td>22</td>
<td>–</td>
<td>6.6</td>
</tr>
<tr>
<td>α-Subunit-only-adenoma</td>
<td>2</td>
<td>–</td>
<td>0.6</td>
</tr>
<tr>
<td>Plurihormonal adenoma type II</td>
<td>4</td>
<td>–</td>
<td>1.2</td>
</tr>
<tr>
<td>Null cell adenoma</td>
<td>75</td>
<td>15</td>
<td>22.5</td>
</tr>
<tr>
<td>Oncocytoma</td>
<td>31</td>
<td>3</td>
<td>9.3</td>
</tr>
<tr>
<td>Unclassified</td>
<td>6</td>
<td>–</td>
<td>1.8</td>
</tr>
<tr>
<td>Total</td>
<td>334</td>
<td>35*</td>
<td>100</td>
</tr>
</tbody>
</table>

*17 cases: 16 with 2 tumours and 1 with 3 tumours.

### Table 2

Multiple adenomas.

<table>
<thead>
<tr>
<th>Adenoma type</th>
<th>Largest tumour</th>
<th>2nd/3rd tumour</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRL cell adenoma</td>
<td>PRL cell adenoma</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PRL cell adenoma</td>
<td>Null cell adenoma</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Null cell adenoma</td>
<td>Null cell adenoma</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Oncocytoma</td>
<td>Null cell adenoma</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>ACTH cell adenoma, densely granulated</td>
<td>Null cell adenoma</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ACTH cell adenoma, densely granulated</td>
<td>PRL cell adenoma</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>ACTH cell adenoma, sparsely granulated</td>
<td>Oncocytoma</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>TSHoma</td>
<td>Two null cell adenomas</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>
PRL cell adenomas

One hundred and thirty-two (39.5%) of the detected adenomas were immunopositive for prolactin, ranging in size from 0.1 to 6 mm (median 1.2 mm). The adenomas consisted of medium-sized slightly pleomorphic tumour cells with chromophobic or weakly acidophilic often elongated cytoplasm and were classified as sparsely granulated PRL cell adenomas.

Mixed GH/PRL cell adenoma

One tumour measuring 2 mm in diameter was immunopositive for both GH and prolactin, and was classified as sparsely granulated mixed GH/PRL cell adenoma.

TSHoma

Only two tumours (0.6%) with a tumour size of 0.8 and 1 mm exhibited exclusive staining of tumour cells for TSH.

ACTH cell adenoma/Crooke’s cell adenoma

A total of 47 tumours were counted among ACTH producing adenomas. Tumour size varied from 0.15 to 5 mm in diameter (median 1.4 mm). Twenty-seven of the ACTH producing tumours were composed of uniform tumour cells with slightly dense chromatin and distinct PAS positive basophil cytoplasm corresponding to a densely granulated ACTH cell adenoma. Nineteen adenomas with weakly granulated PAS positive tumour cells were classified as sparsely granulated adenomas. As these cases did not show Crooke’s cells in the tumour-free pituitary a distinct hypercortisolism could be excluded (13, 14). There was one case of Crooke’s cell adenoma with Crooke’s hyaline change within the tumour cells. Twenty-one ACTH cell adenomas (44.7%) exhibited an adjacent ACTH cell hyperplasia.

Gonadotroph cell adenoma

A total of 22 adenomas were classified as gonadotroph cell adenomas, varying in tumour size from 0.15 to 20 mm (median 1.55 mm). Two macroadenomas had tumour sizes of 12 and 20 mm. The adenomas consisted of monomorphic cells with chromophobic cytoplasm and mostly sinusoidal growth pattern. Eleven tumours were positive for FSH and LH and eight cases were positive for FSH. One case showed immunohistochemical staining for LH, one for LH and α-subunit and one for FSH, LH and α-subunit.

α-Subunit-only adenoma

Two adenomas with a tumour size of 0.8 and 2 mm were exclusively positive for the α-subunit of glycoprotein hormones.

Null cell adenoma/oncocytoma

According to their definition, null cell adenomas and oncocytomas were immuno-negative for any hormone, but may contain some scattered positive cells. The tumour size ranged from 0.1 to 7 mm (median 1.5 mm). We found 75 null cell adenomas with mostly small cells and 31 oncocytomas consisting of large tumour cells with slightly acidophilic PAS negative cytoplasm.

Plurihormonal adenomas

Plurihormonal adenomas or multihormonal adenomas secreted unrelated hormones not including the combinations GH/PRL/TSH or FSH/LH. The plurihormonal adenomas varied in tumour size from 0.4 to 10.1 mm (median 2 mm), including one macroadenoma measuring 10.1 mm. A total of five tumours showed immunohistochemical staining for GH, PRL and glycoprotein hormones (plurihormonal adenoma type I). Four
tumours contained FSH, LH and TSH or GH (plurihormonal adenoma type II) (Table 4).

**Unclassified adenomas**

Six adenomas were unclassified due to methodical deficiency. The small tumour tissue was not contained in all sections for immunohistochemical staining. Tumour size ranged from 0.14 to 1.8 mm (median 0.7 mm), mean 0.89 mm.

**Tumour size**

The overall tumour size ranged from 0.1 to 20 mm in diameter (median 1.5 mm, interquartile range, 1.65). One hundred and thirty-eight (41.3%) tumours had a tumour size of 1 mm or less and 76 adenomas (22.7%) had a tumour size of ≥3 mm. Only three tumours were macroadenomas corresponding to a tumour size of more than 10 mm (Table 3). There has been no significant correlation between gender and tumour size (Fig. 1) or adenoma type and corresponding tumour size (Fig. 2).

### Table 4 Plurihormonal adenomas.

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Plurihormonal adenoma type</th>
<th>GH</th>
<th>PRL</th>
<th>TSH</th>
<th>FSH</th>
<th>LH</th>
<th>α-SU</th>
</tr>
</thead>
<tbody>
<tr>
<td>173</td>
<td>I</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<td>175</td>
<td>I</td>
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<td>X</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>178</td>
<td>II</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>179</td>
<td>II</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>180</td>
<td>II</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>181</td>
<td>II</td>
<td>X</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>

α-SU: α-subunit.

**Clinical data**

Clinical data concerning hypertension, diabetes mellitus and other endocrinological symptoms were collected (Table 5). No symptoms of adrenocortical hormone hypersecretion were reported. Ninety-nine patients suffered from hypertension and 65 patients were reported to have diabetes mellitus. Cases of hyper- and hypo-thyroidism were quite rare (six and four cases respectively), but none of them exhibited a TSH cell adenoma. There was a significantly higher incidence of diabetes mellitus in the group of ‘other’ adenomas (TSH cell adenomas, plurihormonal adenomas without GH secretion and unclassified adenomas) (Fisher’s exact test, P = 0.007).

**Figure 1** Gender and tumour size. Only the largest tumour is counted among the 17 cases of multiple adenomas.

**Figure 2** Adenoma type and tumour size. Only the largest tumour is counted among the 17 cases of multiple adenomas. PRL cell adenoma; ACTH, ACTH cell adenoma and Crooke’s cell adenoma; FSH, gonadotroph cell adenoma; α-SU, α-subunit only adenoma; Nc, null cell adenoma; Oc, oncocytoma; GH, GH cell adenoma, mixed Gh–PRL-cell adenoma, GH secreting plurihormonal adenoma; Other, TSH cell adenoma, plurihormonal adenoma (without GH secretion), and unclassified adenoma.
Statistical evaluation

No significant association was detectable between tumour size and sex (Mann–Whitney test). Evaluation of the data with Fisher’s exact test exhibited a higher incidence of diabetes in the group of other adenomas (TSH cell adenomas, plurihormonal adenomas without GH secretion and unclassified adenomas) \((P < 0.007)\). No associations between gender and adenoma type, adenoma type and hypertension or adenoma type and tumour size were evident.

Discussion

Incidence of subclinical adenomas showed no sex predominance in accordance with data in studies published previously (2, 6, 15, 16).

In some cases with very tiny adenomas, difficulties to distinguish between small adenomas and nodular hyperplasias were noticeable, but in most cases the loss of normal stromal pattern and acinar growth pattern was obvious.

Most adenomas in the present study were PRL cell adenomas (39.5%). In previously published autopsy studies, PRL cell adenomas also represented the majority of pituitary adenomas and the incidence ranged from about 40 to 50% (1, 3, 9, 17). In most surgical series, the incidence of prolactinomas was lower because of the medical therapeutic option of these tumours (17–19).

A total of 106 (31.7%) adenomas (75 null cell adenomas and 31 oncocytes) were identified. In the literature, the incidence of null cell adenomas or adenomas without immunohistochemical staining in postmortem pituitaries ranges from 18 to 50% (2, 6, 9, 20).

Forty-seven adenomas (14.1%) were ACTH cell adenomas; one of them was composed of Crooke’s cells. Other autopsy studies found lower percentages up to 7.2% (2, 9, 20), whereas ACTH cell adenomas represent about 15% of adenomas in surgically removed pituitary adenomas (19, 21).

In the current study, 6.6% of adenomas were gonadotroph cell adenomas corresponding to the findings of Abd el-Hamid et al. (2).

Only eight tumours (2.3%) revealed positive staining for GH, although previously reported data ranged from 0 to 18% in postmortem pituitaries (2, 6, 9, 20). Considering all surgically removed pituitary adenomas, GH cell adenomas account for 25–30% (22).

TSH cell adenomas represented only 0.6% of all adenomas in the current study.

Plurihormonal or multihormonal adenomas were classified according to the WHO classification (23), including cases secreting unrelated hormones not showing the combinations GH/PRL/TSH or FSH/LH. In the current study, these tumours were quite rare (2.7%).

Seventeen cases (5.4%) exhibited a total of 35 multiple adenomas. Other authors described multiple tumours in 0.9–19.4% (6, 20, 24). Eighteen of thirty-five multiple adenomas were null cell adenomas or oncocytes. Kontogeorgos et al. also reported a lack of immunohistochemical staining in the majority of multiple adenomas in autopsy material (24). In contrast to these findings Sano et al. described a predominance of GH producing adenomas in multiple adenomas detected in surgically resected material (25). These differences correspond to the observation that null cell adenomas are slow growing and may be incidentally detected without any symptoms, whereas most GH cell adenomas cause gigantism or acromegaly.

Subclinical pituitary adenomas are predominantly small with a mean tumour size of 1.9 mm in this study; over 30% of the detected adenomas were smaller than 1 mm in diameter. These findings are comparable to the results of Parent et al., who found 62% of adenomas in postmortem pituitaries to be smaller than 3 mm (4) and to a study by Teramoto et al., who found 66% of subclinical adenomas to be 2 mm or smaller (8).
encountered only three macroadenomas among the 334 adenomas. In previously published studies, subclinically or incidentally detected macroadenomas were also very rare (3,7,26).

Our statistical analysis did not reveal a clear significant correlation between clinical data and adenoma type. This is in accordance with the results of McComb et al. (9). There was a higher incidence of diabetes in the group of other adenomas (TSH cell adenomas, plurihormonal adenomas without GH secretion and unclassified adenomas). Interpreting these results, the low number of ‘other’ adenomas (only 10 cases were included in this group) has to be considered. Information about fertility, libido, bone density, physical activity or emotional status was not available.

From our findings, we conclude that adenomas in postmortem pituitaries are different from those in surgical series according to the proportion of adenoma types, functional properties and biological behaviour.

Acknowledgements

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