Gliomas of the cingulate gyrus: surgical management and functional outcome

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Object. In this paper, the authors’ goal was to summarize their experience with the surgical treatment of gliomas arising from the cingulate gyrus.

Methods. The authors analyzed preoperative data, surgical strategies, complications, and functional outcome in a series of 34 patients (mean age 42 years, range 12–69 years; 14 females) who underwent 38 operations between May 2001 and November 2008.

Results. In 7 cases (18%) the tumor was located in the posterior (parietal) part of the cingulate gyrus, and in 31 (82%) the tumor was in the anterior (frontal) part. In 10 cases (26%) the glioma was solely located in the cingulate gyrus, and in 28 cases (74%) the tumor extended to the supracingular frontal/parietal cortex. Most cases (23 [61%]) had seizures as the presenting symptom, 8 patients (24%) suffered from a hemiparesis/hemihypesthesia, and 4 patients (12%) had aphasic symptoms.

The authors chose an interhemispheric approach for tumor resection in 11 (29%) and a transcortical approach in 27 (71%) cases; intraoperative electrophysiological monitoring was applied in 23 (61%) and neuronavigation in 15 (39%) cases. A > 90% resection was achieved in 32 (84%) and > 70% in another 5 (13%) cases. Tumors were classified as low-grade gliomas in 11 cases (29%). A glioblastoma multiforme (WHO Grade IV, 10 cases [26%]) and oligoastrocytoma (WHO Grade III, 9 cases [24%]) were the most frequent histopathological results.

Postoperatively, patients in 13 cases suffered from a transient supplementary motor area syndrome (34%), all of whom had tumors in the anterior cingulate gyrus. In the early postoperative period (30 days) a new deficit occurred in 5 cases (13%, mild motor deficits or aphasic symptoms). One patient had a major bleeding episode 2 days after surgery and was in a persistent vegetative state.

Conclusions. Gliomas arising from the cingulate gyrus are rare. A gross-total resection is often possible and acceptably safe; intraoperative monitoring and neuronavigation are helpful adjuncts. In case of resection of gliomas arising from the anterior cingulate gyrus a supplementary motor area syndrome has to be considered, particularly when the tumor extends to the supracingular cortex. (DOI: 10.3171/2009.6.FOCUS09104)

Key Words • cingulate gyrus • glioma • outcome

The cingulate gyrus surrounds the corpus callosum in a belt-shaped manner at the mesial aspect of the cerebral hemispheres. It is divided into anterior (frontal lobe) and posterior (parietal lobe) portions in the area of the central sulcus. The rostral part surrounds the genu of the corpus callosum and ends in the subcallosal cortex; it continues posteriorly around the splenium of the corpus callosum to become the parahippocampal gyrus at the level of the cingulate isthmus. The adjacent areas of the hemisphere comprise the mesial and hemispheric surface of F1 with the SMA, the paracentral lobule, and the precuneus in the parietal lobe (we summarized the areas adjacent to the cingulate gyrus at the interhemispheric surface as “supracingular”).

Functionally, the cingulate gyrus is part of the limbic system with extensive connectivity to different anatomical and functional areas. In the last decade many studies were published concerning the cingulate area and neuropsychological findings,2,21 functional and diffusion tensor imaging,1,10 lesion studies,3,11 and electrophysiological stimulation studies with implanted electrodes.5,18,22 For an excellent review of data regarding the complex functional role of the cingulate gyrus and the surrounding structures of the frontal lobe, see Rushworth et al.15

The literature concerning surgical intervention in the cingulate gyrus mostly comprises data about functional (stereotactic) neurosurgery for intractable pain,25 depression,9,19 or compulsive disorders.14 Additionally, there are a few small series or case reports about focal epilepsy arising from neoplastic and other lesions of the cingulate gyrus and surgical treatment for seizure control.8,26 The largest series so far for surgical management of tumors arising from the cingulate gyrus was presented by Yaşargil et al. in 1996.24 A recent study summarized data in patients with intermediate gliomas (WHO Grades II and III) arising from the anterior cingulate gyrus.20 Taken together, little is known about functional outcome after resection in this circumscribed area. In this study we report on a homogeneous group of patients, examine the risks of tumor removal, and balance different factors for postoperative deficits.

Abbreviations used in this paper: F1 = superior frontal gyrus; GBM = glioblastoma multiforme; GTR = gross-total resection; KPS = Karnofsky Performance Scale; SMA = supplementary motor area.
Methods

Patients and Clinical Data

Between May 2001 and November 2008, we operated on 996 patients for supratentorial glial tumors in the Department of Neurosurgery at the University of Bonn (1072 resections total). The data of 38 consecutive operations (3.5% of all resections) in 34 patients harboring a glioma arising from the cingulate gyrus were identified by a review of patients’ charts, surgery reports, and MR imaging. The mean age of the included patients was 42 years (range 12–69 years); 14 (41%) were female. Right-sided resections were performed in 12 cases (32%). We excluded patients with tumors primarily arising from F1 and reaching the roof of the lateral ventricle and the supracingular aspect of the frontal lobe.

Preoperative and postoperative data were collected through a chart review and analyzed using a computerized data bank. We included the age of the patients, presenting signs and symptoms, site of resection, postoperative deficits, local and systemic complications, pre- and postoperative KPS scores (10–100), and changes in KPS score after surgery until discharge or during the 30-day postoperative period.

Surgical Management

We routinely recommended a tumor resection for suspected gliomas if a complete resection was possible or at least a meaningful cytoreduction seemed feasible (defined as > 70%). As in a recent study we defined tumor resections as > 90% (no or only minimal residual tumor), 90–70%, and partial. Operative details comprised side and extent of surgery (pure cingulate resection or extending to adjacent regions) and the approach to the tumor. In case of involvement of the central area or the motor tract we routinely used electrophysiological monitoring (continuous motor and somatosensory evoked potential recording and phase reversal); in some cases neuronavigation was applied.

Radiological and Histopathological Data

All patients underwent at least 1 MR imaging study preoperatively for evaluation of tumor location and infiltration in surrounding areas. The degree of resection was measured according to postoperative CT/MR imaging in 26 cases and according to the surgeons’ impressions in 12 cases. All histopathological diagnoses were made at the Department of Neuropathology/German Brain Tumor Reference Center at the University of Bonn based on the WHO criteria.

Statistical Analysis

Dichotomous discrete variables were analyzed using the chi-square test or Fisher exact test. A probability level of 0.05 was accepted for the indication of statistical significance in double-sided testing. Commercially available software was used for statistical analysis (version 17.0, SPSS, Inc.).

Results

Clinical Data

The common presenting symptoms were seizures (23 cases [61%]; Table 1). In addition to 6 cases (16%) with long-lasting refractory epilepsy, we found 17 cases (45%) in which the patients had a recent onset of seizures; in 1 patient the seizures were combined with dysphasic symptoms. In 6 cases (16%) the patients had a hemiparesis, and in 3 cases the patients had left-sided gliomas combined with dysphasic symptoms (overall 4 cases of patients with dysphasia [11%]). Patients in 2 cases (5%) presented with a hemihypesthesia (tumor located in the posterior cingulate gyrus). In most patients it took a few days (up to 1 month) from the first presenting symptoms until CT/MR imaging. In cases of refractory epilepsy the mean duration was 12 years (range 3–28 years). The tumor was found incidentally in 3 patients (MR imaging for chronic earache/deafness, after a minor trauma, or migraine, respectively).
One patient had acute bleeding of a GBM in the anterior cingulate gyrus with occlusion of the ipsilateral Monro foramen and progressive loss of consciousness.

Five patients underwent previous treatment before the referral to our department. Three patients had stereotactic biopsies, and in 1 case the patient underwent implantation of intraparenchymal seeds (WHO Grade II astrocytoma); 1 patient received local radiation without histopathological proof of diagnosis; 1 patient with temporomesial infiltration of a tumor arising from the posterior cingulate gyrus had undergone a temporal lobectomy (WHO Grade II oligoastrocytoma).

The mean preoperative KPS score was 90 (range 60–100); 6 patients had a KPS score < 80, and all of these patients had a supracingular infiltration. Preoperatively, patients with high-grade gliomas were in significantly worse condition and had more often neurological deficits (p < 0.01). All patients with refractory epilepsy harbored low-grade gliomas.

Radiological Data

Most patients had a glioma arising in the anterior part of the cingulate gyrus (31 cases [82%]), and in 7 cases (18%) the tumor was solely located in the anterior cingulate gyrus (Figs. 1 and 2). Three patients with gliomas in the rostral part of the anterior cingulate gyrus had tumor spread to the frontoorbital cortex, and in 1 patient the tumor reached the insular cortex (Fig. 1).

In 3 cases (8%) the patients had a glioma solely in the posterior cingulate gyrus (Fig. 3), and in 4 (11% of total) of the 7 cases of gliomas in the posterior cingulate gyrus the tumor infiltrated supracingular structures of the parietal lobe; in 1 patient the tumor extended to the temporal lobe with infiltration of the hippocampus and amygdala. Overall, in 4 cases (11%) the patients had a limbic spread of tumors beyond the infiltration of the cingulate gyrus.

According to MR imaging criteria, in 16 cases (42%) the glioma infiltrated the corpus callosum; in 2 of these cases there was an infiltration of the contralateral hemisphere, and in 1 case the glioma reached the caput of the caudate nucleus.

Intraoperative Approach

We chose an interhemispheric approach for tumor
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resection in 11 cases, of which 9 had no supracingular extension (90% of all pure cingulate gliomas). In 1 patient with a tumor solely in the right dorsal cingulate gyrus and previous stereotactic biopsy, the interhemispheric approach was not possible due to adhesions and large bridging veins. In 2 patients the tumor infiltrated the medial frontal gyrus, but it did not reach the surface of the hemisphere so that an interhemispheric approach was appropriate to preserve F1.

In the case of an interhemispheric approach, we prefer a large enough craniotomy in an anterior-posterior orientation to be able to avoid bridging veins or retraction of the overlying central cortex. The identification of the callosomarginal and the pericallosal arteries is often difficult because of bulging of the tumor mass that overlaps the vessels. A contralateral extension of the tumor was quite common, and in some cases even the falx or the arachnoid membrane of the contralateral mesial surface was infiltrated. Neuronavigation is helpful for planning the trepanation and the approach to the tumor.

A transcortical approach is appropriate if the tumor extends to the supracingular structures and reaches the surface of the hemisphere. In most cases the margins of the tumor were apparent at the surface, and if necessary the relation to the central sulcus was identified electrophysiologically (phase reversal). The vessels of the interhemispheric cleft were preserved with debulking of the tumor and subpial resection at the mesial surface. As mentioned above, this procedure might be misleading if the tumor did not respect the arachnoid membrane.

In 18 cases (47%) we opened the lateral ventricle to remove the tumor completely; in 6 cases (all tumors with extended infiltration of the frontal lobe) the surgeon left a closed drain in the wide-opened ventricle, which was to be opened in case a blood clot caused an occlusive hydrocephalus. In all patients the drain was removed after 3 days. One of these patients suffered from a transient meningeal inflammation (aseptic meningitis) 5 days after removing the drain.

A > 90% tumor resection was achieved in 32 cases (84%) and > 70% in another 5 cases (13%). In this latter group of patients the tumor had infiltrated the central area, the basal ganglia, or the contralateral corpus callosum, so that a GTR was not possible. Four cases in which reoperation was performed were included in the series. In 1 patient the surgery was stopped at < 70% resection of the tumor due to intraoperative technical breakdown of electrophysiological monitoring. We completed the resection of the remaining tumor near the motor cortex after 12 weeks when the initial SMA syndrome was resolved (WHO Grade III oligoastrocytoma in the anterior cingulate gyrus).

Of the other 3 patients with repeated surgeries, 2 underwent surgery for tumor recurrence (a WHO Grade II oligoastrocytoma transformed into a WHO Grade III oligoastrocytoma after 84 months; an anaplastic astrocytoma transformed into a WHO Grade IV GBM after

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Fig. 2. Axial MR images. Contrast-enhanced axial T1-weighted (A) and FLAIR (B) MR images obtained preoperatively. Contrast-enhanced axial T1-weighted (C) and FLAIR (D) MR images obtained postoperatively. These images show an astrocytoma (WHO Grade II) in the right anterior cingulate gyrus. The patient presented with occasional seizures.

Fig. 3. Preoperative MR images. Coronal FLAIR (A), sagittal contrast-enhanced T1-weighted (B), and axial T2-weighted (C) images showing an oligoastrocytoma (WHO Grade III) in the right posterior cingulate gyrus with contralateral bulging. The patient presented with hemiparesis.
38 months), 1 patient with refractory epilepsy continued to have seizures and was referred for complete lesionectomy after 8 months (histopathological result: WHO Grade I dysembryoplastic neuroepithelial tumor). In 1 patient with a GBM (WHO Grade IV) in the left anterior cingulate gyrus with supracingular and callosal infiltration, major bleeding occurred 2 days after surgery and required revision. Resection was done with the aid of intraoperative electrophysiological monitoring (continuous motor evoked potential [MEP] recording and phase reversal) in 23 cases (61%) and with neuronavigation in 15 cases (39%, in 5 cases with image-fusion of fiber tracking [diffusion tensor imaging]).

**Functional Outcome**

Patients in 13 cases (34%) who underwent tumor resection in the anterior cingulate gyrus suffered from different degrees and duration of transient neurological impairment (SMA syndrome) (Table 2). Eleven of them had a supracingular extension (85% of all patients with SMA syndrome postoperatively; 46% of all patients with tumors infiltrating the supracingular area). Nine patients had a motor deficit, 2 had aphasic symptoms, and 2 patients had a combination of both. All patients with speech disturbances had resections in the left hemisphere. There was no statistical correlation between the occurrence of SMA syndrome and tumor size, histological entity, or extent of tumor resection (pure cingulate vs cingulate with supracingular infiltration).

After a 30-day period (or at discharge) 4 patients had residual paresis of the leg: 3 of the 4 patients were able to walk without aid, and 1 patient had additional reduced fine motor skills of the hand. Of these patients, 2 had tumors in the anterior cingulate gyrus and the other 2 had tumors in the posterior cingulate gyrus. Both patients with tumors in the anterior cingulate gyrus had supracingular extension approximate to the motor strip. In 1 patient the initial mutism resolved to a distinct anomia at discharge. The patient who needed revision after a bleeding episode 2 days postoperatively remained in a vegetative state. Thus, overall permanent morbidity was 16% (that is, deficits lasting longer than the hospital stay or longer than 30 days). We found no statistical correlation between the incidence of permanent neurological deficits and location of the glioma (either anterior vs posterior cingulate gyrus or pure cingulate vs cingulate with supracingular infiltration).

In the short-term observation period, the mean postoperative KPS score was 80 (range 20–100); 11 patients had a KPS score < 80 and 5 patients had a deterioration of > 20 in score. There was no statistical correlation between the postoperative KPS score or change in KPS score and

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**TABLE 2: Postoperative functional deficits**

<table>
<thead>
<tr>
<th>Location &amp; Tumor Type</th>
<th>No. of Cases (%)</th>
<th>SMA S (13 cases)</th>
<th>HP (4 cases)</th>
<th>KPS Score Worse &gt;20 (5 cases)†</th>
<th>KPS Score &lt;80 (11 cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior cingulate gyrus</td>
<td>31 (81.6)</td>
<td>7 (22.6)</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pure</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ext supracingular</td>
<td>24 (77.4)</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>posterior cingulate gyrus</td>
<td>7 (18.4)</td>
<td></td>
<td></td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>pure</td>
<td>3 (42.9)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>ext supracingular‡</td>
<td>4 (57.1)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
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<tr>
<td>tumor grade (WHO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LGG</td>
<td>11 (28.9)</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>HGG</td>
<td>27 (71.1)</td>
<td>8</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>age (yrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;50</td>
<td>25 (65.8)</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>≥50</td>
<td>13 (34.2)</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>extent of resection (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥90</td>
<td>32 (83.2)</td>
<td>10</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>&lt;90</td>
<td>6 (16.8)</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>preop KPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥80</td>
<td>32 (83.2)</td>
<td>12</td>
<td>4</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>&lt;80</td>
<td>6 (16.8)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

* There was no statistical correlation between location, tumor grade, age of patients, extent of resection, or KPS score, and postoperative deficits. Abbreviation: S = syndrome.
† This column represents patients whose KPS scores declined > 20 points.
‡ One patient had temporomesial infiltration.
location of the glioma (either anterior vs posterior cingulate gyrus or pure cingulate vs cingulate with supracingular infiltration). Other potentially predictive parameters for the postoperative course such as age or tumor grade showed no statistical correlation with KPS score or postoperative deficits (transient or permanent). Three patients had an improvement of the presenting symptoms (2 patients with aphasia and 1 with a hemiparesis), and in 5 patients the KPS score improved.

**Histopathological Results**

Detailed histopathological results are summarized in Table 3. More than 70% of all patients harbored malignant gliomas (WHO Grades III and IV), and 29% of all tumors were mixed gliomas. Taking into account that our patients were somehow selected because of our specialization in epilepsy surgery with overrepresented low-grade tumors (long-term epilepsy-associated tumors*), the distribution of high- versus low-grade tumors in this small series is similar to large series of patients with primary brain tumors/gliomas.4 As in all patients with supra- or infratentorial gliomas we routinely recommended adjuvant radio- or chemotherapy with high-grade tumors (WHO Grades III and IV).

**Discussion**

Gliomas arising from the cingulate gyrus are rare. Only 3.5% of all supratentorial gliomas surgically treated in our department were located in the anterior or posterior cingulate gyrus, and most of them spread to the surrounding supracingular cortex. There are few reports about surgical treatment of gliomas in the cingulate gyrus,20 and little is known about the functional outcome in this specific entity of paralimbic tumors.

**Clinical Data**

As in other series, the common presenting symptoms for tumors of the cingulate gyrus are seizures.20 This may reflect the epileptogenic disposition of this area like other limbic and paralimbic structures, for example, the insular cortex17,23 or mediobasal tumors of the temporal lobe.56 With infiltration of the surrounding cortical areas there may evolve additional symptoms such as motor or speech deficits. Patients suffering from high-grade gliomas had more often neurological deficits and worse KPS scores preoperatively than those with low-grade gliomas.

**Intraoperative Approach**

The rate of GTR of gliomas in the cingulate gyrus (> 90%) in our series was 84%; when eloquent areas were infiltrated a substantial cytoreduction (> 70%) was achieved in 13%. In 1 patient a 2-step resection was necessary because of technical breakdown of intraoperative monitoring in the first operation.

For most pure cingulate gliomas, the interhemispheric approach is feasible, and this approach led to complete tumor resection in 9 of 10 patients. We used a transcortical approach for most cases with supracingular infiltration, particularly when the tumor reached the surface of the hemisphere. With the aid of neuronavigation and electrophysiological monitoring, the orientation in the respective area and relationship to eloquent areas of these deep-seated tumors is simplified.

**Functional Outcome**

More than one-third of the patients with gliomas in the anterior cingulate gyrus suffered from different degrees of transient motor deficits and/or speech disturbances. Of patients with transient deficits, 85% had extensive supracingular resections. All patients with speech disturbances were resected in the presumably dominant left hemisphere. The rate of permanent, but mostly mild, morbidity was 16%. Unfortunately, 1 patient had a major bleeding episode 2 days postoperatively and remained in a vegetative state.

The SMA syndrome is a well-known sequela after surgery in the superior frontal gyrus. The incidence of transient deficits in the literature after resections of the SMA was up to 89%. Although most authors have described a complete recovery after up to 3 months for motor deficits and up to 8 months for speech disturbance, in all studies concerning motor deficits a low rate of mild but permanent morbidity in terms of disturbed coordination is reported.7,13,27 This may reflect the “normal morbidity” of resections near the central area, but perhaps resection of an SMA is not always without a long-term effect, as most authors have stated. Further studies are needed to evaluate speech impairment in detail to see if there are any subliminal permanent deficits after resections in the SMA.

In our study, SMA syndrome with motor deficits was more frequent when resections were done in the left frontal lobe (not significant). This predominance cannot be found elsewhere in the literature and may be due to the small number of patients in our study.

There was no new somatosensory deficit after resection of gliomas of the posterior cingulate gyrus, but 2 patients (1 patient with a pure cingulate tumor and 1 with supracingular infiltration) suffered from a mild paresis in the contralateral leg, which likely was an effect of retraction after the interhemispheric approach.

### Table 3: Histopathological results*

<table>
<thead>
<tr>
<th>Type</th>
<th>No. of Cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNET (WHO Grade I)</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>ganglioglioma (WHO Grade I)</td>
<td>3 (7.9)</td>
</tr>
<tr>
<td>astrocytoma</td>
<td>12 (31.6)</td>
</tr>
<tr>
<td>(WHO Grade II)</td>
<td>4 (10.5)</td>
</tr>
<tr>
<td>(WHO Grade III)</td>
<td>8 (21.1)</td>
</tr>
<tr>
<td>oligoastrocytoma</td>
<td>11 (28.9)</td>
</tr>
<tr>
<td>(WHO Grade II)</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>(WHO Grade III)</td>
<td>9 (23.7)</td>
</tr>
<tr>
<td>GBM (WHO Grade IV)</td>
<td>10 (26.3)</td>
</tr>
<tr>
<td></td>
<td>38 (100)</td>
</tr>
</tbody>
</table>

* DNET = dysembryoplastic neuroepithelial tumor.
Gliomas of the cingulate gyrus

In the short-term observation period, the rate of postoperative deficits was higher and the KPS score was lower in the group with high-grade gliomas, but we found no statistical significance for an unfavorable course postoperatively with malignant gliomas. Patients with high-grade gliomas had a significantly higher rate of deficits preoperatively (see above).

Conclusions

Gliomas arising from the cingulate gyrus are rare; seizures are the predominant presenting symptoms. A GTR of the mostly malignant tumors is often possible and acceptably safe. In case of resection of gliomas arising from the anterior cingulate gyrus, an SMA syndrome has to be considered.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Acknowledgments

The authors thank their colleagues from the Departments of Neuroradiology and Neuropathology, University Hospital Bonn, for continuous and productive collaboration.

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Manuscript submitted April 14, 2009. Accepted June 1, 2009.

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