Long-term seizure outcome following surgery for
dysembryoplastic neuroepithelial tumor

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Object. Resection of dysembryoplastic neuroepithelial tumor (DNET) is thought to result in favorable seizure outcome, but long-term follow-up data are scarce. The authors present a review of 18 patients who underwent surgical removal of a DNET: 12 via temporal lobectomy and six via lesionectomy.

Methods. The mean long-term follow up was 10.8 years (median 10.4 years, range 7.8 to 14.8 years), and results obtained during this time period were compared with previously reported short-term (mean 2.7 years) seizure outcome data. In the current study, 66.7% patients had an Engel Class I outcome and 55.6% had an Engel Class IA outcome compared with 77.8% and 55.6%, respectively. Temporal lobectomy (Engel Class I, 83.3%; Engel Class IA, 66.7%) led to a better seizure outcome than lesionectomy (Engel Classes I and IA, 33.3%). Two patients (11.1%) required repeated operation and both had an incomplete lesionectomy initially.

Conclusions. Results indicated that complete resection of a DNET leads to a favorable seizure outcome, with epilepsy cure in those who had experienced early postoperative seizure relief. Long-term seizure outcome after surgery is predictable based on the result of short-term follow up.

KEY WORDS • brain tumor • dysembryoplastic neuroepithelial tumor • epilepsy surgery • temporal lobectomy • lesionectomy • long-term outcome

F irst described in 1988 by Daumas-Duport, et al.,11 DNETs are benign intracortical tumors with a maldevelopmental origin, often occurring in association with early-onset complex partial epilepsy that progresses to medically intractable epilepsy. Surgical lesion removal, complete or incomplete, is reported to result in favorable seizure outcome with no evidence of radiological or clinical recurrence.

Authors of many published studies have analyzed DNETs together with other epileptogenic lesions, such as hippocampal sclerosis, low-grade gliomas, or FCD. Reported postsurgical outcomes may not truly reflect results effected by surgical removal of DNETs because seizure outcome may differ due to the underlying pathological entity. In addition, most published studies focusing on DNETs consisted of either a limited number of patients or a short-term follow up. As investigators of postsurgical seizure outcome for other epileptogenic lesions have demonstrated, prolonged longitudinal follow up is essential to understand the true outcome. Late recurrences and “running down phenomena” are not uncommon and vary depending on the underlying pathophysiology.5,37,39

A short-term follow-up (mean 2.7 years) review of 18 patients following resection of DNETs at our institution was reported on by Davis, et al.,13 in 1997. An Engel Class I seizure outcome in 77.8% of patients was achieved. In the current paper we determined the long-term seizure outcome following resection of DNET in the same cohort of 18 patients.

Clinical Material and Methods

Patient Population

Between August 1988 and August 1995, 18 patients with DNETs underwent resection at Austin Hospital. The short-term follow-up (mean 2.7 years) results were published by Davis, et al.,13 in 1997.

Data Collection and Analysis

Data obtained from the original medical records included sex, age at seizure onset, age at operation, preoperative neuroimaging studies, operative site, type of surgery performed, histopathological results, and short-term seizure outcome according to the Engel criteria.15 These data were reconfirmed with a review of the medical records and the Comprehensive Epilepsy Program Database at the hospital.

Evaluation of long-term seizure outcome in the current study was performed through telephone interviews with the patients and their family, family doctors, and neurologists; reviews of the medical records; and reviews of the Comprehensive Epilepsy Program Outcome Database at our hospital. Seizure outcome was graded according to the Engel

Abbreviations used in this paper: AED = antiepilepsy drug; DNET = dysembryoplastic neuroepithelial tumor; FCD = focal cortical dysplasia; MR = magnetic resonance.
Dysembryoplastic neuroepithelial tumors

**Table 1**

Engel classification of postoperative seizure outcome*

<table>
<thead>
<tr>
<th>Engel Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>free of disabling seizures</td>
</tr>
<tr>
<td>A</td>
<td>completely seizure free since surgery</td>
</tr>
<tr>
<td>B</td>
<td>only nondisabling simple partial seizures since surgery</td>
</tr>
<tr>
<td>C</td>
<td>some disabling seizures after surgery, but free of disabling seizures for at least 2 yrs</td>
</tr>
<tr>
<td>D</td>
<td>generalized convulsion w/ AED withdrawal only</td>
</tr>
<tr>
<td>II</td>
<td>rare disabling seizures (almost seizure free)</td>
</tr>
<tr>
<td>A</td>
<td>initially free of disabling seizures, but rare seizures currently</td>
</tr>
<tr>
<td>B</td>
<td>rare disabling seizures since surgery</td>
</tr>
<tr>
<td>C</td>
<td>more than rare disabling seizures after surgery, but rare seizures for at least 2 yrs</td>
</tr>
<tr>
<td>D</td>
<td>nocturnal seizures only</td>
</tr>
<tr>
<td>III</td>
<td>worthwhile improvement</td>
</tr>
<tr>
<td>A</td>
<td>worthwhile seizure reduction</td>
</tr>
<tr>
<td>B</td>
<td>prolonged seizure-free intervals for more than half of the follow-up period, but not less than 2 yrs</td>
</tr>
<tr>
<td>IV</td>
<td>no worthwhile improvement</td>
</tr>
<tr>
<td>A</td>
<td>significant seizure reduction</td>
</tr>
<tr>
<td>B</td>
<td>no appreciable change</td>
</tr>
<tr>
<td>C</td>
<td>seizures worse</td>
</tr>
</tbody>
</table>


**Table 2**

Summary of postoperative seizure outcomes, according to the Engel classification*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Time From Seizure Onset to Surgery (yrs)</th>
<th>Date of Surgery</th>
<th>Type of Op</th>
<th>Follow-Up Period (yrs)</th>
<th>Engel Outcome 1995</th>
<th>Current</th>
<th>Return to Work</th>
<th>AEDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>58</td>
<td>36</td>
<td>01/18/1993</td>
<td>ant TL + H</td>
<td>10.4</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>30</td>
<td>28</td>
<td>11/06/1989</td>
<td>ant TL + H</td>
<td>13.6</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>22</td>
<td>20</td>
<td>08/16/1990</td>
<td>ant TL + H</td>
<td>12.8</td>
<td>ID</td>
<td>IVC</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>49</td>
<td>20</td>
<td>01/28/1993</td>
<td>ant TL + H</td>
<td>10.4</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>39</td>
<td>15</td>
<td>09/03/1992</td>
<td>ant TL + H</td>
<td>13.8</td>
<td>IB</td>
<td>IIIA</td>
<td>Y</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>48</td>
<td>36</td>
<td>03/31/1993</td>
<td>lat TL</td>
<td>10.3</td>
<td>IB</td>
<td>IB</td>
<td>Y</td>
</tr>
<tr>
<td>7</td>
<td>23</td>
<td>24</td>
<td>14</td>
<td>06/02/1989</td>
<td>ant TL + H</td>
<td>10.0</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>32</td>
<td>14</td>
<td>10/02/1989</td>
<td>ant TL + H</td>
<td>12.7</td>
<td>ID</td>
<td>IC</td>
<td>Y</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>32</td>
<td>22</td>
<td>06/08/1994</td>
<td>pst temporal lesionectomy†</td>
<td>9.0</td>
<td>IVB</td>
<td>IB</td>
<td>Y</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>11</td>
<td>4</td>
<td>10/03/1994</td>
<td>ant TL + H</td>
<td>8.7</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>14</td>
<td>12</td>
<td>05/12/1994</td>
<td>ant TL + H</td>
<td>9.1</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>12</td>
<td>18</td>
<td>25</td>
<td>7</td>
<td>08/31/1988</td>
<td>ant TL + H</td>
<td>14.8</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>13</td>
<td>30</td>
<td>38</td>
<td>8</td>
<td>02/21/1990</td>
<td>ant TL + H</td>
<td>13.3</td>
<td>IA</td>
<td>IA</td>
<td>N</td>
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<tr>
<td>14</td>
<td>24</td>
<td>25</td>
<td>1</td>
<td>08/14/1995</td>
<td>frontal lesionectomy</td>
<td>7.8</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>15</td>
<td>22</td>
<td>22</td>
<td>&lt;1</td>
<td>10/06/1994</td>
<td>frontal lesionectomy</td>
<td>8.7</td>
<td>IA</td>
<td>IA</td>
<td>Y</td>
</tr>
<tr>
<td>16</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>05/04/1995</td>
<td>frontal lesionectomy</td>
<td>8.1</td>
<td>IIIA</td>
<td>IID</td>
<td>Y</td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>20</td>
<td>12</td>
<td>12/03/1992</td>
<td>parietal lesionectomy</td>
<td>10.5</td>
<td>IIIA</td>
<td>IIIA</td>
<td>Y</td>
</tr>
<tr>
<td>18</td>
<td>13</td>
<td>43</td>
<td>30</td>
<td>09/17/1992</td>
<td>parietal lesionectomy‡</td>
<td>10.8</td>
<td>IIIIB</td>
<td>IID</td>
<td>Y</td>
</tr>
</tbody>
</table>

* H = hippocampectomy; op = operation; pst = posterior; TL = temporal lobectomy.
† A repeated operation was performed 12/21/1995 for residual DNET.
‡ A repeated operation was performed 12/13/2001 for FCD.

Results

**General Results**

Eighteen patients underwent resection of a DNET within the period specified in Table 2. There were eight male and 10 female patients in the cohort. The documented age at seizure onset ranged from 2 to 30 years (mean 15 years and median 16 years), whereas the age at operation ranged from 8 to 58 years (mean 30 years and median 28 years). All patients had medically intractable epilepsy, with a duration ranging from 0.5 to 36 years (mean 15 years).

Twelve patients underwent temporal lobectomy: 11 anterior temporal lobectomy with hippocampectomy and one lateral temporal lobectomy. Six patients underwent lesionectomy. The sites of lesionectomy included the frontal lobe (three patients), parietal lobe (two patients), and posterior temporal lobe (one patient).

All patients had undergone preoperative computerized tomography and MR imaging. Fluorine-18 fluorodeoxyglucose positron emission tomography scans were obtained in seven patients. Imaging findings have been previously described.

The pathological specimens obtained in all 18 patients were reviewed. This analysis confirmed 15 complex DNETs and three mixed DNET–gangliogliomas, the latter of which were all situated in the temporal lobe.

All 18 patients were successfully contacted, with no loss to follow up. The mean duration of follow up was 10.8 years (median 10.4 years and range 7.8–14.8 years).

**Overall Seizure Outcome**

A short-term follow up (mean 2.7 years) of postoperative seizure outcomes using the Engel classification scheme previously revealed that 14 patients (77.8%) achieved Engel classification (Table 1). Reports on the patients’ most recent MR images of brain were also obtained.

**Statistical Analysis**

Statistical analysis was performed using the chi-square test to evaluate the possible significance of temporal lobectomy and lesionectomy on prognosis. Results were considered significant at a probability value less than 0.05.
Class I; no patient (0%) Class II; three patients (16.7%), Class III; and one patient (5.6%), Class IV (Fig. 1).

In our long-term follow-up study (mean 10.8 years), 12 patients (66.7%) achieved Engel Class I; four patients (22.2%), Class II; one patient (5.6%), Class III; and one patient (5.6%), Class IV.

All 10 patients (55.6%) with complete seizure freedom (Engel Class IA) at the postsurgical short-term follow up remained seizure free at the long-term follow up.

**Temporal Lobectomy Compared With Lesionectomy**

During the short-term follow up, all 12 patients (100%) who had undergone temporal lobectomy for a DNET achieved an Engel Class I seizure outcome; in particular, eight among these patients (66.7%) achieved an Engel Class IA seizure outcome (Fig. 2). In contrast, only two (33.3%) of six patients attained Engel Class I and IA seizure outcomes following lesionectomy.

During the long-term follow up, 10 (83.3%) of 12 patients who had undergone temporal lobectomy for a DNET achieved an Engel Class I seizure outcome; only two (33.3%) of six patients who had undergone lesionectomy attained a Class I outcome. The difference between the two procedures was statistically significant (p < 0.05, chi-square test). The trend for this difference remained but was not statistically significant for Engel Class IA outcomes of 66.7% (eight of 12 patients) and 33.3% (two of six patients) for temporal lobectomy and lesionectomy, respectively.

All eight patients who had been seizure free since the temporal lobectomy for a DNET (Engel Class IA) at the short-term follow up continued to be seizure free at the long-term follow up (Table 2). Similarly, the two patients who had been seizure free (both harbored frontal lobe DNETs) at the short-term follow up after lesionectomy remained seizure free at the long-term follow up.

**Functional Outcome**

Ten (55.6%) of 18 patients were not taking any AEDs at the most recent review. Eight (80%) of the 10 patients with an Engel Class IA seizure outcome remained so without AEDs. Eight (66.7%) of 12 patients from the temporal lobectomy group were off medication compared with two (33.3%) of six patients from the lesionectomy group.

Sixteen patients (88.9%) were able to return to work: 15 patients resumed fulltime or parttime work and one woman resumed full domestic duties. The two patients who did not return to work belonged to the temporal lobectomy group. One of these patients had poor short-term memory function; the other reported that her seizures became worse following an alleged assault.

**Repeated Operation**

Two patients (11.1%) required a repeated operation (Table 2); both (Cases 9 and 18) belonged to the lesionectomy group (Engel Class IVB and IIIB, respectively), for a rate of 33.3% in the lesionectomy group. One patient had residual DNET and the other had residual FCD. Both patients experienced improvement after the repeated operation (Engel Classes IIIB and IID). None of the patients from the temporal lobectomy group required repeated operation. The difference between the two groups in terms of the repeated operation rate was statistically significant (p < 0.05, chi-square test).

**Changes in Seizure Outcome Between the Two Follow-Up Periods**

Between the two follow-up periods, two patients (Cases 8 and 16) had an improvement in seizure outcome from Engel Classes ID and IIIA to IC and IID, respectively. During the same 8-year period, two patients (Cases 3 and 5) suffered deterioration in seizure outcome from Engel Classes ID and IB to IVC and IIA, respectively. Note, however, that the deterioration in seizure outcome reported by the patient in Case 3 could not be verified. She had undergone a left temporal lobectomy and hippocampectomy for a left parahippocampal mixed DNET–ganglioglioma in 1990. At the 5-year postoperative review, she had experienced only one generalized tonic–clonic seizure after withdrawal of AEDs (Engel Class ID). Her most recent review was complicated by numerous psychosocial, legal, and compensation issues. She reported experiencing two to three complex partial seizures every month and two to three generalized tonic–clonic seizures every year. The seizures reportedly followed an alleged assault, with seizure frequency and intensity being worse than those suffered preoperatively (Engel Class IVC). Despite this circumstance, she refused AEDs and neurological reviews. Her latest MR image (4 months ago) did not furnish evidence of a DNET recurrence or any other potential cause for the seizures.
Comparison With Published Results

A comparison with other published results is represented in Table 3. Only those studies with at least five patients with DNETs are included.

Neuroimaging Follow Up

A review of each patient’s follow-up MR image (range 3 months–13 years postoperatively) was conducted. There was no recurrence demonstrated on neuroimaging at a mean follow up of 4 years.

Discussion

Disease Origin and Pathological Features

The term “DNET” was introduced by Daumas-Duport, et al.,11 in 1988, following a review of 39 patients from St. Anne Hospital and the Mayo Clinic. These lesions were originally thought to have an origin in dysembryogenesis,31 although debates continue about their nature, from malformation in cortical development to outright neoplasm. Barkovich, et al.,4 classified DNETs as “malformations due to abnormal neuronal and glial proliferation, abnormal cell types, neoplastic, associated with disordered cortex” as well as gangliogliomas and gangliocytomas. This view is supported by the existence of FCD in the vicinity or as part of DNETs. Recently, Palmimi, et al.,46 classified DNETs together with gangliogliomas as dysplastic tumors representing the extreme end of the histopathological spectrum of FCD. Note, however, that most neuropathologists and neurosurgeons consider the lesion to be outright neoplastic, albeit developmental in origin. Daumas-Duport, et al.,11 described them as neoplastic in their original classification. According to the World Health Organization classification of tumors (2000), DNETs are included in the category of neuronal and mixed neuronal–glial tumors, corresponding histologically to Grade I.10 Authors of several studies focused on DNET cell kinetics tend to support this view.9,20 The proliferative labeling index with antibodies to Ki-67 (MIB-1) can be as high as those observed in more malignant glial tumors. Both neoplastic and dysplastic views have merit. Perhaps there is an association or overlap between developmental and neoplastic biological features typified by the mixed glioneural tumors such as DNETs.

Three histological forms of DNETs have been described, but this subclassification is thought to carry no clinical, management, or prognostic implication.6–12 The complex type is the form of DNET originally described by Daumas-Duport and colleagues11 in 1988. It consists of specific glioneural elements that form columnar structures, glial nodules that give the tumor a multinodular architecture, and foci of cortical dysplasia. The simple form, described in 1993, consists of only the unique glioneural element without additional nodular components.9 The more controversial non-specific variant of DNET, lacking the glioneural component and multinodular architecture but resembling astrocytoma, was proposed in 1999 to account for tumors histologically indistinguishable from low-grade gliomas but associated with a similar clinical presentation and neuroradiological profile and absent clinicoradiological recurrence on follow up.12

We found three cases of mixed DNET–ganglioglioma.

TABLE 3

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Follow Up (yrs)</th>
<th>% Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authors &amp; Year</td>
<td>w/ DNET</td>
<td>Mean</td>
</tr>
<tr>
<td>present study</td>
<td>18</td>
<td>10.8</td>
</tr>
<tr>
<td>Daumas-Duport, et al., 1988</td>
<td>39</td>
<td>9.0</td>
</tr>
<tr>
<td>Luyken, et al., 2003</td>
<td>25</td>
<td>8.0†</td>
</tr>
<tr>
<td>Fernandez, et al., 2003</td>
<td>14</td>
<td>7.3</td>
</tr>
<tr>
<td>Kirkpatrick, et al., 1993</td>
<td>27</td>
<td>5.8</td>
</tr>
<tr>
<td>Aronica, et al., 2001</td>
<td>13</td>
<td>5.0</td>
</tr>
<tr>
<td>Nolan, et al., 2004</td>
<td>26</td>
<td>4.3</td>
</tr>
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<td>20</td>
<td>3.2</td>
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<td>5</td>
<td>2.9</td>
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<td>74</td>
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<td>21</td>
<td>NR</td>
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<tr>
<td>Wolf, et al., 1995</td>
<td>43</td>
<td>NR</td>
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<tr>
<td>Østertun, et al., 1996</td>
<td>16</td>
<td>NR</td>
</tr>
<tr>
<td>Koeller &amp; Dillon, 1992</td>
<td>6</td>
<td>NR</td>
</tr>
<tr>
<td>Zentner, et al., 1995</td>
<td>19</td>
<td>NR</td>
</tr>
<tr>
<td>Reis, et al., 2000</td>
<td>6</td>
<td>NR</td>
</tr>
</tbody>
</table>

* NR = not reported; † Number represents median value.

Few cases of this lesion have been reported since it was first described by Daumas-Duport in 1993,5,21,45,58. This mixed form was postulated to represent a “transitional form” not requiring differentiation from other DNETs on the basis of prognostic or therapeutic significance.18 Authors of several published studies have suggested a small risk of malignant transformation in ganglioglioma.1,3,12,33,34,55,57 It is unclear whether this risk applies to the ganglioglioma component of the mixed DNET–ganglioglioma. The three patients with the mixed form in our study experienced no lesion recurrence or progression according to neuroimaging studies at a mean long-term follow up of 10.8 years; the number of cases is too small to permit any definite conclusions, however.

A predilection for a cerebral cortex site is a distinguishing feature of DNETs, with the temporal lobe (especially medial structures) being the most common location.6–12,22,49,64 In our series, two-thirds of the DNETs were located in the temporal lobe, with the other third situated in extratemporal supratentorial cortices. Data from recent case studies have shown that DNETs also exist in the caudate nucleus and other subcortical regions, such as the cerebellum and brainstem. This phenomenon corresponds to the topography of the secondary germinal layers and is consistent with the hypothesis that DNETs arise from the secondary germinal center.2,7,17,30,32,35,36,44,49,62,65 Some DNETs exist as part of multifocal lesions.35,49

Clinical Presentations

In epilepsy surgery, the incidence of DNETs has been quoted to range from 0.8 to 19%.36–12,42,45,47,64 In our experience, 18 DNETs were identified from 337 resections for
only 44% of patients in our series had an age between 11 and 30 years at the time of surgery. This rate is less than that in other published series, perhaps given the fact that we provide a predominantly adult neurosurgery service.

Patients with DNETs usually present as children or young adults with partial seizures. These seizures progress to medically refractory partial epilepsies with or without secondary generalization. Some authors have reported the presence of focal deficits in as many as 15% of patients with DNETs.\(^3,11\) Headache due to raised intracranial pressure may be a presenting feature in approximately 5% of patients.\(^11,18,52\) Rare cases of spontaneous intralesional hemorrhage have been reported,\(^3,6\) and most of these are usually chronic and insidious. In our series, all patients presented with pharmacoresistant seizures as the predominant feature and none had an abnormal neurological examination.

**Imaging Findings**

The neuroimaging features of DNETs have previously been reported.\(^8,11,16,20,31,34,45,50–52,59,60\) On computerized tomography scanning, these lesions are usually intracortical, hypodense, and well-demarcated. Occasionally, calcification and contrast enhancement may be present. Often, there is calvarial remodeling, suggestive of a longstanding lesion. Vasogenic edema and mass effect are rarely observed. On MR imaging studies, they usually have a low signal on T2-weighted images and a high signal on T1-weighted images, with occasional Gd enhancement. The lesion may have a megagyric or pseudocystic appearance. The increased sensitivity of MR imaging in revealing and delineating DNETs partly explains the increased detection and treatment of DNETs as well as the better postoperative outcomes in patients with symptomatic epilepsy.

**Surgery and Outcome**

There is consensus in the literature that DNETs are benign and do not require adjuvant chemotherapy or radiotherapy. Resection, complete or incomplete, is thought to result in a favorable postoperative seizure outcome with no clinically or neuroimaging-demonstrated recurrence. Note, however, that authors of most of these studies analyzed DNETs combined with other epileptogenic lesions, included a limited number of patients, or reported on a relatively short-term follow up. The results of seizure outcome after resection of DNETs might be skewed by the inclusion of epileptogenic lesions with better (such as cavernoma) or worse (such as FCD) seizure prognosis. Studies with small sample sizes might not have enough power to reveal patients with poor seizure outcome. The duration of the follow up is important. As discussed earlier, a late recurrence and the “run-down phenomenon” were noted in the long-term follow up of patients following resection for hippocampal sclerosis.\(^6,7,39\) It is uncertain whether these factors also apply to DNETs. Furthermore, a short-term follow up may not have revealed any possibility of regrowth, recurrence, or malignant transformation. Hammond, et al.,\(^19\) reported on a case of a complex DNET that had undergone malignant transformation to a glioblastoma multiforme 11 years after the initial subtotal resection. It is possible that the two lesions might have been merely coincidental. Perhaps the original lesion was a mixed DNET-ganglioglioma, and the malignant transformation actually occurred in the previously unrecognized focus of the ganglioglioma. These authors attributed the lack of other reported cases to the absence of long-term follow up on DNETs. This case again highlights the need for studies on long-term follow ups after resection of DNETs.

**Long-Term Seizure Control**

The longest mean follow up was 10.8 years (median 10.4 years) after resection of DNETs, although the minimal follow up of 7.8 years was more representative of the true long-term outcome.

Table 3 is a summary of all published series consisting of five or more cases of DNETs. The incidence of an Engel Class I seizure outcome ranges from 52.4 to 90.0%.\(^3,11,13,14,16,23,24,29,36,43,45,51–53,63,66\) This favorable outcome was achieved in 66.7% of the patients in the current series. Note that the patients in our analysis were older at seizure onset (mean 15 years old), had epilepsy for a longer period before surgery, and were older at surgery. Given the retrospective nature of our study, it was not always possible to determine the reason for a delay in surgery. Most of the patients experienced seizure onset before the advent of MR imaging and were identified for surgery during the early MR imaging era; therefore, patients suffered a longer duration of epilepsy prior to surgery. A longer duration of epilepsy has been associated with a poorer postoperative seizure outcome.\(^4,8\) This result may be explained by the “kindling effect” theory, which suggests the recruitment of a perilesional or remote secondary epileptogenic zone with repeated seizure activity.\(^2,6,8\) Improved detection rates and shorter time intervals before surgery may account for the better outcome observed in recent series. Furthermore, one third of the patients in our study had extratemporal DNETs, a location associated with a worse postoperative seizure outcome than those with temporal lesions. These factors were previously found to be associated with a poorer postoperative seizure outcome.\(^5,15\) In addition, we were particularly stringent with seizure outcome measurement. Even though one may question whether the patient in Case 3 actually suffered from worsening seizures (Engel Class I to IV), we labeled her as such. She thus represented one of two patients who no longer had an Engel Class I outcome when compared with the short-term seizure status. All 18 patients underwent surgery in the late 1980s and early 1990s. Improvements in neuroimaging and surgical technique may account for better results in the more recent studies.

**Short-Term Seizure Control Predicts Long-Term Seizure Control**

Our results also showed that immediate postoperative seizure control is remarkably stable over several years. All patients who were seizure free (Engel Class IA) at the mean short-term follow up of 2.7 years (seizure freedom rate 55.6%) remained seizure free at a mean long-term follow up of 10.8 years (seizure freedom rate 55.6%). Comparing long-term and short-term follow up, 11% of the patients improved, 11% deteriorated, and 11% required repeated operation. There were few major changes in the classification of seizure outcome between the two follow-up periods. These
findings are in agreement with those of Aronica, et al., who studied a cohort of 13 patients (mean age at operation 27 years, mean age at seizure onset 11 years) with a 5-year follow up and found no difference in the seizure freedom rate between the 1-year short-term follow up (58%) and the 5-year long-term follow up (58%).

Nolan, et al., reviewed a cohort of 26 children (mean age at surgery 10 years, mean age at seizure onset 7 years) and reported a decrease in seizure freedom—an Engel Class I outcome—in 85% of the patients at 12 months postsurgery and in 62% at a mean follow up of 4.3 years postsurgery. Results of the Kaplan–Meier survival curve revealed that a 3-year seizure-free outcome was still predictive of long-term outcome; all seizures recurred before the 3rd postoperative year.

On the basis of these results, a patient who is seizure free 3 years after resection of a DNET can be considered cured. Persistent seizures may be due to residual lesions. No recurrent lesion was noted during our long-term follow up. Both patients who had undergone a repeated operation in our series harbored residual lesions that served as persistent seizure foci. These findings contrast with the accepted view that the resection of DNETs, complete or incomplete, leads to favorable seizure outcome. In both cases, repeated surgery resulted in improved seizure outcome; therefore, it is recommended in patients who, after subtotal resection, continue to have seizures because of the residual DNET, provided that eloquent cortex can be preserved. Adjuvant radiotherapy and chemotherapy in patients with subtotally resected DNETs should be avoided. Daumas-Dupont, et al., found that in patients with subtotally resected DNETs, radiotherapy and chemotherapy did not confer any additional benefit in seizure or oncological outcome but were complicated by visual field abnormalities and radionecrosis. Rushing, et al., reported on a case of the malignant transformation of a subtotally resected DNET into an anaplastic astrocytoma 3 years after adjuvant radiotherapy and chemotherapy. These study data reveal that there is no role for radiotherapy and chemotherapy in the management of subtotally resected DNETs.

Temporal Compared With Extratemporal DNETs

Consistent with data in other lesional epilepsy surgery studies, temporal lobectomy for DNETs led to a significantly better postoperative seizure outcome than did extratemporal lesonectomy in our series. One third of the patients who had undergone lesonectomy required a repeated operation. In contrast, no repeated surgery was required in patients who had undergone temporal lobectomy. The difference in outcome may be explained by several factors. First, extratemporal lesonectomies are more likely to result in incomplete DNET resections, especially in eloquent cortical regions. Second, DNETs are commonly embedded within dysplastic cortex, which is more likely to be removed when performing a temporal lobectomy. In comparison, residual dysplastic cortex is more likely to be spared during an extratemporal lesonectomy. These residual epileptogenic tissues may explain the difference in outcomes between temporal lobectomy and extratemporal lesonectomy.

Conclusions

Dysembryoplastic neuroepithelial tumors are benign epi-leptogenic lesions that occur in young patients. Complete resection of these lesions produces a favorable postoperative seizure outcome without tumor recurrence or progression, especially in cases of temporal lesions. Postoperative seizure outcome remains fairly stable over the years, and long-term seizure freedom is predictable based on a short-term follow up of 2 to 3 years. Incomplete resection of DNETs may lead to persistent seizure activity; however, repeated surgery in such cases leads to improved seizure control.

References

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