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Neuroimaging of a pilocytic astrocytoma with anaplastic features and diffusion tensor imaging characteristics

Lara Walkoff, MD; Andrew J. Degnan, MD; Mark Ghassibi; Robert V. Jones, MD; Jonathan H. Sherman, MD; and Lucien M. Levy, MD, PhD

We report the MRI findings of an adult patient with a (rare in adults) biopsy-proven pilocytic astrocytoma with anaplastic features. Diffusion tensor imaging may potentially provide information on cell proliferation, vascularity, and fiber destruction, which can have implications for treatment and prognosis. In this case, tractography and fractional anisotropy maps demonstrated displacement of adjacent parenchyma and relatively intact fractional anisotropy, suggesting a pilocytic rather than an anaplastic astrocytoma.

Case report

A 57-year-old Caucasian female with a known history of a 20-year, stable midline cerebellar mass presented with severe gait ataxia. Conventional brain MRI scans included diffusion tensor imaging (DTI). MRI data was processed to obtain tractography and fractional anisotropy (FA) maps using GE FuncTools software. MR images were examined for extent and location of tumor as well as invasion, destruction, or displacement of brain parenchyma and white-matter tracts. A 4.0 x 3.9-cm solid cystic lesion with lobulated margins in the cerebellar vermis was observed on T2-weighted MRI (Figs. 1A, 1B), which had increased in size from prior studies. There was also herniation of the vermis with effacement of the quadrigeminal plate cistern, mild herniation of cerebellar tonsils below the level of foramen magnum, and partial obstruction of CSF outflow at the level of the 4th ventricle. Tractography (Figs. 2A, 2B) and FA maps (Fig. 3) suggested on the basis of imaging that fiber tracts surrounding the lesion were displaced, but fiber integrity (as represented by fractional anisotropy) was maintained. This suggested a less aggressive type of neoplastic lesion.

The patient underwent tumor-debulking surgery via a suboccipital craniotomy, with good outcome. The histopa-
Thology showed a largely circumscribed astrocytoma with associated macrocysts, microcalcifications, eosinophilic granular bodies, and rare Rosenthal fibers, consistent with a benign entity such as a pilocytic astrocytoma (PA) (Fig. 4). However, focally localized atypical features were also present, including a hypercellular focus with increased mitotic activity and pseudopalisading necrosis, and vascular proliferation, consistent with PA with anaplastic features (Fig. 5). Immunohistochemistry demonstrated GFAP positivity, p53 negativity, and focally positive MIB1 labeling. In light of this patient's longstanding history of a midline cerebellar mass, it is likely that this mass may have been a stable nonanaplastic PA that eventually developed anaplastic features around the time of symptom progression.

A followup MRI performed three months after resection demonstrated expected postoperative changes without evidence to suggest recurrence.

Discussion

This case presents unusual findings, as PA is unusual in adulthood. Typically, PAs present as benign cystic neoplasms (features are outlined in the summary table). PAs
Neuroimaging of a PA with anaplastic features and diffusion tensor imaging characteristics

Figure 6. 57-year-old female with a midline cerebellar pilocytic astrocytoma with anaplastic features. Comparison case of a 68-year old male with focal glioblastoma in cerebellum on conventional T2-weighted MRI (A, arrow). Fractional anisotropy (B) map shows decreased anisotropy (arrow), and tractography axial and coronal maps (C, D) demonstrate imaging-based invasion and destruction of adjacent fiber tracts (arrows). Brighter pixels have higher anisotropy; normal fractional anisotropy is shown as white.

with anaplastic features are even less common, composing an estimated 1.7% of PAs (1). In one study examining 34 cases of PA with anaplastic features, 24% were associated with neurofibromatosis type 1, and 12% were associated with prior irradiation of a PA (1), neither of which were present in this patient. Typically, PA occurs in the cerebral hemispheres in adult patients, whereas cerebellar midline PAs are more common in the pediatric population. On MRI, PAs usually appear intense to hypointense on T1-weighted imaging and may have a hyperintense cystic portion, mixed signal soft-tissue portion, and enhancement of a mural nodule on T2-weighted imaging. Occasionally, necrosis with a central nonenhancing zone is present; however, hemorrhage is rare (2).

While there are currently no definitive diagnostic criteria for PAs with anaplastic features, histopathologically, they are similar to PAs, containing eosinophilic granular bodies, microcysts, and Rosenthal fibers. A PA with anaplastic features often contains greater than 4 mitoses per 10 high-powered fields (HPF), as well as pseudopalisading necrosis (1), both features of the lesion in this case.

Clinically, the most common presenting feature of PA in adults is headache, and in one study, 20% of patients presented with truncal ataxia (3). The behavior and prognosis of such entities are notoriously difficult to predict, but they are typically more aggressive with less favorable prognoses than PAs without anaplastic features (2). From a neuroimaging standpoint, initial CT and MRI findings such as lesion size, location, and classification have historically been inadequate in predicting clinical course (4). From a histopathologic standpoint, features such as history of radiation, of PA precursor, and of necrosis have been associated with a decreased progression-free survival (1). While PAs with anaplastic features do not have defined criteria under World Health Organization (WHO) classification, evidence suggests that PAs with anaplastic features and pseudopalisading necrosis behave similarly to WHO grade-3 neoplasms (1).

Recently, an increasing number of studies have been published on the use of diffusion tensor imaging (DTI), examining tractography and FA values for pre-operative planning to allow for optimal resection and preservation of clinically significant fiber tracts. By measuring diffusion of water along white-matter tracts, DTI can be used to demonstrate fiber tracts. FA also reflects the 3-D directional variations of water motion. Tractography and FA maps have been used to classify a tumor’s effect on fiber tracts, such as disruption, displacement, infiltration, or edema (5-7), in an attempt to better classify the histopathologic and behavioral characteristics of the tumor. It should be noted that these are imaging-based terms; apparent disruption by tractography may be a limitation of the technique and may not be analogous to disruption of white-matter tracts. Additionally, using FA values for regions of interest around the tumor and comparing them with those on the contralateral side, a variation in FA value can be calculated and used to classify the tumor into one of the aforementioned categories (6).

As a comparison case, we also include images from an adult male with a cerebellar glioblastoma multiforme (GBM) (Fig 6A), a comparison included in the differential table. Tractography and FA mapping demonstrate destruction rather than displacement of adjacent fiber tracts (Figs. 6A-D).

We report here the imaging findings of a biopsy-proven pilocytic astrocytoma with anaplastic features. Tractography and qualitative FA maps were used to attempt to predict the behavior of the mass and its effect on the adjacent fiber tracts, and revealed imaging-based displacement of the fiber tracts instead of destruction. We postulate that this patient had a bland nonanaplastic PA that then developed focal anaplastic features. The patient’s followup MRI at three months revealed no evidence of recurrence; however, close monitoring will be required, as the limited extant literature suggests that PA with anaplastic features may have a high recurrence rate.

Pilocytic astrocytomas with anaplastic features are rare entities with notoriously unpredictable behavior. DTI with tractography and fractional anisotropy mapping can be helpful for both presurgical planning and for predicting the tumor’s behavior with regard to adjacent fiber tracts.
Acknowledgments

We thank Fausto Rodriguez of The Johns Hopkins University Hospital for his consultation on the pathologic specimen.

Summary table

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Often unknown cause, but have been seen to arise from a previous PA precursor</th>
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<tbody>
<tr>
<td>Incidence</td>
<td>Approximately 1.7% of all PAs</td>
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<tr>
<td>Gender ratio</td>
<td>N/A</td>
</tr>
<tr>
<td>Age prediction</td>
<td>Third decade</td>
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<tr>
<td>Treatment</td>
<td>Surgical resection</td>
</tr>
<tr>
<td>Prognosis</td>
<td>Difficult to predict, but most often behaves as a WHO grade 2 or 3 tumor</td>
</tr>
<tr>
<td>Findings on imaging</td>
<td>Usually appear intense to hypointense on T1-weighted imaging and have a hyperintense cystic portion, mixed signal soft-tissue portion, and enhancement of a mural nodule</td>
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Differential table

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>MRI</th>
<th>MRI-DWI</th>
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<tbody>
<tr>
<td>Typical PA</td>
<td>PAs usually appear intense to hypointense on T1-weighted imaging and have a hyperintense cystic portion, mixed signal soft-tissue portion, and enhancement of a mural nodule; surrounding edema may be present</td>
<td>Tractography and FA mapping show displacement of adjacent fiber tracts</td>
</tr>
<tr>
<td>PA with anaplastic features</td>
<td>Similar to PA</td>
<td>Similar to PA</td>
</tr>
<tr>
<td>Glioblastoma multiforme</td>
<td>Similar to PA</td>
<td>Tractography and FA mapping show displacement and destruction of adjacent fiber tracts</td>
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References