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

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

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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
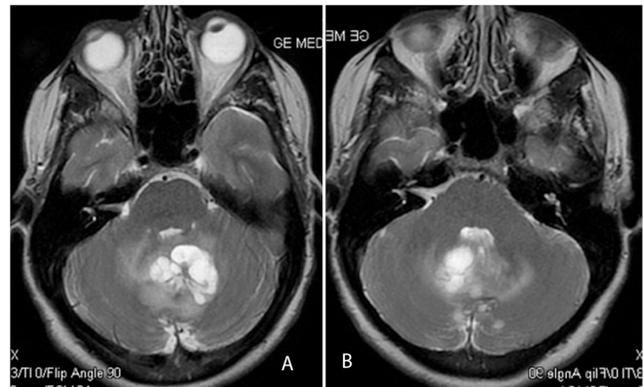

Figure 1. 57-year-old female with a midline cerebellar pilocytic astrocytoma with anaplastic features. Conventional MRI T2-weighted scans show a solid and cystic cerebellar mass with surrounding edema on two contiguous slices (**A**, **B**).

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-

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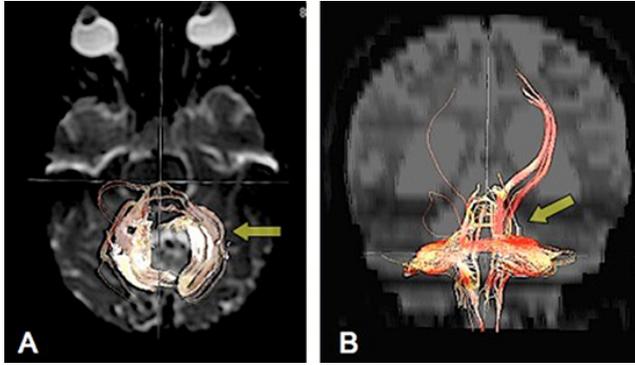
Figure 2. 57-year-old female with a midline cerebellar pilocytic astrocytoma with anaplastic features. Diffusion tensor axial (**A**) and coronal (**B**) tractography in this patient demonstrates displaced but intact cerebellar fiber tracts surrounding the lesion.

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.
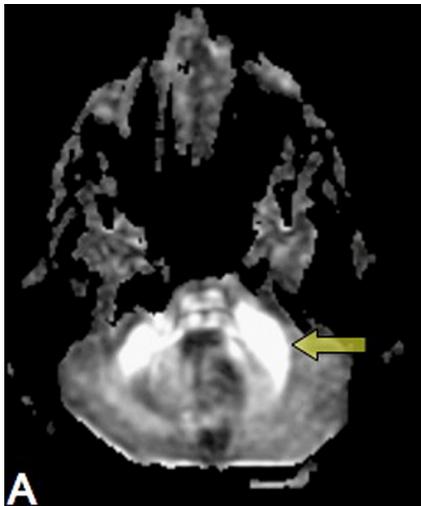

Figure 3. 57-year-old female with a midline cerebellar pilocytic astrocytoma with anaplastic features. Fractional anisotropy map in this patient shows intact fiber integrity surrounding the lesion. Brighter pixels have higher anisotropy; normal fractional anisotropy is shown as white.

A followup MRI performed three months after resection demonstrated expected postoperative changes without evidence to suggest recurrence.
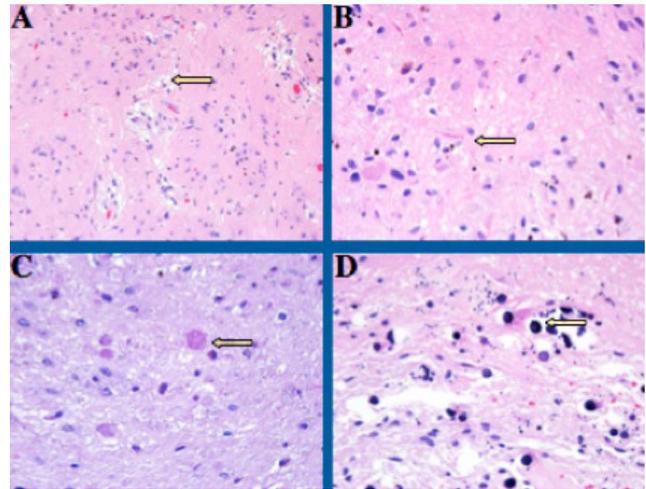
Figure 4. 57-year-old female with a midline cerebellar pilocytic astrocytoma with anaplastic features. Tumor histology in patient shows features (arrows). **A**. Dense and loose zones with microcysts. **B**. Rosenthal fibers and hemosiderin. **C**. Eosinophilic granular bodies. **D**. Microcalcifications.
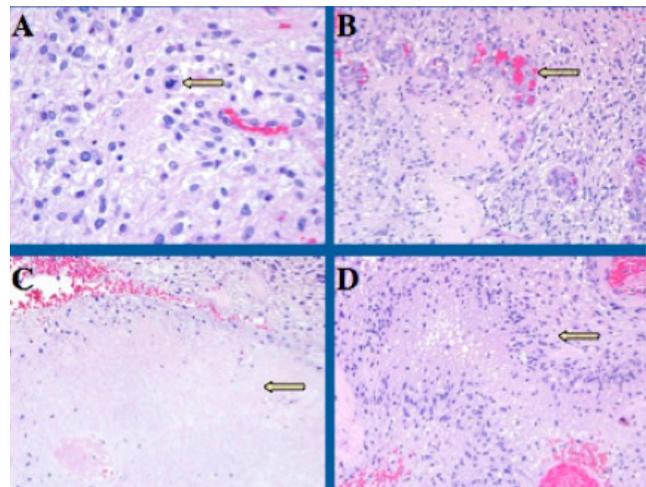
Figure 5. 57-year-old female with a midline cerebellar pilocytic astrocytoma with anaplastic features. Tumor histology in patient shows features (arrows). **A**. Mitotic figures. **B**. Vascular proliferation. **C**. Nonpalisading necrosis. **D**. Necrosis with a pseudopalisade.

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
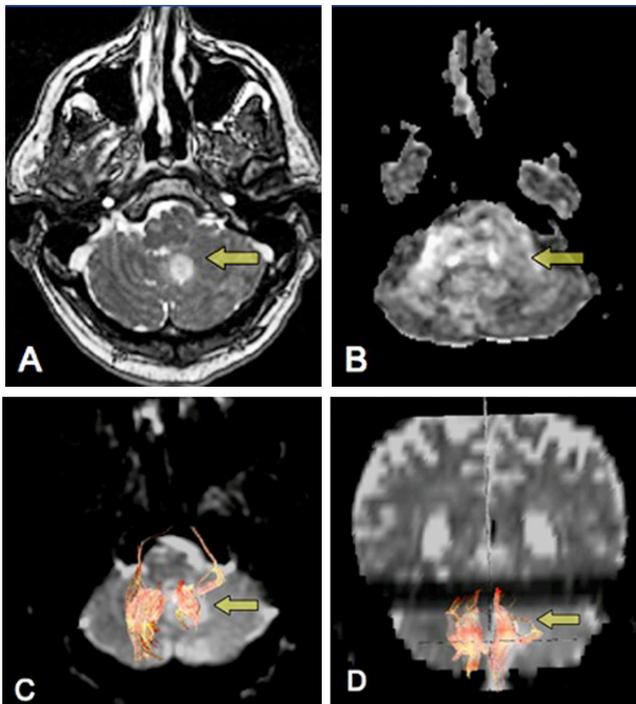
Figure 6. 57-year-old female with a midline cerebellar pilocytic astrocytoma with anaplastic features. Comparison case of a 68-year old male with focal glioblastoma in cerebellum on conventional T2-weighted MRI (**A**, arrow). Fractional anisotropy (**B**) map shows decreased anisotropy (arrow), and 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 pre-

sented 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.

Summary table

Etiology	Often unknown cause, but have been seen to arise from a previous PA precursor
Incidence	Approximately 1.7% of all PAs
Gender ratio	N/A
Age prediction	Third decade
Treatment	Surgical resection
Prognosis	Difficult to predict, but most often behaves as a WHO grade 2 or 3 tumor
Findings on imaging	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

Differential table

Diagnosis	MRI	MRI-DWI
Typical PA	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	Tractography and FA mapping show displacement of adjacent fiber tracts
PA with anaplastic features	Similar to PA	Similar to PA
Glioblastoma multiforme	Similar to PA	Tractography and FA mapping show displacement and destruction of adjacent fiber tracts

References

1. Rodriguez F, Scheithauer B, Burger P, Jenkins S, Giannini C. Anaplasia in pilocytic astrocytoma predicts aggressive behavior. *Am J Surg Pathol.* 2010 Feb;34(2):147-60 [PubMed]
2. Azad A, Deb S, Cher L. Primary anaplastic pilocytic astrocytoma. *J Cli Neurosci.* 2009 Dec;1704-6 [PubMed]
3. Bell D, Chitnavis B, Al-Sarraj S, Connor S, Sharr M, Gullan R. Pilocytic astrocytoma of the adult--clinical features, radiological features and management. *Br J Neurosurg.* 2004 Dec; 18(5):613-6 [PubMed]
4. Strong J, Hatten Jr H, Brown M, et al. Pilocytic astrocytoma: correlation between the initial imaging features and clinical aggressiveness. *AJR Am J Roentgenol.* 1993 Aug; 16(2):369-72 [PubMed]
5. Witwer B, Moftakhar R, Hasan K, Deshmukh P, Haughton V, Field A, Arfanakis K, et al. Diffusion-tensor imaging of white matter tracts in patients with cerebral neoplasm. *J Neurosurg* 2002 Sept 97(3):568-75 [PubMed]
6. Yen P, Teo B, Chiu C, Chen S, Chiu T, Su C. White matter tract involvement in brain tumors: a diffusion tensor imaging analysis. *Surg Neurol.* 2009 Nov; 72(5):464-9 [PubMed]
7. Wei C, Guo G, Mikulis D. Tumor effects on cerebral white matter as characterized by diffusion tensor tractography. *Can J Neurol Sci.* 2007 Feb; 34(1):62-8 [PubMed]