Pilocytic astrocytoma. Forms of presentation

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Abstract
Our purpose is to illustrate and describe typical and atypical imaging findings of supra- and infratentorial pilocytic astrocytoma (PA) on computed tomography (CT) and magnetic resonance imaging (MRI). Thirty-two patients with PA were selected from our case series. Twenty-four patients had confirmed PA from histologic analysis. The remaining 8 patients presented optic pathway gliomas and PA was the most relevant presumptive diagnosis. All patients, 20 male and 12 female (age range 10 months-65 years), underwent unenhanced and enhanced MRI. Diffusion-weighted imaging and MR spectroscopy (MRS) were performed in 6 patients, and 6 patients underwent CT scan.

The locations of the PA selected (n = 32) were: optic pathway and hypothalamic-chiasmatic region (n = 17), cerebellum (n = 7), thalamus (n = 6) and cerebral hemisphere (n = 2).

On MRI, most PA appeared as solid-cystic masses, iso- to hypointense on T1-weighted images and hyperintense on T2-weighted images and FLAIR, with post-contrast enhancement.

Four patients presented atypical characteristics: 1 solid cerebellum PA with calcifications, 1 hypothalamus PA in a child without neurofibromatosis type 1 (NF1) with no contrast enhancement and 1 cerebral hemisphere PA in a 65 year-old woman.

PAs are regarded as grade I tumors by the World Health Organization (WHO) classification. The optic pathway and the hypothalamic-chiasmatic region, as well as the posterior fossa are the most frequent locations. PAs are typically well-circumscribed and solid-cystic lesions with low cellularity and slow growth.

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Keywords: Pilocytic astrocytoma; glioma; magnetic resonance imaging.

Introduction
Pilocytic astrocytomas (PA) are slow growth, highly vascular and well circumscribed tumors that infiltrate the surrounding tissues. According to the World Health Organization classification, PAs are classified as grade I gliomas. PAs have low cellularity and low mitotic activity, and metastatic spread is unusual. Rarely, PAs may undergo malignant transformation1, 2. PAs occur most commonly in children and young adults, as 75% of cases manifest in the first 2 decades of life. These tumors show no gender predilection1.

Most PAs occur near the midline, usually arising from the cerebellum, the optic nerve and chiasm, around the third ventricle, and the region of the hypothalamus-thalamus1-3.

The aim of this study is to report a case series and describe typical and atypical imaging findings of supra- and infratentorial PAs on computed tomography (CT) and magnetic resonance imaging (MRI).

Materials and methods
For this study, we selected 32 patients with PA from our case series. Diagnosis of PA was confirmed on histological examination in all but 8 patients with optic pathway glioma who did not undergo biopsy because PA was the most relevant presumptive diagnosis. Twenty patients were males and 12 were females, with an age range between 10 months and 65 years. All patients had a gadolinium-enhanced brain MRI available, but only 6 had diffusion-weighted imaging and MR spectroscopy performed, and 6 patients also had a CT performed.

Eight patients had neurofibromatosis (NF) type 1 as baseline disease. Seven of these patients had PA involving the optic pathway and 1 had a PA located in the thalamic-midbrain region.
Results

The locations of the PAs selected (n = 32) were: optic pathway and hypothalamic-chiasmatic region (n = 17), cerebellum (n = 7), thalamus (n = 6) and cerebral hemisphere (n = 2) (table 1).

PAs located in the cerebellum (n = 7) included 6 solid-cystic masses (fig. 1) and 1 solid lesion with calcifications of atypical characteristics (fig. 2). In all patients, there was heterogeneous enhancement of the solid portion of the tumor and peripheral enhancement of the cystic portion. One case was a predominantly cystic recurrence of an operated vermian PA (fig. 3).

As regards PAs located in the optic pathway and in the hypothalamic-chiasmatic region (n = 17), 2 cases showed only optic nerve involvement, with increased size and signal intensity on T2-weighted images in the optic nerve, with no postcontrast enhancement. Five cases showed only chiasmatic involvement with increased optic chiasm size (3 with no postcontrast enhancement and 2 with intense enhancement) and 4 cases demonstrated involvement of both the optic nerves and chiasm (2 with no postcontrast enhancement (fig. 4) and

Table 1: Our case series of pilocytic astrocytomas.

<table>
<thead>
<tr>
<th>Patient</th>
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</table>

IV: intravenous; NF: neurofibromatosis.
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2 with chiasmal enhancement (fig. 5). Five patients had solid-cystic tumors in the hypothalamic-chiasmatic region, with intense postcontrast enhancement (figs. 6 and 7). In only one case (a 3-year-old child), a solid PA of atypical characteristics was identified in the left hypothalamic region, protruding over the left ventricle with no chiasmal involvement and appearing hyperintense on T2-weighted images and FLAIR, with no post intravenous contrast enhancement (fig. 8). The atypical feature of this case was the tumor location and the lack of postcontrast enhancement.

We identified 2 cases of PA of the cerebral hemisphere: one in a 20-year-old female patient, with a PA located in the left parietotemporal region, which had no vasogenic edema and was predominantly cystic, with a postcontrast enhancing mural nodule (fig. 9); the other in a 65-year-old patient was a solid-cystic PA with calcification and involvement of the left thalamus (fig. 10). The atypical feature of this case was, in addition to the location of the tumor, the age of the patient at the time of diagnosis, as PAs are more common in children and young adults.

Six cases of PA were identified in the thalamic-midbrain region: 3 had thalamic and midbrain involvement (figs. 11 and 12), 1 was a predominantly cystic lesion with a mural nodule originating from the midbrain and involving the right thalamus (fig. 13), and the remaining 2 were circumscribed to the thalami, with no midbrain involvement. As regards the form of presentation, 5 were solid-cystic lesions with post intravenous contrast enhancement and 1 was a solid lesion without postcontrast enhancement. Of all tumors located in this region (n = 6), 3 extended to the ipsilateral lentiform nucleus.

As regards the cases studied by MR spectroscopy (n = 6), we identified a decrease in the N-acetylaspartate (NAA) peak and an elevation of the choline peak in the solid portion of the tumor along with elevated lipid and lactate peak (1.3-1.5 ppm). In the case of the PA of the left hypothalamus, as it was a solid lesion, there was no elevation of the lipid and lactic acid peak, but there was an increase in the choline peak (with a choline/creatine ratio of 1.3) and a decrease in the NAA peak (fig. 8).

In the patients who had diffusion-weighted imaging performed, facilitated diffusion was observed in the cystic portion of the tumor, while in the solid portion diffusion was similar to that of the brain parenchyma. In the case of the left hypothalamic PA protruding over the third ventricle, facilitated diffusion was observed, suggesting low cellularity (fig. 8).

Discussion

PAs generally appear on CT as well-demarcated lesions with a round or oval shape, solid-cystlike characteristics and occasional calcifications. In 94% of these tumors, there is an intense enhancement of the solid component after contrast administration. At MRI, PAs appear isointense to hypointense on T1-weighted images, and hyperintense on T2-weighted images. These lesions present scarce peritumor edema in comparison with high-grade 1 glial neoplasms, and usually show intense en-
Figure 3 Cerebellar astrocytoma (recurrence after surgery). (a) MRI shows in the left cerebellar hemisphere and vermis a heterogeneous, predominantly cystic, bilobed lesion that appears hypointense on T1-weighted images and hyperintense on T2-weighted and FLAIR images (high protein content), with postcontrast peripheral enhancement. (b) MR Spectroscopy (short and long echo time) shows elevation in choline (red arrow) and lactate and lipid (white arrow) peaks.

Figure 4 Pilocytic astrocytoma of the optic pathway in a 7-year-old patient with neurofibromatosis type 1: involvement of both optic nerves (white arrows), with increased thickness. In addition, there is involvement of the optic chiasm (white circle), with an increase in its volume and signal intensity on T2-weighted images.
hancement of the solid portion and peripheral enhancement of the cystic portion. Histologically, PA manifests in a biphasic pattern, composed of a combination of glial tissue (with numerous vacuoles and occasional microcysts) and compacted piloid tissue. The piloid tissue is composed of dense sheets of elongated bipolar cells that demonstrate fine fibrillary processes and abundant Rosenthal fibers.

Complete resection is the objective of the surgical management of PAs, as the prognosis is excellent when PAs are totally resected. However, PAs of the hypothalamic-optic chiasm region are not amenable to total resection because of the high rate of morbidity and mortality associated with surgery in this region (including damage to the pituitary gland, optic pathway, hypothalamic structures and carotid arteries).

Cerebellar pilocytic astrocytoma

In pediatric patients, cerebellar astrocytomas are the most common astrocytomas (85%).

Cerebellar PAs are typically cystlike masses with a mural nodule, composed of one or more cysts and occasional calcifications. The solid portion is of variable size and proportion, ranging from a mural nodule at the periphery of the cyst to a completely solid lesion (the latter being less common). The association between cerebellar PA and hemorrhage is extremely rare, but the presence of hemorrhage might be related to abnormal vasculature within the tumor.

MR spectroscopy shows in the solid portion of the tumor an elevated choline peak and a decrease in the NAA peak. The choline/NAA ratio is usually elevated (ranging between 1.80 and 3.40), and the choline/creatine ratio is also elevated (with values similar to those reported above). Furthermore, the lactate peak may also be elevated in these tumors (evidencing a lactate doublet at 1.33 ppm), and there may be a minimal elevation of lipids, although not as high as that noted in glioblastoma and metastasis.

Diffusion-weighted sequences show facilitated diffusion in the cystic portion while, according to various authors, in the solid portion of PAs the apparent diffusion coefficient (ADC) is within the range of 1.13 to 1.92 x 10^-3 mm²/s. Rumbold

Figure 5 Pilocytic astrocytoma of the optic pathway. MRI: (a) FLAIR images show hyperintensity in the optic chiasm and optic tracts; (b) T2-weighted images show enlargement of both optic nerves, predominantly on the right side (red arrows) with enlargement of the optic chiasm, which appears hyperintense (white arrow); (c) T2- and T1 post-contrast weighted images show a large mass that appears hyperintense on T2-weighted images, located in the hypothalamic-chiasmatic region, with extension to the sellar region and interpeduncular cistern, which shows heterogeneous postcontrast enhancement, with a central area of low uptake, probably related to the presence of necrosis.
et al found in posterior fossa PAs values of ADC within the range of 1.4 to 2.09 x 10^-3 mm^2/s. Thus, on diffusion-weighted sequence, PAs usually have higher ADC values than ependymomas and medulloblastomas, in correlation with tumor cellularity (which is higher in the latter two cases)\textsuperscript{7-10}. Complete resection is the objective of the surgical management of PAs, as the prognosis is excellent when PAs are totally resected, with a 10-year survival rate of over 94% and a 20-year survival rate of 79\%. If partial resection is performed, PAs may recur or even extend to the ventricular system and cisterns. It is estimated that 5-10% of low-grade gliomas may show leptomeningeal dissemination. Dissemination is believed to be part of the natural history of an untreated pilocytic astrocytoma.\textsuperscript{11} In our series, there was a case of recurrence of operated cerebellar PA, with dissemination to the vermis and the left cerebellar hemisphere (fig. 3). The main differential diagnosis that should be considered is hemangioblastoma, as PA usually appears as a cystic lesion with a mural nodule that enhances after intravenous contrast administration.

Figure 6 Pilocytic astrocytoma of the optic pathway. (a and b) MRI shows a heterogeneous lesion involving the optic chiasm, with an increase in its volume associated with a cystic lesion located in the third ventricle (yellow arrow); the presence of small cysts in the optic chiasm is confirmed on T2-weighted sequence (red arrows); (c) no restriction is observed on diffusion-weighted images (a finding that suggests low cellularity).
Supratentorial pilocytic astrocytomas

Supratentorial PAs may be located in the optic nerves, in the region of the hypothalamus and chiasm, basal ganglia (thalamus) or the cerebral hemisphere. In adults, PAs are more common in the supratentorial region.

Pilocytic astrocytoma of the optic pathway and hypothalamic-chiasmatic region

When PA arises within the optic nerve, it infiltrates the nerve and causes fusiform enlargement and kinking of that structure. In children, optic pathway PAs are more likely to arise in the optic nerve, whereas in adolescents and young adults they are more commonly located in the optic chiasm.

The association of PA with NF1 is well known. PA is the most common tumor seen in this population (15-21%) and typically involves the optic nerve or chiasm.

There are differences between optic pathway gliomas in patients with and without NF1. In patients with NF1, optic pathway gliomas are characterized by enlargement and increased tortuosity of the optic nerve, because of a circumferential perineural infiltration extending to the subarachnoid space. The central portion of the optic nerve is generally preserved. At MRI, these tumors typically appear isointense on T1-

Figure 7 Hypothalamic-chiasmatic pilocytic astrocytoma. On the previous page, MRI: (a) T2-weighted images, (b) T1-weighted images and (c) gadolinium-enhanced T1-weighted images, showing a heterogeneous and solid lesion with a cystic/necrotic centre, located in the hypothalamic/chiasmatic region, showing heterogeneous postcontrast enhancement. Small hypointense areas are observed on T2-weighted images, which appear hyperintense on T1-weighted images, related to hemorrhagic areas (red arrows). On this page, (d) Diffusion-weighted imaging shows no water diffusion restriction; (e) MR spectroscopy demonstrates an increase in the lipid peak, in correlation with the presence of necrosis.
weighted images and hyperintense on T2-weighted images because of gliomatosis. In the optic chiasm, these tumors are small and homogeneous, they have no cystic component and enhancement is observed in some cases. In our series, there were 8 patients with NF1: in 7 patients, the PA involved the optic pathway and in 1 patient the PA was located in the thalamus-midbrain. As regards optic pathway PAs, 6 were solid lesions and 1 was a solid-cystic lesion; 4 cases showed not postcontrast enhancement.

In patients without NF1, the characteristics of these tumors are similar to those of PAs located in other sites, as they appear as well-demarcated masses with a solid-cystic component and postcontrast enhancement. Histologically, these tumors display intraneural growth.

PAs may also involve the hypothalamus. PAs of the hypothalamus appear as well-circumscribed tumors with a solid-cystic component.
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Figure 9 Cerebral hemisphere pilocytic astrocytoma. MRI shows a cystic lesion on the left cerebral hemisphere, in the temporoparietal region; the lesion appears hyperintense on T2-weighted and FLAIR images, and hypointense on T1-weighted images, with a postcontrast enhancing mural nodule (arrows).

Figure 10 Cerebral hemisphere pilocytic astrocytoma. (a) Computed tomography shows a cystic/solid lesion on the left temporoparietal region, with calcified areas (arrows) and a slight peritumor edema and mass effect with midline shift and collapse of the posterior horn of the ipsilateral lateral ventricle; (b) MRI shows hypointensity on T1-weighted images and hyperintensity on T2-weighted and FLAIR images, with heterogeneous postcontrast enhancement of the solid portion; (c) Images of the surgical procedure, showing drainage of the cystic portion and excision of the solid portion.
component. These tumors may contain cysts and show heterogeneous postcontrast enhancement. The typical clinical manifestations of PAs of this location are delayed pubertal development and symptoms associated with the mass effect of the tumor\textsuperscript{14}.

We report a rare case of atypical characteristics, located in the left hypothalamic region, with protrusion over the third ventricle. This tumor was solid, with no cystic component and no enhancement after intravenous contrast administration. ADC map showed facilitated diffusion and on MR spectroscopy, the choline/creatine ratio was 1.3. Both findings were consistent with the low cellularity of the lesion (even lower than that of a PA of typical characteristics) (fig. 8). Pathology was confirmed by biopsy.

Even if several cases of involution of optic pathway PA with NF1 have been reported, the mechanism behind it is not well known\textsuperscript{15}. Tumor growth deceleration has also been reported, being directly proportional to the age of the patient, and cases of PA involution have been reported in patients without NF1. Apoptosis and a humoral and cellular immune response to the lesion are believed to play a role in the mechanism of PA involution\textsuperscript{16}. In our series, a 3-year-old patient with NF1 and PA in the hypothalamic-chiasmatic region showed partial involution 3 years after initial diagnosis, having received no treatment (fig. 14).

\textbf{Pilocytic astrocytomas of the cerebral hemispheres and basal ganglia}

Cerebral hemispheres and basal ganglia are rare locations for PAs, but those tumors arising in the cerebral hemisphere are more likely to occur in the temporal lobes\textsuperscript{1}. These are solid lesions with a cystic component and may have calcifications; after intravenous contrast administration, the solid portion usually exhibits heterogeneous enhancement, while the cystic portion shows peripheral enhancement. These tumors show low cellularity and mitotic activity, and have slow
growth; therefore they are typically not associated with vaso-
getic edema\textsuperscript{17}. Differential diagnoses to be considered include pleomorphic xanthoastrocytoma and ganglioma, because of their similar imaging characteristics.

In our series, a 65-year-old patient had a solid-cystic left tem-
poroparietal supratentorial PA with calcifications in the solid portion and without vasogetic edema. This case was atypi-
cal because of the supratentorial parenchymal location of the tumor and because of the patient’s age, as these tumors are usually seen in children and young adults (fig. 10).

PAs may also involve the thalamus and midbrain. According to some authors’ reports, these tumors arise at the interface of the thalamus and midbrain, involving both. Clinical presentation consists in slow and progressive spastic hemiparesis. Because of their location, these lesions are considered to be

Figure 13 Midbrain-thalamic pilocytic astrocytoma. (a and b) MRI shows a heterogeneous, predominantly cystic lesion, with a solid, heterogeneous nodule (red arrow) originating from the midbrain and extending cephalically, involving the right thalamus. The cystic portion is slightly hyperintense on T1-weighted images and markedly hyperintense on T2-weighted and FLAIR images due to the presence of a high protein-hemorrhagic content (blue arrow). The solid portion shows postcontrast heterogeneous enhancement; (c) Diffusion-weighted imaging shows mild water diffusion restriction in the solid portion.
unresectable. Surgery is associated with high morbidity and mortality; therefore these tumors are treated with chemotherapy and radiotherapy.\textsuperscript{18}

**Conclusion**

PAs are low-grade gliomas (classified as grade I by the World Health Organization) more commonly located in the optic pathway, the hypothalamic-chiasmatic region and the posterior fossa. These tumors are typically well-circumscribed and solid-cystic lesions with low cellularity and slow growth. If total resection is performed, patients have a high rate of survival. At MRI, these lesions appear isointense to hypointense on T1-weighted images, and hyperintense on T2-weighted images, with scarce peritumor edema. The solid portion of the lesion shows intense enhancement, while the cystic portion exhibits peripheral enhancement. MR spectroscopy demonstrates an elevated choline peak, a decrease in the NAA peak in the solid portion of the tumor and, in some cases, an increase in lactate.

**Conflicts of interest**

The authors declare no conflicts of interest.
References


