Cystic-appearing Intracranial neoplastic lesions

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Abstract
Cystic and cyst-appearing intracranial lesions are common findings of brain neoplastic tumors. This paper intends to reviewed the origin of this lesion, radiologic appearance and differential diagnosis as guidance for the treating physician. This paper will review the cystic lesions of neoplastic etiology that most frequently occur in the brain.

Keywords
Brain, cysts, neoplasms, tomography, magnetic resonance imaging

Introduction
A cystic lesion can be defined as an epithelium-lined cavity that contains fluid or semisolid material.¹⁻³
Expansive lesions may be entirely cystic or have cavitory areas and are sub-classified into intra-or extra-axial lesions depending on their location.
The most common intracranial expansive cystic lesions are detailed in Table 1.
The purpose of this article is to illustrate the wide spectrum of intracranial cystic lesions of neoplastic origin and describe their morphologic characteristics.

Intra-axial tumors⁴⁻⁵

Differential diagnoses are mentioned in Table 2.

1) Pilocytic astrocytoma
This is the most common glial tumor in children and young adults, usually located near the midline. Two-thirds of lesions occur in the cerebellum, in the optic chiasma, around the third ventricle and in the hypothalamic-pituitary region. In adults, one-half of tumors are supratentorial.⁴⁻⁷
Cerebellar astrocytomas have been reported to be associated with neurofibromatosis type I, Ollier’s disease and Turcot and PHACE syndromes.⁴⁻⁶⁻⁸
Signs and symptoms depend on location. In the posterior fossa tumors, there is a mass effect with signs of raised intracranial pressure.⁶
These tumors appear as well-circumscribed solid/cystic masses of round or oval shape, with a solid mural nodule, occasionally with a necrotic center.⁶⁻⁷

There is a more aggressive variant known as pilomyxoid astrocytoma.⁵
On computed tomography (CT), these tumors appear as iso- to hypodense solid/cystic expansive masses; calcifications are rare, and there is enhancement of the solid component after intravenous (IV) contrast administration.⁴⁻⁶⁻⁷
On MRI, the cystic component appears isointense on T1- and T2-weighted images compared with cerebrospinal fluid (CSF)

<table>
<thead>
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<th>Location</th>
<th>Examples</th>
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<tr>
<td>Intra-axial</td>
<td>Pilocytic astrocytoma</td>
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<td>Hemangiblastoma</td>
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<td>Ependymoma</td>
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<td>Medulloblastoma</td>
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<td>Ganglioglioma</td>
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<td>Pleomorphic xanthoastrocytoma</td>
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<td>Dysembryoplastic embryonal tumor</td>
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<td>Glioblastoma multiforme</td>
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<td>Metastasis</td>
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<td>Extra-axial</td>
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<td>Craniopharyngioma</td>
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Source: References 4, 5.
signal intensity, and hyperintense on FLAIR images, and it is associated with a mural nodule that is usually isointense on T1-weighted sequences and hyperintense on T2-weighted / FLAIR images, generally enhancing after the administration of gadolinium (Fig. 1).4-7

Both the cystic and solid components may enhance after gadolinium administration.6,7

2) Hemangioblastoma
This is a rare vascular tumor, generally associated with von Hippel-Lindau disease, although these tumors may be seen sporadically.5,8 Hemangioblastomas occur in young patients in the cerebellum or, less commonly, in the spinal cord.9,8

On CT, these tumor appear as cystic/solid posterior fossa masses, with enhancement of the solid portion after IV contrast administration.

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**Fig. 1** Brain MRI. (A) Axial T1-weighted, (B) coronal T2-weighted, (C) axial FLAIR and (D) gadolinium-enhanced axial T1-weighted images. Seven-year-old male patient with headaches and dizziness. The images show an expansive, predominantly cystic lesion on the right cerebellar hemisphere (star) with an eccentric solid mural nodule (arrows). The lesion produces mass effect with midline shift to the left, surrounded by a mild vasogenic edema. The solid portion shows irregular enhancement after gadolinium administration. Considering patient’s age and clinical presentation, the lesion is consistent with pilocytic astrocytoma (confirmed by biopsy).

**Table 2:** Differential diagnoses of cystic-appearing intracranial neoplastic lesions.

<table>
<thead>
<tr>
<th>Tumors with cystic components</th>
<th>Differential diagnoses</th>
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<tbody>
<tr>
<td>Pilocytic astrocytoma</td>
<td>Ependymoma and medulloblastoma (children in the posterior fossa) Metastases or hemangioblastoma (adults)</td>
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<tr>
<td>Hemangioblastoma</td>
<td>Pilocytic astrocytoma</td>
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<tr>
<td>Central neurocytoma</td>
<td>Oligodendroglia, Pilocytic astrocytoma, subependymal giant cell astrocytoma, ependymoma, menin giomas</td>
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<tr>
<td>Craniopharyngioma</td>
<td>Pituitary adenoma, hypothalamic or optic pathway glioma, Rathke cleft cyst, epidermoid cyst, thrombosed aneurysms</td>
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<td>Ependymoma</td>
<td>Supratentorial intraparenchymal: Pilocytic astrocytoma, Pleomorphic xanthoastrocytoma, primitive neuroectodermal tumor, ganglioglioma/gangliocytoma and oligodendroglioma</td>
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<tr>
<td>Medulloblastoma</td>
<td>Pilocytic astrocytoma, atypical teratoid/rhabdoid tumor and ependymoma</td>
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<tr>
<td>Ganglioglioma</td>
<td>Ependymoma</td>
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<tr>
<td>Pleomorphic xanthoastrocytoma</td>
<td>Meningioma, glioblastoma, DNET, oligodendroglioma, metastasis</td>
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<td>Dysembryoplastic neuroepithelial tumor (DNET)</td>
<td>Gangliocytoma, Pilocytic xanthoastrocytoma</td>
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<tr>
<td>Glioblastoma</td>
<td>Metastasis, abscesses</td>
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<tr>
<td>Metastasis</td>
<td>Abscesses, glioblastoma, astrocytoma, Pleomorphic xanthoastrocytoma</td>
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<td>Meningiomas</td>
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<td>Schwannomas</td>
<td>Meningiomas</td>
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<td>Pituitary macroadenoma / Craniopharyngioma</td>
<td>Craniopharyngioma /pituitary macroadenoma</td>
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Fig. 2 Brain MRI. (A) Axial T1-weighted, (B) T2-weighted images, (C) Axial and (D) coronal T1-weighted images with gadolinium. Images show a cystic expansive lesion on the left cerebellar hemisphere (star), with internal septa and a peripheral mural nodule. The solid portion strongly enhances after gadolinium administration (arrows). The diagnosis of Hemangioblastoma was confirmed by pathology.

Fig. 3 Brain MRI. (A) Axial T1-weighted image, (B) axial T2-weighted image (C) coronal T2-weighted image and (D) gadolinium-enhanced axial T1-weighted image. A solid expansive lesion originates near the foramen of Monro, containing multiple cysts (arrows) and causing midline shift and left supratentorial obstructive hydrocephalus, heterogeneously enhancing after gadolinium administration. Central neurocytoma was diagnosed by biopsy.

3) Central neurocytoma
This is a benign tumor, formerly known as “ependymoma of the foramen of Monro” or “intraventricular oligodendrogliaoma”. Typically intraventricular, located in the lateral ventricles close to the foramen of Monro, although it may have other locations (gray nuclei, fourth ventricle, intramedullary location, etc.), this tumor usually affects young adults and has a favorable prognosis.

4) Ependymoma
These tumors may be either supratentorial (40%) or infratentorial (60%) in location. The former may affect the brain parenchyma or ventricular cavities, being more common in young patients. Those arising in the posterior fossa occur in children. Symptoms vary and depend on tumor location (supra/infratentorial), with possible manifestations of increased intracranial pressure secondary to obstructive hydrocephalus. These tumors appear as heterogeneous, well-demarcated, lobulated lesions with a solid/cystic component, with an attachment to the septum pellucidum.

Digital angiography is a diagnostic tool that may be considered, given the high vascularity of these tumors.

On MRI, these tumors appear as iso- to hypointense lesions on T1-weighted sequences and hyperintense on T2-weighted sequences, with a strongly enhancing solid mural nodule. On T2-weighted sequences, signal voids occur because of the high vascularity of these tumors. Calcifications are rare and the presence of spontaneous hyperintensity on T1-weighted sequences is suggestive of recent bleeding. Digital angiography is a diagnostic tool that may be considered, given the high vascularity of these tumors.

Central neurocytomas present with symptoms of increased intracranial pressure secondary to obstructive hydrocephalus. These tumors appear as heterogeneous, well-demarcated, lobulated lesions with a solid/cystic component, with an attachment to the septum pellucidum.

Central neurocytomas appear heterogeneous on CT; on MRI, they have a “bubbly” appearance due to the presence of cysts. These tumors appear isointense on T1-weighted sequences, iso- to hyperintense on T2-weighted sequences, with associated calcifications in 50% of cases.

Ependymomas are typically supratentorial or infratentorial, occurring in young patients or children. Symptoms depend on tumor location and can include increased intracranial pressure, headaches, and neurologic deficits. Digital angiography is used to evaluate the vascularity of these tumors.
pressure occurring most frequently with infratentorial tumors due to their intraventricular location. Patients with supratentorial Ependymoma may experience headache, seizures or neurologic deficit.12,13 These tumors appear as masses with cystic areas and chunky calcification, and may occasionally bleed.12 Supratentorial ependymomas are larger in size (owing to their typically intra-parenchymal location) and tend to contain a cystic component, while infratentorial ependymomas commonly have an intraventricular location and therefore are smaller in size.13 On CT, solid areas are iso-to hypointense. On MRI, they are iso- to hypointense on T1-weighted images and iso- to hyperintense on T2-weighted images.12,13 The cystic component is similar in signal intensity to the CSF on T1- and T2-weighted images, with no complete suppression on FLAIR due to its high protein content.12 Enhancement is heterogeneous and irregular with associated areas of necrosis (Fig. 4).12,13 On gradient echo sequences (GRE), blooming may be seen in calcifications or foci of hemorrhage, with restricted diffusion on diffusion-weighted imaging.12,13 Some intraparenchymal supratentorial ependymomas may manifest as expansive solid/cystic lesions with mural nodule and associated calcification.12,13 Intraventricular ependymomas may extend into the adjacent brain parenchyma and cause vasogenic edema. Ependymomas located in the fourth ventricle tend to fill it as a “plaster cast” and may extend through the foramen of Luschka and Magendie, causing dissemination of the disease.12

5) Medulloblastoma
This is the most common malignant tumor of the central nervous system (CNS) in pediatric age.14,15 Symptoms depend on tumor location, with symptoms of increased intracranial pressure secondary to obstructive hydrocephalus being common.14 These tumors are often associated with Turcot syndrome type 2, Gorlin-Goltz syndrome, Li Fraumeni syndrome, Rubinstein-Taybi syndrome, Fanconi anemia and Nijmegen syndrome.14 Medulloblastomas are frequently located at the posterior fossa midline, involving the vermis, extending into the fourth ventricle, with leptomeningeal dissemination; therefore a complete evaluation of the neuroaxis should be performed.14,15 In adults and older children, these tumors may be located in the cerebellar hemispheres and present cystic degeneration.14,15 On CT, medulloblastomas appear hyperdense (due to their highly cellular nature), with variable peripheral edema, and calcifications may occur in about 20% of cases.14,15 Enhancement is variable.14 On MRI, these tumors appear hypo- to isointense on T2-weighted images, being predominantly homogeneous with little necrotic, hemorrhagic or calcic component. Heterogeneity on T2-weighted sequences associated with a “honeycomb” pattern of enhancement allows identification of the anaplastic variant of medulloblastoma with a sensitivity of 100% (Fig. 5).14,15

6) Ganglioglioma
This is a well differentiated neuroepithelial tumor that occurs in children and young adults, with a predilection for the temporal lobe, being a common cause of epilepsy.5,16,17 This tumor may also occur in the parietal and frontal lobes.16 It is a solid-cystic enhancing mass, partially located in the periphery of a cerebral hemisphere.16 Calcifications are common and may be surrounded by vasogenic edema.5,16 On CT, gangliogliomas have a variable appearance. The most

**Fig. 4 Brain MRI.** (A) Axial T1-weighted (b) T2-weighted (C) DWI, (D) gadolinium-enhanced T1-weighted images. Expansive solid-cystic lesion seen at the left temporoparietal level, with mass effect pushing on the ipsilateral lateral ventricle. There is poor and irregular enhancement after gadolinium administration (arrow). Ependymoma was diagnosed by pathology.
frequent presentation is a hypodense mass with irregular/heterogeneous enhancement.\textsuperscript{16,17}

On MRI, the appearance of these tumors is variable and nonspecific: they may have a cystic component, be hypo- to isointense on T1-weighted images with associated cortical dysplasia, and be hyperintense on T2-weighted images.\textsuperscript{5,16,17}

7) Pleomorphic xanthoastrocytoma
This is a superficial cortical supratentorial tumor, occurring most often in the temporal lobe, followed by the frontal and occipital lobes.\textsuperscript{5,16,18} It predominantly affects young patients with a history of seizures and it is associated with cortical dysplasia.\textsuperscript{18}

This tumor appears as a frequently cystic supratentorial mass containing a solid mural nodule that is adjacent to the leptomeninges.\textsuperscript{16}

On CT, the tumor is seen as a hypo- to isoattenuating mass.\textsuperscript{16}
Calcification is rare.\textsuperscript{16}

On MRI, the solid portion is hypo- to isointense on T1- and T2-weighted images, while the cystic portion is hypointense on T1-weighted images and hyperintense on T2-weighted images (Fig. 7).\textsuperscript{16}

The solid portion shows irregular enhancement and, in 70% of cases, there is an associated enhancement of adjacent leptomeninges, with the appearance of a “dural tail”.\textsuperscript{5,16}

8) Dysembrioplastic neuroepithelial tumor (DNET)
DENTs occur in children and adolescents, often with a history of epilepsy.\textsuperscript{19,20}

These are supratentorial cortical tumors commonly located in the temporal lobe, of multinodular solid/microcystic “bubbly” appearance, without peripheral edema or mass effect.\textsuperscript{19-21}

On CT, DNETs appear as well-demarcated hypodense masses.\textsuperscript{21}

On MRI, these tumors appear as “bubbly” lesions due to their solid/cystic appearance, with these portions being slightly more hyperintense than the CSF, while solid components appear

Fig. 5 Medulloblastoma. MRI (A) Axial T2-weighted image; (B) sagittal T1-weighted image and (C) gadolinium-enhanced axial T1-weighted image. Expansive, heterogeneous infratentorial midline mass distorting the fourth ventricle and irregularly enhancing after gadolinium administration (arrows). The T2-weighted sequence shows a cystic component (star).

Fig. 6 Brain MRI. (A) Axial T1-weighted image, (B) Axial T2-weighted image, (C) coronal T2-weighted image and (D) gadolinium-enhanced axial T1-weighted image. Multicystic lesion with septa (arrows) on the right temporal lobe, at the level of the hippocampus, surrounded by vasogenic edema. The lesion partially compresses the temporal horn of the ipsilateral lateral ventricle and heterogeneously enhances after gadolinium administration. Ganglioglioma was diagnosed.
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DNETs are wedge-shaped, contain multiple internal septa and may cause remodeling of the inner table (60%) (a finding that may be seen in other cortical tumors) and develop calcification, with no or faint enhancement after gadolinium administration (Fig. 8). DNETs are characterized by the “FLAIR hyperintense ring sign”: this is a well-defined thin ring of hyperintensity on FLAIR at the borders of the tumor, separating it from healthy brain parenchyma. 

Glioblastoma (formerly glioblastoma multiforme)
In 2016, the World Health Organization (WHO) updated the classification of CNS tumors (Table 3), replacing the old designation of glioblastoma multiforme with IDH-wild type glioblastoma (without mutation), IDH-mutant glioblastoma and glioblastoma NOS (not otherwise specified; the presence or absence of mutation is not specified). Glioblastoma is the most common primary malignant brain tumor in adults, accounting for 12%-15% of all intracranial neoplasms.

This tumor is more prevalent in males (3:2) between 45 and 70 years of age, with the cerebral hemispheres being its more common location. Infratentorial or spinal cord location is rare.

Prognosis is often unfavorable owing to the high degree of malignancy, and survival is variable, depending on the type (secondary or de novo), estimated at 14 months.

Glioblastomas may arise de novo (>90%) or progress from an existing low-grade tumor (<10%). On MRI, this tumor appears as an expansive heterogeneous lesion of poorly defined borders, located in the cerebral hemispheres, with portions of cystic appearance due to large areas hypointense on T1-weighted images and hyperintense on T2-weighted images.

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Fig. 7 Brain MRI. (A) Sagittal T1-weighted image, (B) axial T2-weighted image, (C) axial FLAIR and (D) gadolinium-enhanced T1-weighted image. Expansive cystic lesion of left frontal lobe location, surrounded by vasogenic edema, containing an eccentric solid mural nodule with thin septa inside (arrows). After gadolinium administration, there is strong enhancement of the peripheral mural nodule as well as of the above-mentioned septa. The lesion crosses the midline, partially compressing the frontal horns of the lateral ventricles. Pleomorphic xanthoastrocytoma was diagnosed by pathology.

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Fig. 7 Brain MRI. (A) Sagittal T1-weighted image, (B) axial T2-weighted image, (C) axial FLAIR and (D) gadolinium-enhanced T1-weighted image. Expansive cystic lesion of left frontal lobe location, surrounded by vasogenic edema, containing an eccentric solid mural nodule with thin septa inside (arrows). After gadolinium administration, there is strong enhancement of the peripheral mural nodule as well as of the above-mentioned septa. The lesion crosses the midline, partially compressing the frontal horns of the lateral ventricles. Pleomorphic xanthoastrocytoma was diagnosed by pathology.
of necrosis and hemorrhage, heterogeneously enhancing after gadolinium administration and surrounded by extensive perilesional edema (Fig. 9).²⁴,²⁵ Glioblastomas often extend into the corpus callosum crossing the midline, involving the contralateral cerebral hemisphere ("butterfly" gliomas).²⁴ These tumors show areas of restricted diffusion because of their high cellularity and MRI tractography demonstrates destruction or infiltration of fiber tracts.²⁴,²⁷ MR spectroscopy can provide valuable information for characterizing both the lesion and the surrounding parenchyma. There is elevation of choline due to abundant cell membrane proliferation, a marked decrease in N-acetyl aspartate levels due to neuronal cell death and an elevated lipid/lactate peak associated with the cystic-necrotic component, findings that are suggestive of a neoplastic lesion.²⁴ At perfusion MRI, an increased relative cerebral blood volume (rCBV) is a marker of neovascularization in a high-grade glial lesion.²⁴,²⁷

10) Metastasis
A brain lesion in a patient with known malignant tumor suggests the possible presence of metastasis.²⁸ The sources of brain metastases are usually the lung, breast,
melanoma, kidney and tumors of the gastrointestinal tract. Brain metastases are generally located in the white matter/gray matter junction of the cerebral hemispheres, in the perfusion territory of cerebral arteries. On CT, metastases appear iso- to hypodense, surrounded by vasogenic edema, and may not be detected without IV contrast administration. On MRI, these lesions generally appear hypointense on T1-weighted images and hyperintense on T2-weighted images, may show restricted diffusion on DWI, and (completely or irregularly) enhance after gadolinium administration, appearing as ring, punctuate or nodular. Large or highly aggressive lesions may have central necrosis and/or cavitation (Fig. 10).

Extra-axial tumors
Some extra-axial tumors may undergo cystic degeneration or be associated with non-neoplastic cysts. Examples include: meningiomas, schwannomas, craniopharyngiomas or pituitary macroadenomas (Figs. 11-13). Ten to twenty per cent of meningiomas may have cystic degeneration, showing a density or signal intensity similar to that of CSF. Calcifications can be better assessed by CT. Peritumoral cysts occurring adjacent to schwannoma may be arachnoid cysts; meningiomas may trap CSF between the tumor and the cerebral cortex. Craniopharyngiomas or pituitary macroadenomas with suprasellar extension may obstruct and enlarge perivascular spaces. Peritumoral cysts and enlarged perivascular spaces do not enhance, and thus can be distinguished from tumors. The characterization of a cystic-appearing lesion in the CNS enables a proper specific diagnostic approach. This shortens the diagnostic time and provides a therapeutic approach specific to each pathology (Table 1).

Fig. 9 Glioblastoma. Brain MRI. (A) Axial T1-weighted, (B) T2-weighted images, and (C) axial and (D) coronal T1-weighted images with gadolinium enhancement. Expansive solid-cystic mass (star) on the left frontal lobe with associated necrotic areas. Presence of vasogenic edema causing mass effect, with midline shift to the right (arrows) and compression of the frontal horn of the ipsilateral lateral ventricle.

Fig. 10 Cystic metastasis from lung cancer. Brain MRI. (A) Axial T1-weighted, (B) T2-weighted images, (C) DWI and (D) apparent diffusion coefficient (ADC) map. Cystic lesion (arrows) in the right parietal lobe, with focal wall thickening in the posterior region, showing incomplete peripheral restriction on DWI. Metastasis from primary disease was confirmed by pathology.
Ethical responsibilities
Protection of human subjects and animals. The authors declare that no experiments were performed on humans or animals for this investigation.
Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Conflicts of interest
Pablo Sartori declares a possible conflict of interest as a member of Capítulo de Neurorradiología de la Sociedad Argentina de Radiología (SAR, Argentine Society of Radiology).

Fig. 11 MRI of the petrous temporal bone. (A) Axial T1-weighted image, (B) axial T2-weighted image, gadolinium-enhanced axial (C) and coronal (D) T1-weighted images. Heterogeneous lesion with a cystic component (arrows) located in the right cerebellopontine angle; the medial border abuts the pons and the lateral border widens the porus acusticus, extending into the internal auditory canal (IAC) involving the IAC funds. The lesion shows irregular enhancement after gadolinium administration. Cranial nerve VIII schwannoma with a cystic component was confirmed.

Fig. 12 MRI of the pituitary gland. (A) Coronal T1-weighted image, (B) coronal T2-weighted image, (C) gadolinium-enhanced sagittal T1-weighted image and (D) gadolinium-enhanced coronal T1-weighted image. Altered morphology of the pituitary gland due to the presence of a cystic-appearing lesion (star), not enhancing after gadolinium administration. The lesion extends upwards abutting and displacing the optic chiasm. Cystic macroadenoma was confirmed.

Fig. 13 MRI of the sellar region. (A) Coronal T1-weighted image, (B) coronal T2-weighted image and (C) sagittal and (D) coronal T1-weighted images with gadolinium enhancement. Sellar morphology alteration (arrow) resulting from an expansive solid-cystic lesion with spontaneously hyperintense areas on T1-weighted images because of its high protein/blood content, associated with heterogeneous content. The lesion shows irregular enhancement after gadolinium administration. The mass invades laterally the cavernous sinuses and, caudally, the sphenoidal sinus. It extends upwards, abutting and displacing the optic chiasm, invading the third ventricle and the lateral ventricles. Craniopharyngioma was confirmed.
References