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PAEDIATRIC NEURORADIOLOGY

(What's the story) morning glory? MRI findings in morning glory disc anomaly

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Abstract

Purpose Morning glory disc anomaly (MGDA) is a rare congenital ophthalmologic disorder. Historically it has been diagnosed fundoscopically, with little in the literature regarding its imaging findings. The purpose of this study is to further characterize the orbital and associated intracranial magnetic resonance imaging (MRI) findings of MGDA in our tertiary pediatric center.

Methods A retrospective review was performed of fundoscopically-diagnosed cases of MGDA, that had been referred for MRI. All MRI studies were scrutinized for orbital and other intracranial abnormalities known to occur in association with MGDA.

Results 18 of 19 cases of MGDA showed three characteristic MRI findings: funnel-shaped morphology of the posterior optic disc, abnormal soft tissue associated with the retrobulbar optic nerve, and effacement of adjacent subarachnoid spaces. The ipsilateral (intraorbital) optic nerve was larger in one patient and smaller in six. The ipsilateral optic chiasm was larger in two patients and smaller in one.

Conclusion This study represents a comprehensive radiological-led investigation into MGDA. It describes the most frequently-encountered MRI findings in MGDA and emphasizes the importance of MRI in this cohort, i.e., in distinguishing MGDA from other posterior globe abnormalities, in assessing the visual pathway, and in screening for associated intracranial abnormalities – skull base/cerebral, vascular, and facial. It hypothesizes neurocristopathy as an underlying cause of MGDA and its associations. Caliber abnormalities of the ipsilateral optic nerve and chiasm are a frequent finding in MGDA. Optic pathway enlargement should not be labeled "glioma". (239/250).

Keywords MRI · Morning glory · Optic disc · Optic nerve · Glioma

Abbreviations

MGDA	Morning glory disc anomaly
MRI	Magnetic resonance imaging
T	Tesla
CT	Computed tomography
IAM	Internal auditory meatus
ICA	Internal carotid artery
CHARGE	Coloboma, heart disease, choanal atresia, retardation, genital hypoplasia and ear anomalies

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OPG	Optic pathway glioma
OPE	Optic pathway enlargement
CLOVES	Congenital lipomatous overgrowth, vascular malformations, epidermal nevi, skeletal and/or spinal anomalies
PHACES	Posterior fossa abnormalities, hemangiomas, arterial anomalies, cardiac defects, eye abnormalities, sternal cleft and supraumbilical raphe
MMD	Moya Moya disease

Introduction

Morning glory disc anomaly (MGDA) is a rare congenital abnormality of the optic disc, the etiology of which is incompletely understood. It is usually sporadic, unilateral, and an isolated ocular abnormality [1, 2]. However, various pathologies, ranging from ocular and skull base/cerebral to vascular and facial, have been reported in association with this anomaly.

MGDA is typically an ophthalmologic diagnosis. It is characterized, fundoscopically, by a funnel-shaped excavation of the posterior globe, which incorporates the optic disc. Much of the excavated disc is filled with glial tissue. There is an annulus of chorioretinal pigmentary change. The surrounding retinal vessels have an unusual, straightened orientation and are narrowed. Its fundoscopic appearance resembles the morning glory flower [3] (Fig. 1).

It is not widely known that radiologists can identify MGDA on imaging. However, magnetic resonance imaging (MRI) of the brain and orbits can be useful in its diagnosis, especially where fundoscopic examination is difficult and/or in rare instances where there is ophthalmological uncertainty regarding the diagnosis. MRI not only aids in distinguishing MGDA from other posterior globe abnormalities, including coloboma and staphyloma but also facilitates a comprehensive assessment of the visual pathway. Crucially, it allows for screening of associated intracranial abnormalities.

Despite its clinical significance, the radiological literature regarding MGDA is sparse, consisting mostly of case reports and case series [1, 4–6].

Ellika et al. described three characteristic MRI findings in six cases of MGDA [4]. These include:

1. Funnel-shaped morphology of the posterior optic disc with elevation of the adjacent retinal surface
2. Abnormal soft tissue associated with the retrobulbar optic nerve and effacement of the adjacent subarachnoid spaces
3. Posterior discontinuity of the uveoscleral coat.

The purpose of this study is to further characterize the MRI findings of MGDA and its associations—skull base/cerebral, vascular, and facial—in our center.

Materials and methods

Ethical approval was obtained from Western Australia Health. A retrospective review of all cases of MGDA from our institution—Perth Children's Hospital, formerly Princess Margaret Hospital, Western Australia's specialist pediatric hospital and trauma center—was carried out. A radiological report keyword search was performed on our state-wide radiology information system using the terms "morning" and "glory" to identify ophthalmologically-diagnosed cases of MGDA, that had been referred for MRI between January

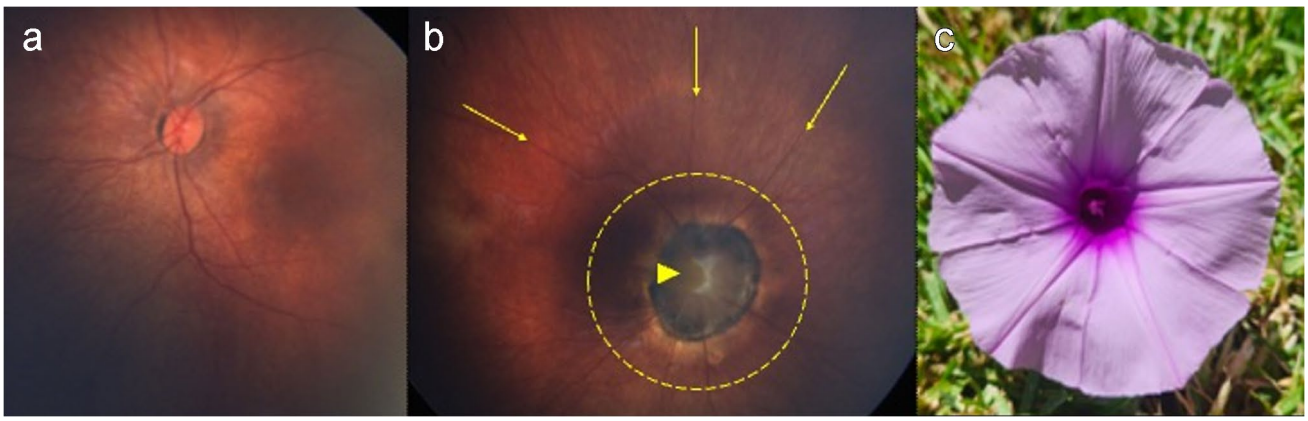

Fig. 1 11 month old girl with right MGDA diagnosed fundoscopically. **a** Normal fundoscopic appearance of the left eye. **b** Abnormal fundoscopic appearance of the right eye, with an enlarged, excavated optic disc, central glial tuft (arrowhead), halo of abnormal chorioretinal pigmentation (dashed circle) and radial orientation of retinal blood vessels (arrows). **c** Morning glory flower, after which this condition is named

2004 and September 2023. The only inclusion criterion was age < 18 years.

Patient characteristics—age, gender, side of MGDA—were documented. All MRIs, frequently multiple studies per patient, were systematically reviewed by two of the authors (CNL, pediatric radiology fellow and RW, specialist pediatric neuroradiologist with 14 years of radiological experience) and any disagreements resolved by consensus. For all studies, we documented the magnetic field strength of the MRI machine (1.5 or 3 Tesla [T]), study quality (degree of motion degradation) and protocol used (high-resolution, T2-weighted, fat-saturated imaging of the orbits, contrast-enhanced T1-weighted imaging of the brain/orbits, angiographic sequence of the brain).

All MRIs were scrutinized for the following findings, which have previously been reported in cases of MGDA [4, 6, 7]: funnel-shaped morphology of the optic disc at the optic nerve head insertion, thickening/corrugation of the adjacent retinal surface, retinal T1 hyperintensity, retinal detachment, abnormal soft tissue associated with the ipsilateral retrobulbar optic nerve, effacement of perioptic nerve subarachnoid spaces, discontinuity in the posterior globe wall, fatty infiltration in the retrobulbar optic nerve sheath, contrast enhancement in the retrobulbar optic nerve, globe caliber, optic nerve caliber (ipsi- and contralateral), optic chiasm caliber, intracranial abnormalities, in particular midline (including skull) defects and vascular abnormalities, known to occur in association with MGDA. Where no dedicated angiographic sequence was available for review, the signal flow voids of the proximal intracranial arteries were assessed for vasculopathy using T2-weighted imaging.

Results

The radiological keyword search yielded 25 results. Four adult/elderly patients were excluded; here, "morning glory" referred to the morning glory sign of progressive nuclear palsy [8], as opposed to MGDA. Three children were also excluded—one underwent computed tomography (CT) only and in the other two, MRI was non-diagnostic due to motion.

In total, 18 children with the condition and 19 cases of MGDA (one child had bilateral MGDA) were included in the study. 13 of 18 children affected were girls. Mean age at the time of first MRI was 4 years and 10 months (2 days—12 years 10 months). In nine of 18 children, the right eye was affected, in eight the left and in one, both.

Imaging was performed at 1.5 T in eight patients and at 3 T in ten. High-resolution, T2-weighted, fat-saturated imaging of the orbits was performed in 17 patients, contrast-enhanced T1-weighted imaging of the brain/orbits in 6 and an angiographic sequence in 14, on at least one occasion.

The following MRI findings were seen in 18 of 19 cases (94.7%): funnel-shaped morphology of the posterior optic disc, abnormal soft tissue associated with the retrobulbar optic nerve and effacement of adjacent subarachnoid spaces. Other common findings were discontinuity in the posterior globe wall (evident in 16 of 19 cases) and thickening of the retinal surface (seen in 15 of 19 cases). Of the seven cases where contrast was given, there was discontinuous enhancement in the posterior globe wall in five patients and enhancement in the retrobulbar optic nerve in four (Fig. 2).

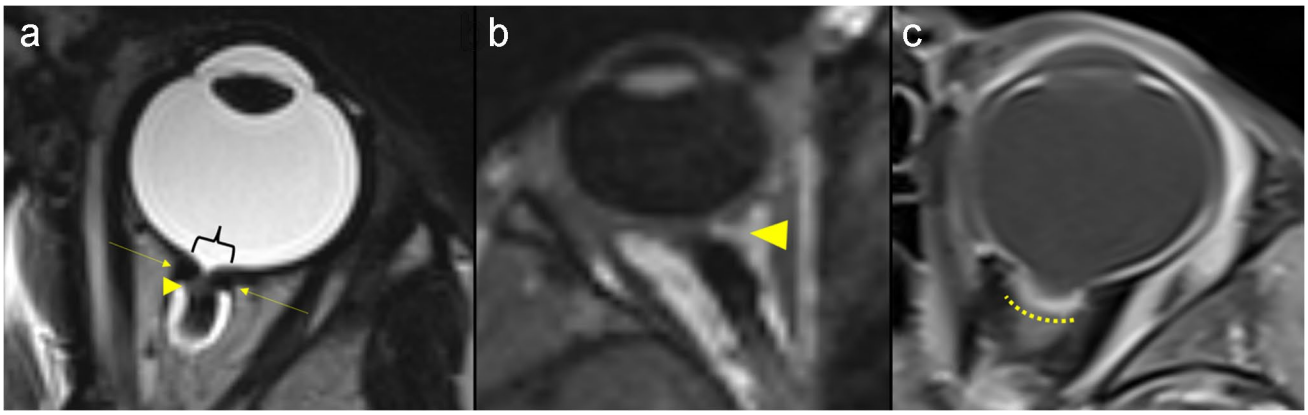

Fig. 2 **a** Axial high-resolution, T2-weighted, fat-saturated MRI of the left orbit in a 31 month old boy with left MGDA diagnosed fundoscopically demonstrates funnel-shaped morphology of the optic disc at the optic nerve head insertion, with discontinuity in the posterior globe wall (bracket), thickening/corrugation of the adjacent retinal surface (arrows), abnormal soft tissue associated with the ipsilateral retrobulbar optic nerve (arrowhead) and effacement of perioptic nerve subarachnoid spaces. **b** Axial T1-weighted imaging of the right orbit in a 5 year 7 month old boy with right MGDA diagnosed fundoscopically demonstrates T1 high signal in the retrobulbar optic nerve sheath (arrowhead), consistent with fat. **c** Axial T1-weighted, fat-saturated, post-gadolinium imaging of the left orbit in a 4 year old girl with left MGDA diagnosed fundoscopically demonstrates discontinuous posterior globe wall enhancement and abnormal enhancement in the retrobulbar optic nerve (dashed line)

The affected globe was smaller in five of 19 cases. The ipsilateral (intraorbital) optic nerve was larger in one patient, smaller in six (including the child with bilateral MGDA) and normal in ten. The ipsilateral optic chiasm was larger in two patients and smaller in one (Fig. 3).

Three children had intracranial abnormalities—one had Chiari 1 deformity and one had Chiari 2 malformation (Fig. 4).

There was one complex congenital case, whereby unilateral MGDA was seen, in conjunction with ipsilateral dysplastic hemimegalencephaly, an enhancing internal auditory meatus (IAM) mass, multiple intradural, extramedullary lipomatous spinal lesions, a low-lying conus medullaris, pathological nerve root enlargement and enhancement and several non-neuroaxis anomalies, including thoracic vasculopathy, aortic coarctation and bilateral renal dysplasia (Fig. 5).

One child had stenosis of the right terminal internal carotid artery (ICA). There was no other definite vascular abnormality (Table 1).

Discussion

This study represents a comprehensive radiological-led investigation into patients with MGDA, illustrating the most frequently-encountered MRI findings.

The etiology of MGDA is disputed. Traboulsi et al. hypothesized that a mesenchymal defect leads to faulty closure of the posterior sclera and lamina cribrosa, permitting posterior herniation of retinal and neural tissue [9]. However, a concomitant defect in the posterior embryonic fissure is possible [9].

MGDA is typically an isolated ocular abnormality that is diagnosed fundoscopically. However, MRI can be helpful in confirming the diagnosis, especially when fundoscopic exam is difficult and/or non-diagnostic. For example, persistent fetal vasculature, which may be associated with MGDA, can make fundoscopic diagnosis challenging [1, 6, 10].

MRI is also helpful in differentiating MGDA from other optic disc abnormalities, i.e., coloboma and staphyloma. Coloboma, unlike MGDA, is typically genetic, and associated with multisystem abnormalities, e.g., CHARGE

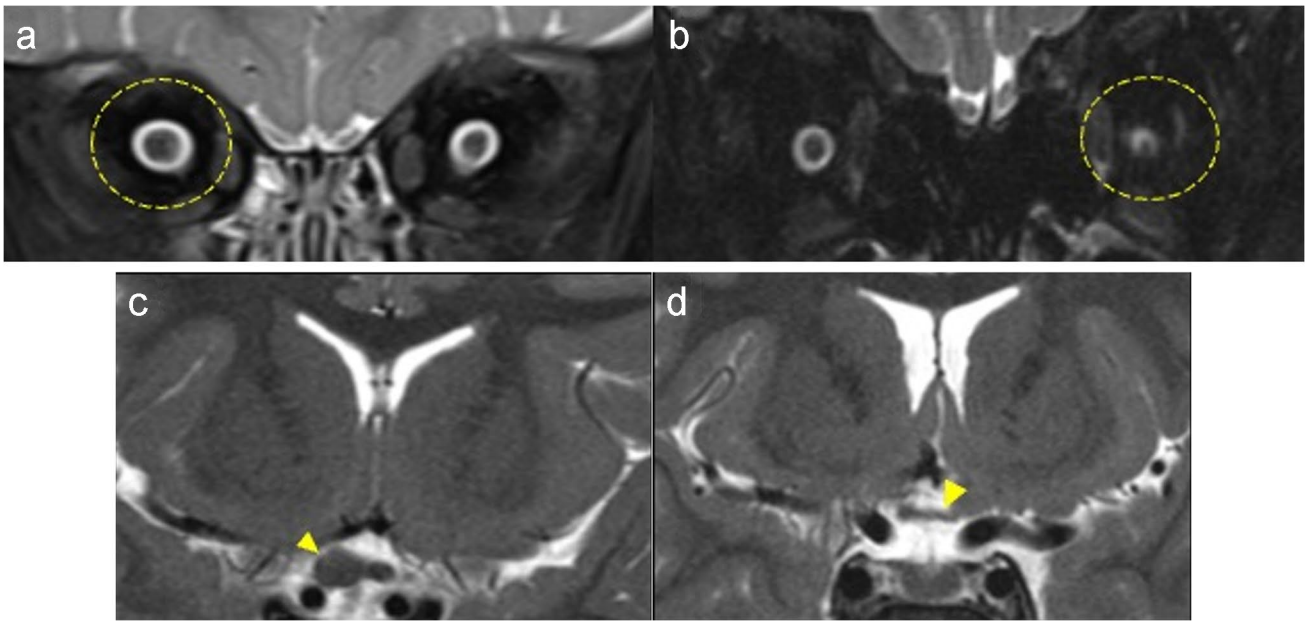

Fig. 3 **a** Coronal high-resolution, T2-weighted, fat-saturated imaging of the orbits in an 11 month old girl with right MGDA diagnosed fundoscopically demonstrates a normal left and abnormal, thickened right intraorbital optic nerve (dashed circle). Note homogenous T2 signal within the enlarged right intraorbital optic nerve; there was no associated enhancement nor progression on 6 month follow-up MRI. **b** Coronal high-resolution, T2-weighted, fat-saturated imaging of the orbits in a 7 year 10 month old girl with left MGDA diagnosed fundoscopically demonstrates a normal right and abnormal, thinned left intraorbital optic nerve (dashed circle). **c** Coronal high-resolution, T2-weighted, fat-saturated imaging of the orbits in the same 11 month old girl as in Fig. 3a demonstrates abnormal, asymmetric enlargement of the right optic chiasm (arrowhead). Note normal T2 signal within the enlarged right optic chiasm. **d** Coronal high-resolution, T2-weighted, fat-saturated imaging of the orbits in a 9 year 11 month old girl with left MGDA diagnosed fundoscopically demonstrates mild, asymmetric thinning of the left optic chiasm (arrowhead)

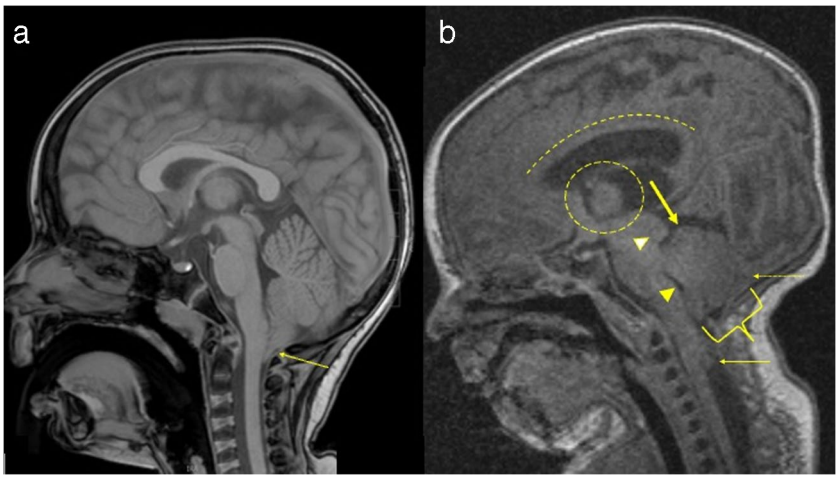

Fig. 4 **a** Midline sagittal T1-weighted imaging of the brain in a 4 year old girl with left MGDA diagnosed fundoscopically demonstrates caudal descent of the cerebellar tonsils (arrow), > 5 mm below the foramen magnum; the tonsils have an abnormal "peg-like" morphology. Findings are consistent with Chiari 1 deformity. **b** Midline sagittal T1-weighted imaging of the brain in a 3 year 5 month old boy with bilateral MGDA diagnosed fundoscopically demonstrates caudal descent of the cerebellar tonsils, which lie at the level of C3 (arrow), a small posterior fossa (bracket), abnormally low attachment of the tentorium cerebelli and low-lying torcula (dashed arrow), towering cerebellum (thick arrow), slit-like fourth ventricle (arrowhead), tectal beaking (open arrowhead), a large massa intermedia (dashed circle) and thin corpus callosum (dashed line). The child also had a lower lumbar myelomeningocele (not shown). Findings are consistent with Chiari 2 malformation

syndrome (coloboma, heart disease, choanal atresia, retardation, genital hypoplasia and ear anomalies), while MGDA is almost never familial [11]. Thus, the distinction between MGDA and coloboma has important prognostic/genetic counselling implications for the child and their family. In MGDA, the optic disc lies symmetrically and centrally within the funnel-shaped excavation of the posterior globe. By contrast, optic nerve coloboma, which occurs due to incomplete closure of the embryonic optic fissure, manifests at the inferonasal aspect of the optic disc or below it [12]. The funnel-shaped excavation of the optic disc seen with coloboma is typically vertically oblong [11]. Crucially, coloboma lacks the abnormal retrobulbar soft tissue that characterizes MGDA [4]. MGDA and optic nerve colobomas are congenital anomalies, whereas staphyloma refers to acquired globe ectasia [7] and on MRI is characterized by focal bulging and thinning of the globe wall, which most commonly occurs posteriorly [13]. The retrobulbar optic nerve is normal (Fig. 6).

MRI also identifies ocular abnormalities that occur in association with MGDA, for example, retinal detachment [1, 6, 14–16], which we encountered in four of our cases and decreased globe caliber [6, 17], which we observed in five of 19 cases.

Several case reports have described enlarged optic nerves/chiasms in the setting of MGDA as optic pathway "gliomas" (OPGs) [18, 19]. However, more recent research has shown that optic pathway caliber abnormalities – both thickening and thinning, affecting anywhere from orbit to chiasm – are common in patients with MGDA [1, 5, 6]. Optic pathway caliber abnormalities were frequent in our cohort, with either thickening or thinning, affecting nerve and/or chiasm in nine of our 18 patients.

Optic pathway enlargement (OPE) in MGDA does not display the characteristic features of OPGs. In our cohort, all cases of OPE demonstrated homogeneously isointense T2 signal, without contrast enhancement (where given) or progression on follow-up imaging. These findings align with the largest MGDA radiological study by Poillon et al. (n = 40), wherein all cases of optic nerve and/or chiasm enlargement displayed homogeneously isointense T1 and homogeneously iso-/hyperintense T2 signal, without abnormal enhancement, restricted diffusion or progression [6]. Sporadic gliomas of the optic nerves are rare and more commonly occur in the setting of neurofibromatosis type 1. OPGs, unlike OPE in MGDA, tend to be heterogenous in signal, with enhancement and progression on follow-up studies [20].

In addition to optic nerve/chiasm enlargement, small caliber optic nerves were common in our cohort and have been previously described by other groups. Nguyen et al., in a series of nine patients with MGDA reported optic nerve/chiasm thickness abnormalities in all cases, with a thinner optic nerve in one patient and irregular optic pathway thickness in all other cases [1]. Ceynowa et al. also described optic nerve thinning in the context of MGDA [21].

Notably, all cases of optic pathway caliber abnormality, both in our cohort and in prior studies [1, 5, 6], occurred ipsilateral to the MGDA. Thus, research to date suggests

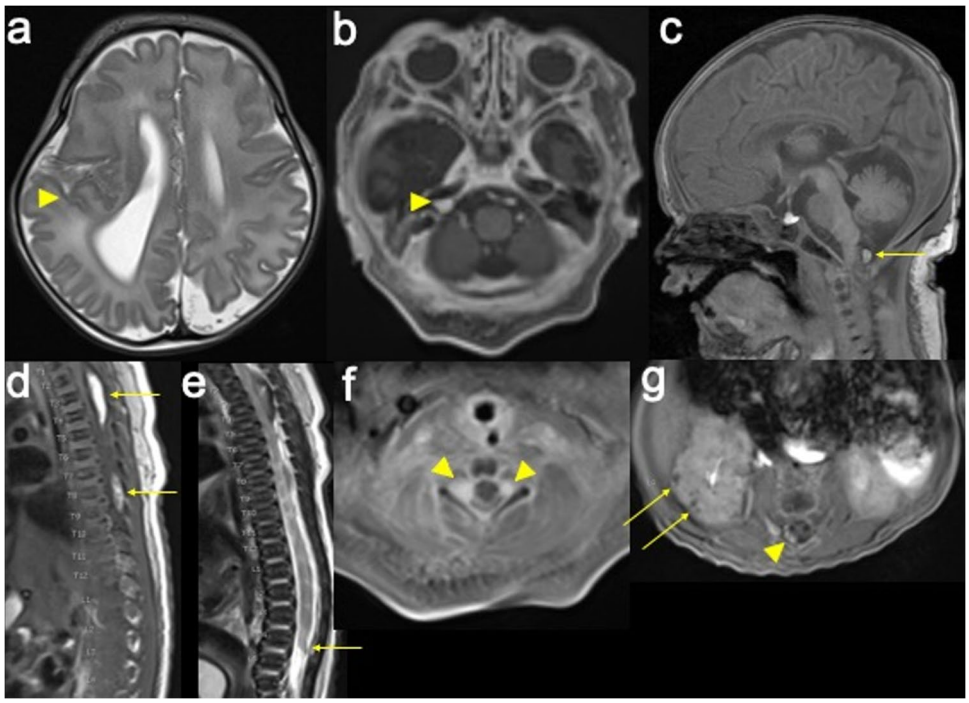

Fig. 5 2 day old girl with congenital verrucous epidermal naevus syndrome, seizures and cranial ultrasound suggesting right hemimegalencephaly and right temporal lobe polymicrogyria. **a** Axial T2-weighted imaging of the brain demonstrates asymmetric enlargement of the right cerebral hemisphere and right lateral ventricle and suspected polymicrogyria involving the right posterior perisylvian cortex (arrowhead). **b** Axial T1-weighted, fat-saturated, post-contrast imaging of the brain demonstrates an enhancing mass in the right IAM (arrowhead). **c** Midline sagittal T1-weighted imaging of the brain demonstrates a lipomatous lesion at the dorsal cervicomedullary junction (arrow). **d** Sagittal T1-weighted imaging of the spine demonstrates further intradural, extramedullary lipomatous lesions in the dorsal spinal canal from T1-T5 and from T7-T9 (arrows). **e** Sagittal T2-weighted imaging of the spine demonstrates a low-lying conus, at the inferior endplate of L4 (arrow). **f** Axial T1-weighted, fat-saturated, post-contrast imaging of the cervical spine demonstrates enlargement of and abnormal enhancement within dorsal root ganglia/nerve roots (arrowheads). **g** Axial T1-weighted, fat-saturated, post-contrast imaging of the spine demonstrates enlargement of and abnormal enhancement within right cauda equina nerve roots (arrowhead). Note also low signal/non-enhancing, cystic foci in the right kidney (arrows), consistent with renal dysplasia. Findings raised suspicion for a systemic overgrowth syndrome, i.e. CLOVES

that optic pathway caliber abnormalities, both thickening and thinning, in the setting of MGDA likely reflect malformative/developmental or dysplastic abnormalities. However, as surgical resection is considered a "last resort" in the treatment of optic nerve gliomas [22], there is a lack of histopathological data at present to support the theory that OPE in MGDA reflects a developmental or dysplastic, as opposed to neoplastic, process. As radiologists, we must be aware of this association, as it may justify an increased interval between follow-up MRIs, particularly in younger children, requiring general anaesthetic for same. It may also obviate the need for potentially-unnecessary and harmful interventions, such as chemo- and/or immunotherapy.

An important role for MRI in MGDA is in screening for various intracranial abnormalities that have been described in association with this condition. These wide-ranging abnormalities, often midline, include basal cephalocoeles, typically trans-sphenoidal [23–25], pituitary gland and/or stalk abnormalities [2, 15, 26, 27], corpus callosal agenesis/dysgenesis [21] and Chiari 1 deformities [28, 29]. The latter was observed in our cohort. We also report here, to the best of our knowledge, the first case of Chiari 2 malformation in the setting of MGDA; on balance, the Chiari 2 malformation and associated lumbar myelomeningocele are felt to be unrelated/incidental to the MGDA. Additionally, we report one complex congenital case whereby MGDA was seen alongside multiple cerebral, spinal and non-neuroaxis abnormalities. This raised suspicion for a systemic overgrowth syndrome, i.e., CLOVES (congenital lipomatous overgrowth, vascular malformations, epidermal nevi, skeletal and/or spinal anomalies), suggesting that MGDA can rarely occur as part of a syndrome. Other craniofacial (typically midline) abnormalities, i.e., cleft lip and palate [16] and facial hemangiomas/PHACES syndrome (posterior fossa abnormalities, hemangiomas, arterial anomalies, cardiac defects, eye abnormalities, sternal cleft and supraumbilical raphe) [17, 21, 30], which are associated with this condition may also be identified on MRI brain in this cohort.

Table 1 Patient characteristics and MRI findings

Patient characteristics			
Gender	13 F	5 M	
Age range	2 days—12 years 10 months	Mean 4 years 10 months	
MRI findings			
Affected side	9 right	8 left	1 bilateral
Funnel-shaped posterior optic disc	18/19 (94.7%)		
Thickening of retinal surface	15/19 (84.2%)		
Retinal T1 hyperintensity	0/19 (0%)		
Retinal detachment	4/19 (21.1%)		
Abnormal soft tissue associated w/ retrobulbar optic nerve	18/19 (94.7%)		
Effacement of subarachnoid spaces	18/19 (94.7%)		
Discontinuity in posterior globe wall	16/19 (84.2%)		
Fatty infiltration in retrobulbar optic nerve sheath	4/19 (21.1%)		
Enhancement in retrobulbar optic nerve	4/7 (57.1%)		
Small ipsilateral globe	5/19 (26.3%)		
Ipsilateral optic nerve calibre	1 increased (5.3%)	6 decreased (31.6%)	
Ipsilateral optic chiasm calibre	2 increased (10.5%)	1 decreased (5.3%)	
Vascular anomaly	1/18 (5.6%)		
Other intracranial abnormality	3/18 (16.7%)		

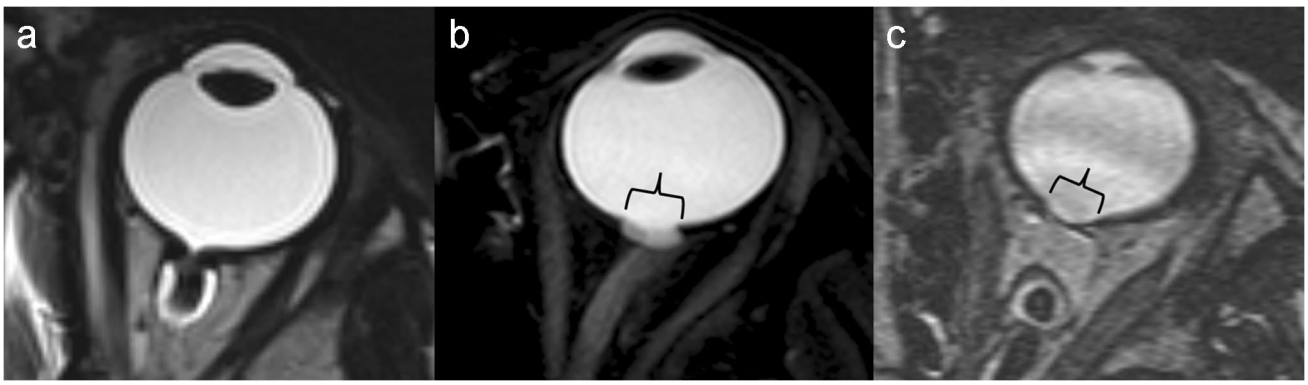

Fig. 6 **a** Note typical MRI findings of MGDA, as described in Fig. 2a above. **b** Coloboma. Note a defect in the posteroinferior left globe, with a normal left retrobulbar optic nerve. **c** Staphyloma. Note broad-based thinning of the posterior globe, remote from the optic nerve head insertion

Vascular abnormalities, most commonly Moya Moya disease (MMD) [27, 31] but also other internal carotid, anterior and middle cerebral artery vasculopathies, including stenoses [15, 32, 33] and agenesis [15, 17, 32] have been described in association with MGDA. Although these vascular abnormalities (apart from MMD) are typically static and likely represent congenital anomalies, reversible carotid artery narrowing has also been described in this context [34]. In our cohort, we encountered one case of terminal ICA stenosis, which did not progress during three years of follow-up.

Neurocristopathy, a disease of the neural crest cells, could explain the various associations of MGDA. Cephalic neural crest cells produce craniofacial mesenchyme, which forms the craniofacial skeleton (skull, adenohypophysis, eye tissues etc.) but also gives rise to smooth muscle cells in the cerebral arteries of the prosencephalon. Hence, cephalic neurocristopathy, a disease of the cephalic neural crest cells, could explain the co-existence of ocular anomalies, basal cephaloceles, pituitary gland/stalk abnormalities, corpus callosal agenesis/dysgenesis, craniofacial anomalies such as cleft lip and palate, PHACES syndrome and MMD [35].

There are several limitations to our study. Our cohort is small, owing to the rarity of this disease. Additionally, some patients with MGDA may not have been captured by our search strategy. Given the retrospective nature of our study and the long period over which data was acquired (almost 20 years), the quality of MRIs and the sequences performed

varied between patients. More recently-performed studies are inherently of higher quality, having been acquired at 3 T field strength, with resultant increased signal-to-noise ratio, higher spatial resolution, potential for isotropic reconstruction and faster acquisition speeds, making images less likely to be motion-degraded [36]. Diagnostic accuracy may have been improved with higher quality studies. However, three findings—funnel-shaped morphology of the posterior optic disc, abnormal soft tissue associated with the retrobulbar optic nerve and effacement of adjacent subarachnoid spaces—were visible in 18 of 19 cases, regardless of study quality, thereby allowing the clinical diagnosis of MGDA to be confirmed.

Conclusions

While MGDA is typically diagnosed fundoscopically, MRI can aid in confirming the diagnosis and in detecting associated malformations—ocular, skull base/cerebral, vascular, and facial. MRI brain, with high-resolution, T2-weighted, fat-saturated imaging of the orbits, contrast-enhanced and angiographic sequences (at least on the index study), should be performed in cases of MGDA, both to assess the globe and to screen for associated abnormalities. Caliber abnormalities of the ipsilateral optic nerve and chiasm are a frequent finding in MGDA. Optic pathway enlargement should not be labeled "glioma".

Data availability The authors confirm that the data supporting the findings of this study are available within the article.

Declarations The authors have no relevant financial or non-financial interests to disclose.

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