



Clinical study

Unruptured brain arteriovenous malformations and hydrocephalus: Case series and review of the literature

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ABSTRACT

Objective: Hydrocephalus is an uncommon presentation of unruptured brain arteriovenous malformations (AVMs). The goal of this case series and literature review is to present possible pathological mechanisms, management strategies and outcomes in patients with hydrocephalus due to unruptured AVMs. **Methods:** Three consecutive patients with hydrocephalus caused by unruptured AVMs as well as all cases previously reported in the literature were retrospectively reviewed to determine clinical symptoms, AVM location, nidus size, venous drainage, mechanism of hydrocephalus, level/cause of obstruction, and degree of hydrocephalus. Management of hydrocephalus, AVM treatment, and follow-up length were evaluated.

Results: Of 350 patients unruptured AVMs, 3 presented with hydrocephalus (0.8%). In the literature review we found an additional 22 patients for a total of 25 cases. Eighteen patients had mechanical obstruction by the draining vein or the AVM nidus, usually at the level of the aqueduct (52%). Impaired cerebrospinal fluid resorption secondary to venous congestion led to hydrocephalus in 7 patients. Ten patients were treated for both the AVM and hydrocephalus, 13 patients underwent treatment of either hydrocephalus, or the AVM alone. Treatment of hydrocephalus, with or without associated treatment of the brain AVM, resulted in improvement of symptoms in 92% of patients. No rupture of the AVM was reported at follow-up.

Conclusions: The most common cause of hydrocephalus in unruptured brain AVMs is mechanical obstruction by the draining vein if it is located in a strategic position. Treatment of hydrocephalus alone or with associated treatment of the AVM is safe and effective.

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1. Introduction

Unruptured brain arteriovenous malformations (AVMs) generally present with seizures, headaches, or are discovered incidentally. However, about 1% of AVMs present with hydrocephalus (HC). The mechanisms of hydrocephalus development in patients with unruptured brain AVMs are still debated. They can include obstruction of the ventricular system at a point of narrowing due to compression by a deep dilated draining vein or impaired cerebrospinal fluid (CSF)-reabsorption due to venous hypertension when a major sinus is involved by the AVM. Increased intracranial pressure has been reported as a possible presentation in patients with unruptured brain AVMs in few case series and case reports [1–8]. In this study we present a systematic review of the literature

and 3 consecutive cases of unruptured AVMs associated with hydrocephalus evaluated at our institution over a 10 year period in order to raise the awareness of the possible pathological mechanisms and respective management strategies.

2. Material and methods

2.1. Institutional case series

The study was approved by our Institutional Review Board. We reviewed data of 350 consecutive patients with a diagnosis of unruptured brain AVM evaluated at our institution over the past 10 years. Patients were included in our study if they (1) gave consent to use of their information for research purposes; (2) had at least one unruptured brain AVM and associated hydrocephalus.

Information collected included: baseline demographic and clinical data (age at presentation and gender); symptoms and signs at presentation, degree of hydrocephalus; location of unruptured brain AVMs; nidus size based on maximal diameter of the lesions; veins draining the AVMs; mechanism of hydrocephalus and

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level/cause of ventricular system compression if its nature was obstructive; treatment of hydrocephalus and/or treatment of the AVMs; outcome and follow-up period of time.

2.2. Literature review

The systematic review is reported according to the PRISMA guidelines [9]. A comprehensive literature search of the databases PubMed, Ovid MEDLINE, and Ovid EMBASE was designed and conducted by an experienced librarian with input from the authors. The key words “AVM,” “arteriovenous malformations,” “brain,” and “hydrocephalus” were used in “AND” and “OR” combinations. The search was limited to articles published from 2000 to 2018. Inclusion criteria were the following: 1) English or Italian language, 2) case series or case reports, 3) studies reporting exclusively unruptured brain arteriovenous malformations, and 3) studies reporting hydrocephalus as clinical presentation. Exclusion criteria were: 1) arteriovenous malformation of the spinal cord, 2) ruptured arteriovenous malformations, and 3) studies reporting any symptom or sign as clinical presentation but hydrocephalus.

For each study, we extracted the following baseline information: number of patients, age and gender, clinical presentation, degree of hydrocephalus, location of the lesions, nidus size, draining veins, mechanism of hydrocephalus and level/cause of obstruction if that was its nature, hydrocephalus and/or AVM treatment, outcome and length of follow-up in months. Outcomes of this study include clinical or radiographic improvement of hydrocephalus, and lack of benefit following hydrocephalus or AVM treatment.

2.3. Statistical analysis

Descriptive statistics are reported including means and proportions. All analyses were performed with JMP 13.0 (www.jmp.com, Cary, NC). No formal statistical comparisons were performed due to small samples sizes and insufficient power to detect differences between groups.

3. Results

3.1. Institutional case series

Three patients out of 350 (0.8%) in our unruptured brain AVMs database presented with hydrocephalus.

Case 1: A 67 years old man who had a ventriculo-pleural shunt placed at an outside institution for management of hydrocephalus secondary to a pineal region AVM presented to our institution with seizure, behavioral changes and fever. At the time of presentation to our institution the shunt was not working (Fig. 1a), due to shunt infection. MRI showed a pineal AVM with nidus size of 3 cm, dilated Internal Cerebral Vein (ICV) and Vein of Galen (VoG) as draining veins (Fig. 1b). The engorged VoG was compressing the posterior 3rd ventricle and the sylvian aqueduct causing a severe obstructive hydrocephalus. The infection was treated successfully and the shunt was replaced, thus the symptoms of hydrocephalus rapidly relieved. The post-revision CT scan showed decompression

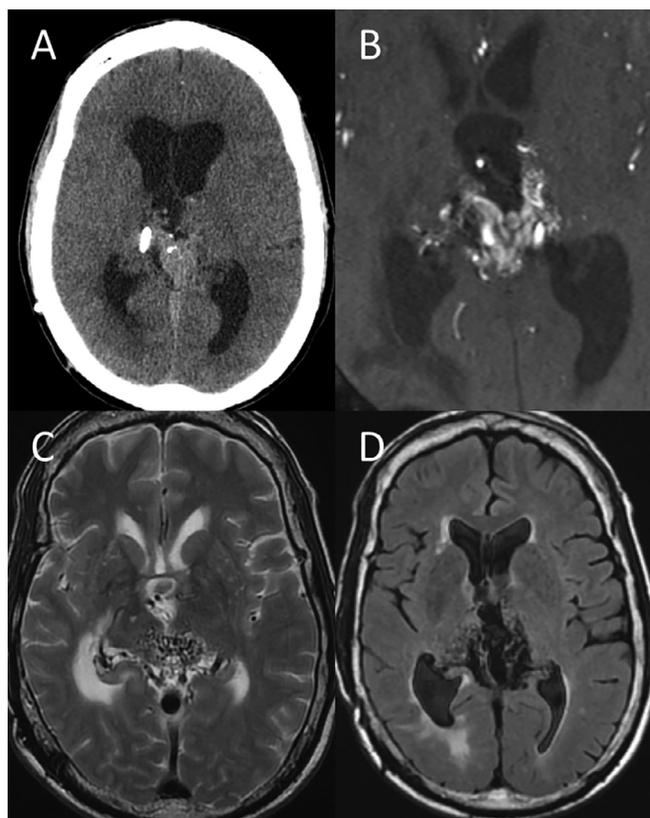


Fig. 1. Patient 1. A. Non-contrast CT shows hydrocephalus with dilatation of the lateral and third ventricles. There is a hyperdense lesion in the posterior wall of the third ventricle. B. 3D TOF MRA shows a midline AVM of the midbrain and thalamus with marked dilatation and ectasia of the bilateral internal cerebral veins. C. Axial T2 MRI shows the AVM in the superior midbrain surrounding the aqueduct. D. Post shunt revision there is marked improvement in hydrocephalus.

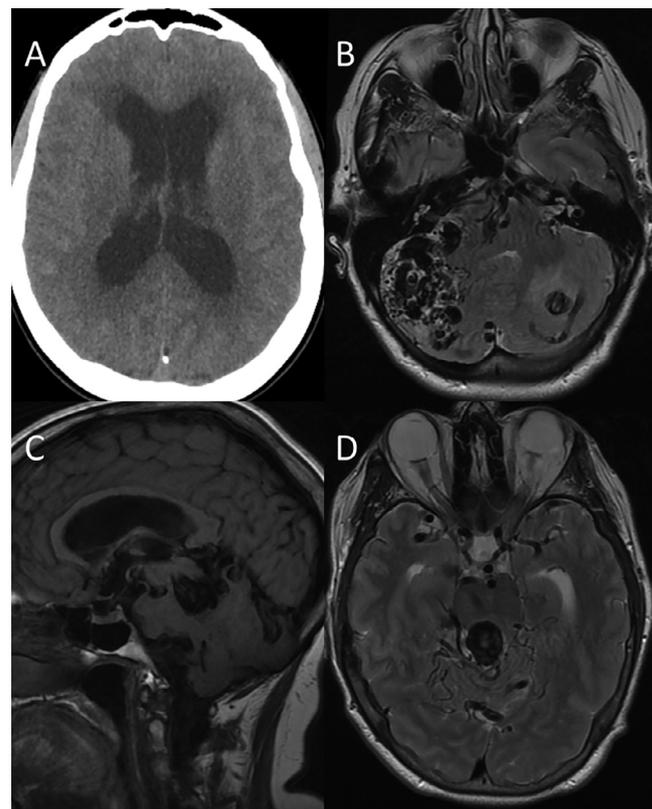


Fig. 2. Patient 2. A. Axial non-contrast CT shows marked dilatation of the lateral ventricles with periventricular edema consistent with transependymal flow of CSF. B. Axial T2 MRI shows a large AVM of the right cerebellar hemisphere draining into a large cerebellar hemispheric vein. There is also a large venous varix with surrounding edema in the left cerebellar hemisphere. C. Sagittal T1 MRI shows dilatation of the lateral ventricles and a large venous varix representing the VoG compressing the aqueduct. D. Axial T2 MRI shows the large VoG varix compressing the aqueduct.

of the ventricles (Fig. 1c). The patient remained stable over a 3 years follow-up period of time. The AVM was left untreated.

Case 2: A 58 year old woman presented to our institution with gait disturbances. The MRI showed enlargement of the ventricles and trans-ependymal edema (Fig. 2). There was a right cerebellar hemispheric AVM with nidus size of 3 cm. The AVM was drained by vermian veins and the ectatic VoG, thus causing compression of the aqueduct. Obstruction of the ventricular system resulted in moderate hydrocephalus. The patient did not undergo any treat-

ment and remained stable over a 9 month follow-up period. The AVM was left untreated.

Case 3: A 40 year old woman presented with slurred speech and gait disturbances. The MRI showed a brainstem AVM with nidus size of 2.5 cm and a dilated VoG as draining vein (Fig. 3). The ectatic VoG was compressing the sylvian aqueduct causing a severe hydrocephalus. A ventriculo-peritoneal shunt was placed, resulting in improvement of her symptoms. The AVM was left untreated. The patient was doing well at 1 year.

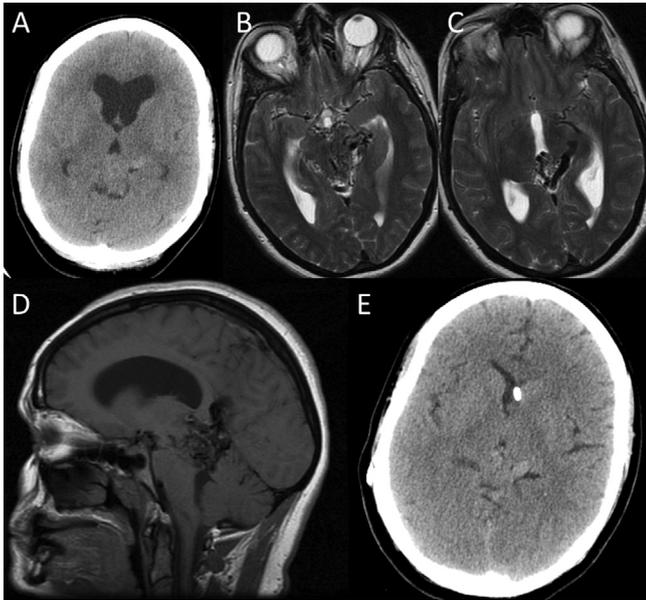


Fig. 3. Patient 3. A. Axial non-contrast CT shows marked ventricular dilatation involving the third and fourth ventricles. B and C. Axial T2 MRI shows a midbrain AVM with drainage into a dilated posterior mesencephalic vein and associated dilatation of the basal vein of Rosenthal (BVR). The posterior mesencephalic vein, VoG and AVM nidus appear to be compressing the aqueduct. D. Sagittal T1 MRI shows the AVM of the posterior midbrain. E. Post shunting non-contrast CT shows resolution of the ventricular dilatation.

Table 1
Demographic data and clinical presentation.

Case no.	Age	Sex	Clinical presentation
1	70	F	Cognitive impairment, gait disturbances, urinary incontinence
2	21	F	Headache, papilledema
3	33	F	Visual loss
4	37	M	Visual loss
5	54	M	Gait disturbances
6	11	M	Headache, nausea, vomiting, papilledema
7	61	M	Gait disturbances
8	16	F	Headache
9	17	F	Headache, loss of consciousness
10	35	M	Headache
11	39	F	Headache, seizures
12	6	F	Headache, papilledema, seizures
13	26	M	Headache, chemosis/proptosis
14	55	M	Headache
15	2	M	Macrocrania
16	42	F	Headache, seizures, cognitive impairment, gait disturbances, urinary incontinence, nystagmus
17	55	M	Headache
18	4	M	Headache, seizures, cognitive disturbances, gait disturbances
19	83	M	Loss of consciousness
20	64	F	Headache
21	63	M	Loss of consciousness, gait disturbances, urinary incontinence
22	16	F	Headache, papilledema
23	67	M	Seizure, cognitive impairment
24	58	F	Gait disturbances
25	40	F	Gait disturbances, slurred speech

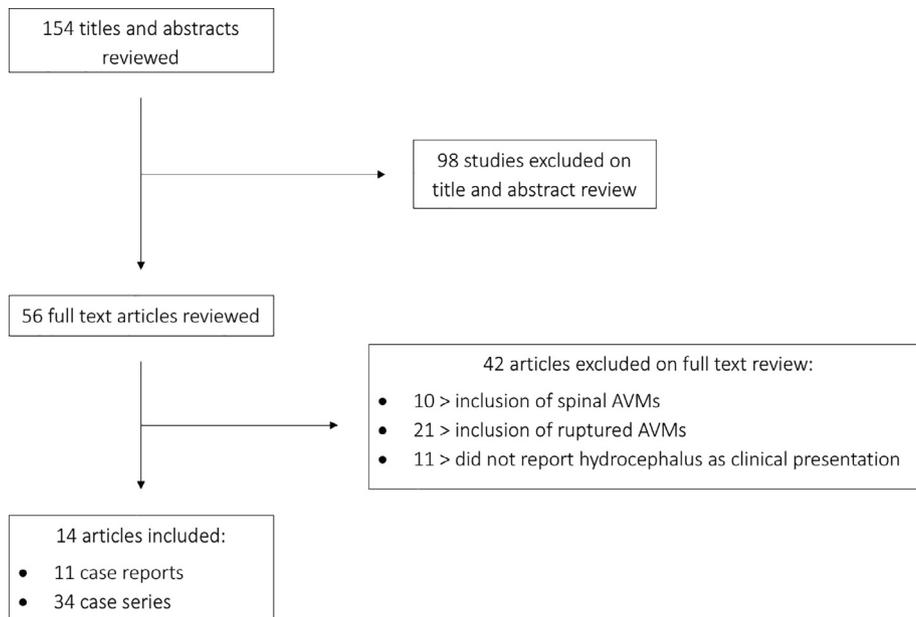


Fig. 4. PRISMA flow diagram.

4. Systematic review

4.1. Literature search

The initial literature search yielded 154 articles. On review of the abstracts and titles, we excluded 98 articles. Fifty-six articles were selected for full-text screening, of which 14 met inclusion criteria [1–8,10–15]. The remaining 48 articles were excluded reasons including 1) inclusion of spinal AVMs (10 articles), 2) inclusion of ruptured AVMs (21 articles), 3) hydrocephalus was not part of the clinical presentation. Fig. 4 shows the flow chart according to the PRISMA statement [9]. Including the 3 cases presented here, a total of 25 patients with hydrocephalus and unruptured brain AVMs were studied in our systematic review.

4.2. Demographics and presentation

Baseline demographic data and clinical presentation of the patient population is summarized in Table 1. There were 13 males and 12 females, whose ages ranged from 2 to 83 years, giving a mean age of 36.8 years. Headache was the most common symptom of presentation (14 pts; 56%) followed by visual symptoms secondary to increased intracranial pressure, and gait disturbances (Fig. 5).

4.3. Mechanisms of hydrocephalus

In this series of patients we identified two different mechanisms of hydrocephalus: 1) 15 patients had an obstructive hydrocephalus related to compression of the ventricular system by an engorged deep venous varix; 2) 7 patients had a hydrodynamic disorder resulting in venous hypertension and decreased CSF reabsorption; notably, these patients developed arterialization of the venous system and particularly the Superior Sagittal Sinus. The hydrocephalus was generally moderate to severe in the first group (94.4%) and mild to moderate in the second group (100%). Lesions

were mostly deeply located in the basal ganglia or midbrain in those patients with obstructive hydrocephalus (55.5%) and superficially located in the cerebellar or cerebral hemispheres in those with a hyperdynamic disorder (85.7%).

The VoG was the most common dilated draining vein causing compression of the ventricular system at the level of the sylvian aqueduct. Less commonly the compressing vein was a dilated vein obstructing the foramen of Monro. The superior sagittal sinus (SSS) was the most common arterialized venous sinus in patients with impaired CSF reabsorption. Mechanisms of hydrocephalus and AVMs characteristics are summarized in Table 2.

4.4. Treatment characteristics and outcomes

Ten patients were treated for both the AVM and hydrocephalus (40%), 13 patients underwent treatment of either hydrocephalus (32%) or the AVM (20%) alone. Two patients (8%) did not receive any treatment. Treatment of the hydrocephalus consisted in VP shunting in 12 patients (66.6%) and 3rd ventriculostomy in 4 patients (22.2%). Among those patients who underwent a VP shunt placement, case no. 5 and case no. 23 required revision of the system following its dysfunction and recurrence of their symptoms; both of them recovered after replacement of the system. Case no. 2 and case no. 16 underwent a lumboperitoneal (LP) shunt and a ventriculoatrial (VA) shunt placement respectively. Overall, treatment of hydrocephalus with or without associated treatment of the brain AVM, resulted in improvement of symptoms in almost every patient (92%). Treatment of the AVM consisted in surgical excision of the lesion in 3 patients (20%), radiosurgery in 3 patients (20%), embolization alone in 6 patients (40%), and embolization followed by radiosurgery in 3 patients (20%). The follow-up period ranged from 2 to 32 months, giving a mean of 9.55 months. Notably, in those patients who underwent treatment of the hydrocephalus alone without concurrent or subsequent treatment of the AVM, no rupture of the AVM was reported at follow-up. Table 3 summarizes treatment, outcome and follow-up period of time for the patient population.

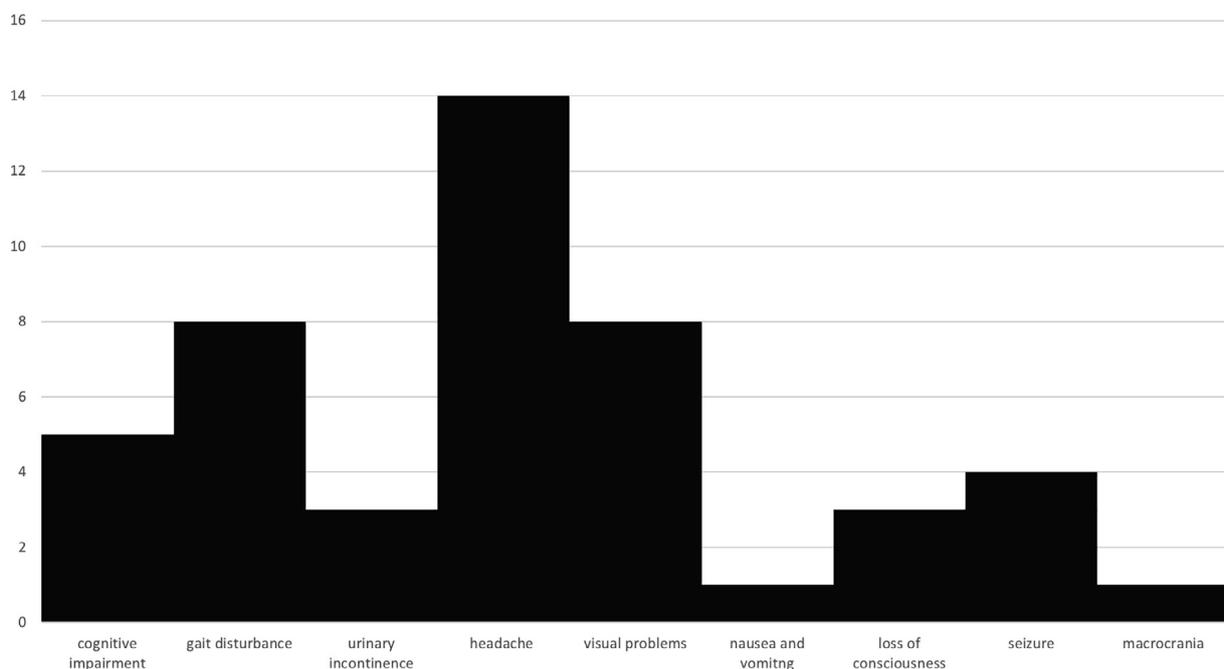


Fig. 5. Clinical presentation.

Table 2
Mechanisms of hydrocephalus and AVMs characteristics.

Case no.	Mechanism of HC	Degree of HC	Lesion Location	Nidus Size (cm)	Venous Drainage	Level/Cause of Obstruction
1	Obstructive	Moderate	Perimesencephalic area	nr	BVR, VoG	Aqueduct/VoG
2	Aresorptive	Moderate	Right frontal parasagittal area	nr	SSS	–
3	Aresorptive	Mild	Left parietal lobe	nr	SSS	–
4	Obstructive	Severe	Right frontal lobe	nr	VoG	3rd ventricle/VoG
5	Obstructive	Severe	Right thalamus, insula, capsula	nr	VoG	Aqueduct/VoG
6	Obstructive	Severe	Perimesencephalic area	nr	ICV, VoG	Aqueduct/VoG
7	Aresorptive	Mild	Posterior third ventricle	2	Transmedullary veins	–
8	Obstructive	Severe	Thalamus	1.5	Perimesencephalic veins, VoG	Aqueduct/VoG
9	Obstructive	Severe	Basal ganglia, thalamus	6	Thalamostriatal veins, ICV, VoG	Left foramen of Monro/ICV
10	Obstructive	Severe	Temporoparietal area	7	Thalamostriatal veins, ICV, VoG	Aqueduct/VoG
11	Obstructive	Mild	Frontal lobe, corpus callosum	3	Thalamostriatal veins, ICV, VoG	Right foramen of Monro/ICV
12	Obstructive	Moderate	Midbrain	2.5	Perimesencephalic veins, VoG	Aqueduct/VoG
13	Obstructive	Severe	Cerebellum	8	Cerebellar veins, VoG	Aqueduct/VoG
14	Aresorptive	Moderate	Cerebellum	3	Cerebellar veins	–
15	Aresorptive	Mild	Cerebellar vermis	3.5	Cerebellar veins	–
16	Obstructive	Severe	Mesencephalon	nr	VoG	Aqueduct/VoG
17	Obstructive	Moderate	Left parietooccipital area	3	VoG	Aqueduct/VoG
18	Aresorptive	Mild	Sylvian fissure	nr	SSS	–
19	Obstructive	Severe	Posterior fossa	nr	VoG	Aqueduct/VoG
20	Obstructive	Severe	Posterior fossa	nr	VoG	Aqueduct/VoG
21	Obstructive	Moderate	Pineal region	nr	VoG	3rd ventricle/VoG
22	Aresorptive	Moderate	Right temporal lobe	3	BVR, TS	–
23	Obstructive	Severe	Pineal region	3	ICV, VoG	Aqueduct/VG
24	Obstructive	Moderate	Cerebellum	3.7	Vermian veins, VoG	Aqueduct/VoG
25	Obstructive	Severe	Brainstem	2.5	VoG	Aqueduct/VoG

Table 3
Treatment, outcome and follow-up.

Case no.	HC Treatment Type	HC Treatment result	AVM Treatment Type	AVM Treatment Result	Follow-up (months)
1	3rd ventriculostomy	Improvement	–	–	nr
2	LP shunt	Improvement	Surgical excision	Improvement	2
3	–	–	Surgical excision	Improvement	3
4	VP shunt	Improvement	Radiosurgery	Improvement	nr
5	VP shunt	Shunt revision followed by improvement	–	–	8
6	VP shunt	Improvement	Embolization, radiosurgery	Improvement	nr
7	–	–	Embolization	Improvement	nr
8	VP shunt	Unchanged	Embolization	Improvement	nr
9	VP shunt	Improvement	Embolization	Unchanged	nr
10	VP shunt	Unchanged	Embolization, radiosurgery	Improvement	nr
11	–	–	Embolization, radiosurgery	Improvement	nr
12	VP shunt	Improvement	Radiosurgery	Unchanged	nr
13	VP shunt	Improvement	–	–	nr
14	VP shunt	Improvement	Embolization	Unchanged	nr
15	–	–	–	–	nr
16	VA shunt	Improvement	Surgical excision	Improvement	2
17	EVD followed by VP shunt	Improvement	Radiosurgery	Improvement	nr
18	–	–	Embolization	Improvement	3
19	3rd ventriculostomy	Improvement	–	–	nr
20	3rd ventriculostomy	Improvement	–	–	nr
21	3rd ventriculostomy	Improvement	–	–	18
22	–	–	Embolization	Improvement	2.5
23	VP shunt	Shunt revision followed by improvement	–	–	36
24	–	–	–	–	9
25	VP shunt	Improvement	–	–	12

5. Discussion

We found that less than 1% of unruptured brain AVMs present with hydrocephalus. There are a variety of mechanisms by which unruptured brain AVMs can cause hydrocephalus including compression of the ventricular system at a point of narrowing such as the sylvian aqueduct, impaired CSF resorption from chronic venous hypertension and overproduction of CSF from AVMs located in the choroid plexus [1,2,5,8,10,11,13,16,17].

In our case series and literature review, we found that obstructive hydrocephalus at the level of the aqueduct was the most common cause of hydrocephalus in patients with unruptured AVMs. This is generally caused by a deep dilated venous system including the thalamostriate-ICV complex or more commonly the VoG. How-

ever, occasionally the AVM itself with its nidus can cause obstruction of the ventricular system. For this reason, obstructive hydrocephalus is generally caused by AVMs deep located in the brain or at least connected with deep draining veins.

Less often, hydrocephalus is provoked by decreased CSF reabsorption due to venous hypertension in major sinus. In this case, the AVM can also be located superficially in the brain or in the cerebellum because its drainage in the venous sinus would cause an increase in the venous pressure thus leading to impaired CSF reabsorption. Because CSF resorption is partly due to a pressure gradient from the ventricles into the pial and transmedullary veins, many authors have hypothesized that increased venous pressure could result in increased CSF retention in the ventricular system [1,2,5,8,13,16,18–20]. A similar mechanism has been postulated

in patients with dural arteriovenous fistulas presenting with a clinical picture resembling normal pressure hydrocephalus [21,22].

5.1. Management of hydrocephalus in patients with brain AVMs

Management strategy should always consider patient characteristics and characteristics of the AVM itself. Brain AVMs are not always easy to treat, especially those causing hydrocephalus, because of their deep location and proximity to eloquent areas [4,11,22]. Moreover, treatment of hydrocephalus alone without treatment of the AVM is effective in relieving symptoms and does not seem to trigger rupture of the AVM. Shunting is an effective means of treating the hydrocephalus and results in high rates of symptom improvement. However, this strategy is not without its limitations due to high rates of shunt malfunction/obstruction and complications related to shunt overdraining (i.e. subdural hematomas or hygromas) [11,23–25].

The potential effect of shunting on the AVM itself is another important consideration. There have been a few reported cases of venous varix dilatation following shunt placement in patients with shunting vascular lesions presenting with hydrocephalus. This is particularly common in patients with VoG malformations but has also been reported in patients with dural arteriovenous fistulas [21,26–30]. This is thought to be secondary to venous engorgement in the setting of decreased CSF pressure. However, this theoretical concern may be less with parenchymal AVMs, as we could not find any case associated with this type of AVM. Another potential effect of shunting for treatment of hydrocephalus from unruptured brain AVMs is the theoretical risk of AVM rupture due to increased arterial pressure in the setting of decreased CSF pressure. We encountered no cases of AVM rupture upon our review of the literature.

6. Conclusions

Unruptured brain AVMs can present with hydrocephalus in less than 1% of cases. The most common mechanism of hydrocephalus development is the compression of the Sylvian aqueduct or the foramen of Monro by a dilated deep draining vein. Less commonly hydrocephalus can be related to a decreased CSF reabsorption in the setting of venous hypertension secondary to the involvement of a major venous sinus from the AVM. Treatment of hydrocephalus, with or without associated treatment of the brain AVM, is effective in relieving symptoms. Treatment of hydrocephalus alone does not appear to correlate with following rupture of the brain AVM.

7. Declarations of interest

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