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Mohammed A. El-Din Habiba

*Department of Neurosurgery and Neuroendovascular Intervention, Faculty of Medicine, Ain Shams University*

Sameh M. Saleh

*Department of Neurosurgery and Neuroendovascular Intervention, Matareya Teaching Hospital, Cairo, Egypt, sameh.matareia2004@gmail.com*

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## REVIEW

# Endovascular management of vein of galen aneurysmal malformations: case series and review of the literature

Mohamed A. Habib <sup>a</sup>, Sameh M. Saleh <sup>b,\*</sup>

<sup>a</sup> Department of Neurosurgery and Neuroendovascular Intervention, Faculty of Medicine, Ain Shams University, Egypt

<sup>b</sup> Department of Neurosurgery and Neuroendovascular Intervention, Matareya Teaching Hospital, Cairo, Egypt

## Abstract

**Background:** Neonates with vein of Galen aneurysmal malformations (VGAMs) who present with heart failure have a high rate of morbidity and mortality, while those who present later in childhood have considerably better outcomes.

**Aim:** To determine the factors that have the greatest predictive value in predicting long-term results in children with VGAM.

**Patients and methods:** Between June 2015 and June 2020, 15 patients (seven infants, eight children) were diagnosed with symptomatic VGAMs, four of whom were suffering from intractable high-output heart failure and received initial endovascular treatment. All of them were treated by endovascular procedures. Staged transarterial route was the management approach with embolic agent with different concentrations.

**Results:** In the four patients, immediate outcomes included management of heart failure and normal neurological performance. On follow-up examination, 11 (73.33%) children had no evidence of neurologic abnormality or heart failure, four (26.66%) infants had mild developmental delays, and two of them improved with time. On digital-subtraction angiography follow-up, twelve had no additional shunting, two had limited flow, and one was awaiting follow-up imaging.

**Conclusion:** Even in the most high-risk neonates and children with VGAMs and heart failure, endovascular therapy combined with current neuroanesthetics and neurointensive care can provide good outcomes.

**Keywords:** Cardiac failure, Embolization, Endovascular management, Vein of Galen aneurysmal malformations

## 1. Introduction

Vein of Galen aneurysmal malformations (VGAMs) are uncommon congenital intracerebral arteriovenous shunts that affect newborns and infants. Although VGAMs account for about 1% of intracranial vascular malformations, they account for ~30% of all vascular malformations in the pediatric-age group [1].

VGAMs are caused by the persistence of an embryonic vascular structure called the median prosencephalic vein, which generally regresses by the 11th week of pregnancy, except for the caudal end, which represents the true vein of Galen [2].

The VGAM should be recognized from what is called aneurysmal dilatation of the true vein of Galen caused by an adjacent brain arteriovenous malformation (AVM) (VGAM or Vein of Galen Aneurysmal Dilatation (VGAD)), which was characterized by a higher incidence of bleeding tendencies [3].

VGAMs are a group of arteriovenous fistulas draining into the dilated median prosencephalic vein. Anterior and posterior choroidal arteries, the pericallosal artery, and perforators from basilar tip represent the main feeders of these fistulas [4].

VGAMs are classified into mural, choroidal, and mixed types. In the mural type, a direct high-flow

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\* Corresponding author at: Al Huria Street, Matarya, Cairo, Egypt. Fax: +022506090.  
E-mail address: [sameh.matareia2004@gmail.com](mailto:sameh.matareia2004@gmail.com) (S.M. Saleh).

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shunt is located within the wall, while in the choroidal type, there is interposition of the arterial feeders and the venous aneurysm, and the mixed types have the two components. The mural kinds of VGAMs are more commonly presented in late infancy with macrocephaly or failure to thrive, and may present with moderate heart failure or asymptomatic cardiomegaly. The choroidal types of VGAMs usually cause cardiac-output failure in newborns [4].

The introduction of endovascular therapy changed the management and outcome of VGAM patients dramatically. The emergence of ICUs and clinicians specialized in the management of severely ill neonates has also played a significant role in the current positive outcomes [5].

The aim of this study was to identify those factors that have the greatest predictive value in predicting long-term results in children with VGAMs.

## 2. Study details

### 2.1. Patient population

In total, 15 cases of VGAMs were diagnosed and treated between the period of June 2015 and June 2020. In total, seven infants and eight children were included in this study. About 10 of them were males and five were females.

### 2.2. Preoperative evaluation

All patients were properly assessed clinically and radiologically by computed tomography and/or MRI brain and supplementary digital-subtraction cerebral angiography.

Clinical presentation and outcome were assessed by the neurological and developmental findings,

which are staged into five grades, with grade 4 representing patients with normal development, grade 3 representing patients having mild level of impairment, grade 2 representing patients having intermediate level of impairment affecting their ability of daily achievements and require obvious help in their interactions but in low need for medications, grade 1 representing patients having a severe form of neurological deficits requiring aggressive care and medical treatment, and grade 0 representing mortality cases.

### 2.3. Treatment strategy

Endovascular management through transarterial route was the treatment choice in all cases. Treatment plan and stages were individualized according to the clinical, radiologic presentations, and angiographic architecture of the lesions.

All the 15 patients underwent endovascular embolization in our neuroendovascular-intervention unit. Staged transarterial approach was the selective technique used to treat all cases using different concentrations of liquid acrylic embolic agents such as Histoacryl opacified with tantalum powder as lipiodol according to the shunt flow.

## 3. Results

Fifteen patients with VGAMs were treated in Matarya Teaching Hospital between June 2015 and June 2020. Two of the children were diagnosed when they were neonates, five between the ages of 6 and 19 months, six between the ages of 3 and 5 years, and two at the age of 12 years. All of the patients who presented during the neonatal period had some degree of cardiac-output failure at the time of presentation.

Table 1. Patients' data, clinical scoring, and presentation.

Case no.	Sex	Follow-up	Age at intervention	Presentation	Clinical score
1	Male	3.5 years	1.5 months	CHF	2
2	Male	12 months	2 months	CHF, dilated scalp veins, and proptosis hydrocephalus	3
3	Male	3 years	6 months	Mild CHF	4
4	Female	2.7 years	8 months	Mild CHF, dilated scalp veins, and hydrocephalus	3
5	Male	2.5 years	9 months	Mild CHF	3
6	Male	16 months	14 months	CHF	3
7	Female	2 years	19 months	Mild CHF	4
8	Male	22 months	3.2 years	Mild CHF, dilated scalp veins, and hydrocephalus	4
9	Female	20 months	3.5 years	Mild CHF, hydrocephalus	4
10	Male	18 months	3 years	Mild CHF	4
11	Male	12 months	5 years	CHF	4
12	Male	3 years	3.8 years	Mild hydrocephalus	3
13	Female	2 years	4.5 years	Mild CHF	4
14	Male	12 months	12 years	Hydrocephalus	4
15	Female	18 months	12 years	Mild CHF, hydrocephalus	4

Four of the patients had intractable high-output heart failure and were treated with endovascular intervention at the outset after initial-emergency pediatric cardiology consultation and assessment. Mild cardiac-output failure was noted in nine cases associated with neurological symptoms due to hydrocephalus in five cases. Neurological symptoms due to hydrocephalus were the main presentation in two cases.

At presentation, one child had moderate developmental delay requiring significant supportive social and medical treatment. Five cases had mild neurological developmental delay requiring some sort of educational support, and the other cases were neurologically normal apart from some of the manifestations of increased intracranial pressure.

The minimum duration of follow-up was 12 months and the maximum duration was 3.5 years with a mean 23.47 months. During this period, the cases were followed clinically and radiologically by computed tomography and/or MRI brain and supplementary digital-subtraction cerebral angiography (Table 1).

Nine of the 15 malformations were classified as choroidal, three were mural, and three were mixed, indicating the presence of both choroidal and mural components. Three patients of the nine cases classified as choroidal VGAMs were having some sort of neurological delay, one of them improved neurologically, and two cases remain unchanged. Of the mural types, two cases were having a degree of neurological delay and both improved neurologically after intervention. Mild neurological developmental delay was noted in one case of both mural and choroidal architecture, which remained unchanged. All cases showed no worsening of their neurological or cardiac condition and those patients that remained unchanged neurologically required mild supportive and educational treatment.

Three cases required cerebrospinal-fluid (CSF) shunting procedure. Ventriculoperitoneal shunt was inserted preintervention in two patients, and post-intervention in one case. All the three cases were of choroidal architecture. Radiological hydrocephalic changes and clinical symptoms improved after intervention in the rest of patients without any shunting procedures. Neuroophthalmological manifestations were noticed in three patients, one in the early infancy and two are older children, in the form of loss of upward gaze, nystagmus, and strabismus. One of them required surgical correction of squint after finishing stages of endovascular management.

Staged intervention was the treatment strategy in all cases. Two sessions were required to treat all cases with mural architecture, three sessions for five

Table 2. Fistula classification, cerebrospinal-fluid diversion, and outcomes.

Case no.	Lesion classification	VP shunt/or not	Outcome score
1	Mural	Not shunted	3
2	Choroidal	Not shunted	4
3	Mixed	Not shunted	4
4	Choroidal	Shunted	3
5	Mural	Not shunted	4
6	Mixed	Not shunted	3
7	Choroidal	Not shunted	4
8	Choroidal	Shunted	4
9	Choroidal	Not shunted	4
10	Choroidal	Not shunted	4
11	Mural	Not shunted	4
12	Choroidal	Not shunted	3
13	Choroidal	Not shunted	4
14	Choroidal	Shunted	4
15	Mixed	Not shunted	4

cases with choroidal architecture, and four sessions for the rest of cases of choroidal architecture, and cases with mixed choroidal and mural architectures.

Histoacryl opacified in lipidol was the embolic agent injected through the microcatheters via arterial route in all cases (Table 2 and Figs. 1–3).

#### 4. Discussion

VGAM represents a rare vascular anomaly characterized by arteriovenous fistulas and shunts that drain into a dilated median vein of Markowski [6].

The lesion is in the midline and is frequently supplied by the limbic system, which includes bilateral choroidal arcades, pericallosal arteries, varied transmesencephalic arteries, and midbrain perforators [7].

The age of the child, the size and location of the VGAMs, the status of venous drainage, such as outflow stenosis or thrombosis, which can redirect venous outflow of the brain, and/or the malformation through alternative venous channels such as the cavernous sinus, and/or transosseous veins, all influence the clinical presentation of VGAMs [8,9]. In particular, venous hypertension can lead to cortical calcifications or even a condition known as ‘melting-brain syndrome,’ which is an irreversible condition [8].

Typically, neonates present with signs of severe cardiopulmonary distress and/or high-output heart failure. Macrocephaly, hydrocephalus, and/or seizures are common in infants [10,11]. Developmental delay or failure to thrive associated with complicating medical factors (e.g. long-standing cerebral venous hypertension, cardiac decompensation) are the presenting symptoms in some infants [11].

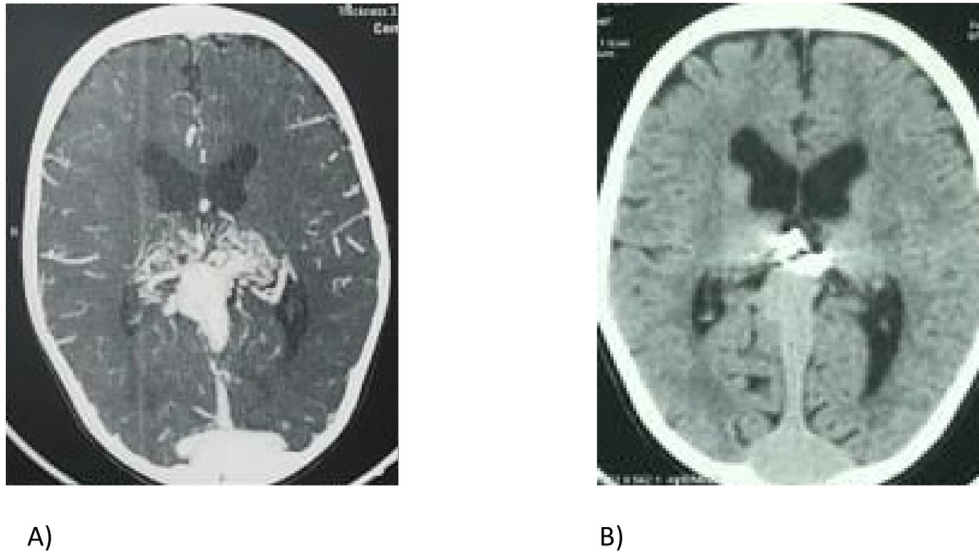


Fig. 1. (A) Axial CT angiographic view through the VGAM of female child. (B) Axial CT after the first session of embolization. CT, computed tomography; VGAM, vein of Galen aneurysmal malformation.

Cranial bruit, dilated scalp veins, proptosis, and/or recurrent epistaxis are some of the other presenting signs and symptoms [10].

The advent of endovascular neurointerventional techniques has significantly improved the prospects

for successful management of patients with VGAM lesions, which were previously bleak. Several treatment strategies have been advocated in the medical literature raising the questions about the proper timing of intervention, suitable

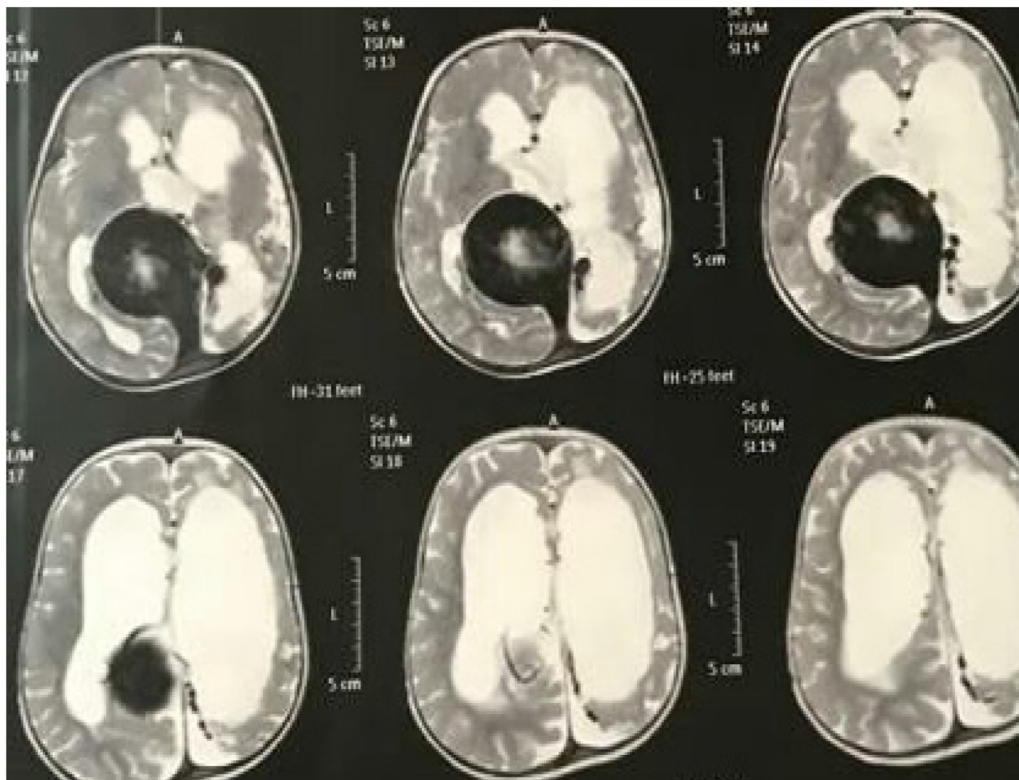


Fig. 2. Axial T2-weighted image of MRI brain through VGAM. VGAM, vein of Galen aneurysmal malformation.



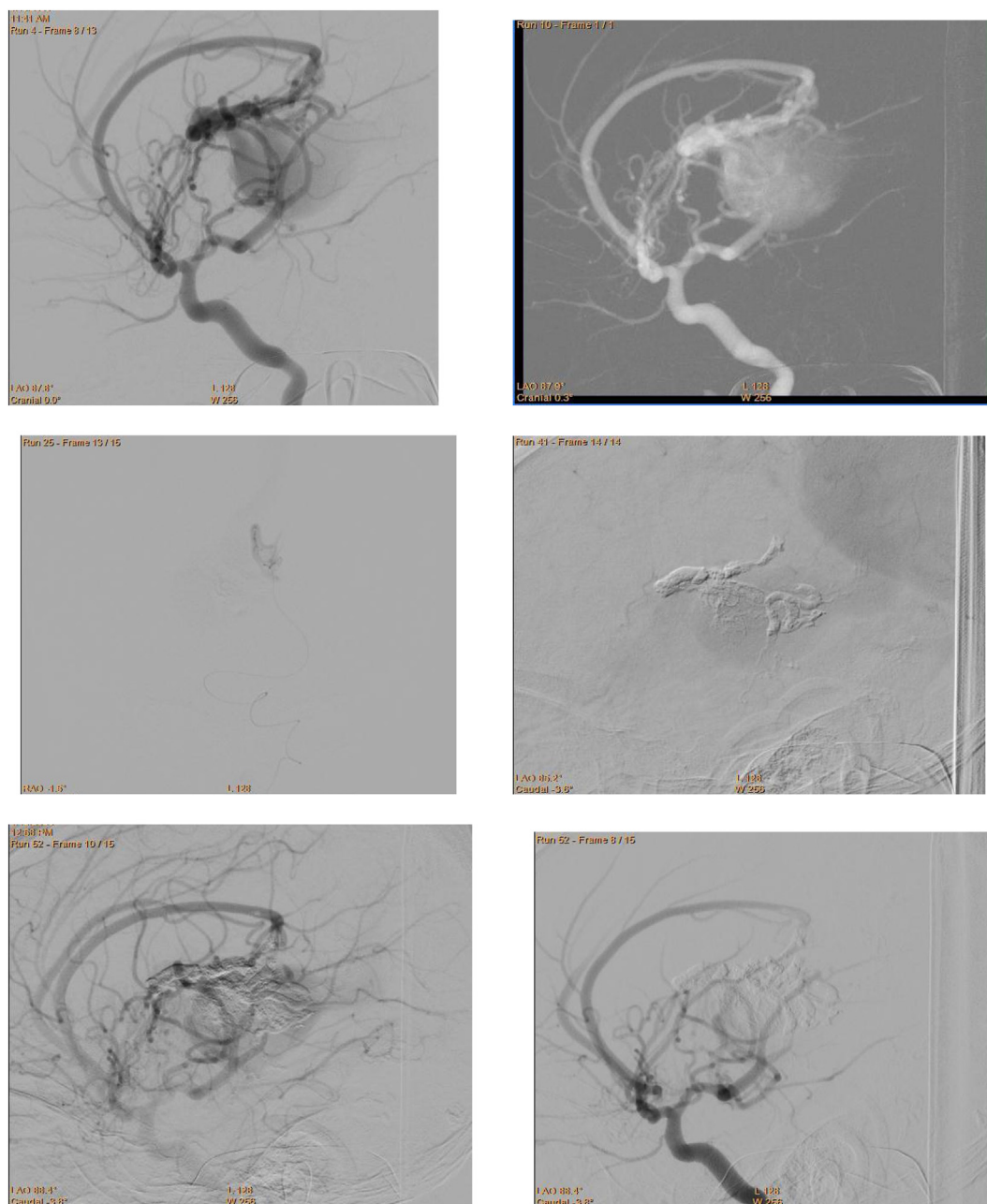


Fig. 3. Steps of embolization of a case of VGAMs using histoacryl glue. VGAM, vein of Galen aneurysmal malformation.

technique of approach (arterial or venous), embolization agents, and timing of management of concomitant hydrocephalus [12].

The use of liquid-acrylic embolic agents is advocated by several researchers in endovascular procedures for treating patients with VGAMs.

Among the advantage of these agents is the ability to inject them through very small catheters, which are suitable to navigate the tortuous anatomy of VGAMs. Acrylics provide permanent occlusion, reducing the possibility of recanalization. In the

hands of a skilled operator, their use can significantly reduce procedure time.

In our study, 15 cases of VGAM were diagnosed and treated between the period of June 2015 and June 2020. In total, seven infants and eight children were included in this study. About 10 of them were males and five were females. Two of the patients were diagnosed when they were neonates, five between the ages of 6 and 19 months, six between the ages of 3 and 5 years, and two at 12 years of age.

Thirty-one youngsters (18 males, 13 girls) were included in the Gopalan et al. [13] study, with 28 of them still alive. The median age at presentation was 9.6 months (range, 1.2 months–11 years and 7 months), with the majority of children presenting in their first year of life. The most prevalent clinical manifestation ( $n = 24$ ) was macrocrania. Parents' observations of prominent facial veins ( $n = 9$ ), developmental delay ( $n = 8$ ), focal neurological impairments ( $n = 8$ ), heart failure ( $n = 7$ ), seizures ( $n = 5$ ), and headache ( $n = 5$ ) were among the other clinical symptoms (not mutually exclusive). Headache and prominence of facial veins were noticed only in patients presenting after the age of 2 years.

Nine of the 15 malformations in this study were classified as choroidal, three were mural, and three were mixed, indicating the presence of both choroidal and mural components. Of the nine choroidal cases, three patients were having some sort of neurological delay, one of them improved neurologically and two cases remain unchanged. Of the mural types, two cases were having a degree of neurological delay and both improved neurologically after intervention. Mild neurological developmental delay was noted in one case of both mural and choroidal architecture that remained unchanged.

Seven of Jones et al. [12] cases were classed as mural, five as choroidal, and one as having both mural and a more complex nidus anteriorly. Five of the mural cases had some form of congestive heart disease.

Only partial occlusion of the shunt, according to certain interventionists, should be done in a single session. In some circumstances, complete occlusion has been found to be harmful because of normal perfusion-pressure breakthrough in previously underperfused parts and consumptive coagulopathy with resulting bleeding problems [14].

In this study, two sessions were required to treat all cases with mural architecture, three sessions for five cases with choroidal architecture, and four sessions for the rest of cases of choroidal architecture and cases with mixed choroidal and mural architectures. Histoacryl opacified in lipidol was the embolic agent injected through the microcatheters via arterial route in all cases.

In the Mitchell et al. [5] trial, four out of five patients had staged embolization, with the interval varying based on the anatomical and clinical findings postembolization. A single procedure was performed in one patient who died in this series. In nine (60%) of the 15 interventions, transarterial embolization was used in combination with other techniques; the preferred agent was N-butyl cyanoacrylate (NBCA), which was used alone (seven

procedures) or in combination with coils (two procedures).

With transvenous embolization, knowing when to stop could be a difficult decision because when stopped too early, recurrence is almost guaranteed while stopping too late, total occlusion might aggravate heart failure due to acutely increased afterload.

Endovascular embolization in the treatment of VGAMs has resulted in a significant improvement in patient outcomes. Our preferred access is the transarterial embolization, which is more effective in managing heart failure when there are only one or a few arterial-feeding pedicles.

Mitchell et al. [5] found in their study that the presence of multiple tiny feeders that could not be navigated easily during the transarterial technique, especially in unstable newborns, evolves the concept of starting the treatment plan with transvenous approach for transient control of cardiac-output failure to allow improving the patient's general condition and anatomical architecture to give chance for second intervention through the arterial side.

In a recent systematic evaluation of 667 patients who underwent endovascular embolization between 1987 and 2014, Yan et al. [14] found that 68% had a favorable outcome and 32% had a poor outcome, including 10% who died.

This study showed that immediate control of heart failure with normal neurological function had been achieved in four cases. On follow-up examination, 11 (73.33%) infants exhibited no signs of cardiac failure or neurologic impairment, four (26.66%) infants showed mild developmental delay, and two of them improved in the follow-up visits. With long-term follow-up, excellent cognitive and functional outcomes are achieved.

On digital-subtraction angiography follow-up, 12 had no additional shunting, two had limited flow, and one was awaiting follow-up imaging.

Over the course of 21 years, Lasjaunias et al. [7] found that 74% of VGAM patients treated with endovascular embolization had normal neurological development, 15% were moderately retarded, and just 10% of the surviving patients had severe neurological abnormalities. There were 23 youngsters that died.

Jones et al. [12] found that after endovascular embolization, seven of 13 patients (two of eight patients presented as neonates with heart failure and the other five patients presented beyond the neonatal period) had a normal or near-normal performance from 1987 to 2001.

Also, Fullerton et al. [15] found that 14 of 23 children who had VGAM endovascular treatment

between 1983 and 2002 get a good outcome without neurological deficits.

Ellis et al. [16] recently reported excellent long-term cognitive and functional outcomes following VGAM endovascular occlusions.

In Stephan et al. [17] study, from the 16 neonates who had systemic cardiac signs as their first VGAM symptoms, 12 of them were successfully controlled with digitalis diuretic therapy and were embolized in infancy, with a 67% survival rate and normal cerebral development. The four babies who were not treated after diagnosis died soon after birth from severe heart failure or multiorgan failure, as well as serious brain damage. The authors emphasized the need for transarterial embolization and avoiding treatment during the early neonatal period before total stabilization of general condition.

About one-third of neonatal patients in the largest series reported by Lasjaunias and colleagues were deemed unsuitable for intervention due to poor general condition. About 36.4% of the 88 newborns who were treated by endovascular-embolization technique are alive and have normal neurologic development, 54.5% have moderate psychomotor maldevelopment, and 9.1% have severe psychomotor maldevelopment. This age group had a 52% overall death rate [2].

In a separate study, Khullar et al. [18] found that 32.7% of neonatal patients had satisfactory outcomes, with normal development or mild developmental delay. The mortality rate among newborns was 35.6%, whereas 31.7% had a 'fair' prognosis, with moderate or severe functional and neurological developmental delays.

In the presence of evident imaging diagnostic criteria suggesting the presence of high-flow lesions, Mitchell et al. [5] recommended that treatment should be planned for 6 months of age even if there is no neurological developmental delay, but frequent radiological and clinical evaluations are indicated to detect any signs of cerebral ischemia or hydrocephalus if the management of lesions is delayed beyond the age of 6 months. Endovascular embolization would subsequently be used as soon as possible; hydrocephalus often reacts to the obliteration of the arteriovenous shunt.

The Bicetre score can be used to assess and draw the management plan for newborns presented with VGAMs. It is based on the Lasjaunias et al. [7] research group's experience with more than 300 VGAM patients. The patients are classified according to their cerebral, cardiac, respiratory, hepatic, and nephrological states [19]. It is suggested to postpone treatment, until the child is 5–6-months old if

cardiovascular and neurologic symptoms are stable (Bicetre score >12). An emergency endovascular embolization should be performed if the Bicetre score is 8–12 points. There is no reason for an aggressive intervention in the case of the presence of serious neurological deficits or medically uncontrolled cardiac insufficiency (Bicetre score 8) [7].

CSF diversion for treatment of hydrocephalus in children with VGAMs remains a point of controversy, as preembolization ventricular drainage might exacerbate problems that could affect the cerebral venous circulation. The definite causes of hydrocephalic changes are not exactly listed. Many radiological findings were noticed in different studies and clinical trials, including compression of cerebral aqueduct, downward displacement of cerebellar tonsils, and impaired cerebral venous outflow with subsequently impaired CSF circulation. Some caregivers experienced serious complications after CSF shunting done before endovascular embolization, including intraventricular hemorrhage, intracerebral hemorrhage, and progressive parenchymal damage. Hemorrhagic cerebral insults diagnosed in patients with VGAMs in some studies were supposed to be a result of changes in venous-pressure gradients in underdeveloped subependymal vessels. Fortunately, we did not have any serious hemorrhagic insults in this study.

It is better to postpone ventricular drainage, until all embolization procedures are complete as the hydrocephalic findings mostly improve and no CSF-diversion procedures needed as noticed in most of our cases apart from the two cases that required preintervention shunting and the other one that required postintervention CSF diversion.

In this study, escape of glue to the venous sinuses occurred in 12 sessions of nine patients with no significant sequelae or further needed management. Small hematoma at the site of femoral-artery puncture occurred in four patients and managed conservatively.

Intraventricular hemorrhage and subarachnoid hemorrhage were among procedural complications experienced by other caregivers. Jones et al. [12] had three of their patients complicated by intraventricular hemorrhage, two of whom were premature neonates. Subarachnoid bleeding occurred in one child during the embolization process, possibly as a result of vascular injury during catheter installation, perfusion-pressure breakthrough, or a combination of both. An episode of intracranial bleeding as a result of shunt insertion was reported in one patient in this study.

In a study by Gopalan et al. [13], nineteen embolizations in 14 patients complicated by



intraprocedural problems. The most prevalent of these ( $n = 12$ ) was glue escape into the venous sinuses, which was related to venous sinus thrombosis in four cases. The four cases were managed by endovascular procedures with no residual neurological deficits. Iliac-artery occlusion ( $n = 1$ ) and intraventricular hemorrhage ( $n = 1$ ) were among other complications.

Some researchers believe that venous stenosis is a risk factor for the development of cerebral bleeding in those patients with VGAM during the journey of management [20].

#### 4.1. Conclusion

Staged endovascular transarterial embolization using liquid-acrylic embolic agent by different concentrations according to shunt flow represents an effective strategy with a good long-term outcome in treating patients with VGAMs who are properly selected according to an accurate clinical scoring system. This technique also represents an initial safe and promising approach to control cardiac-output failure in newborns with VGAMs when medications fail.

#### Conflicts of interest

There is no conflict of interest.

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