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ORIGINAL ARTICLE

Liquid embolization agents for arteriovenous malformations: A preliminary experience from a tertiary care teaching hospital

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ABSTRACT

Objectives: This study aimed to assess clinical profile, arteriovenous malformation (AVM) characteristics, and outcomes associated with treatment.

Patients and methods: This retrospective descriptive study was conducted between June 1, 2021, and May 31, 2022. Twenty-seven patients (16 males, 11 females; mean age: 41.7±8.6 years; range, 15 to 65 years) diagnosed with AVM undergoing embolization within the defined period were included. The inclusion criteria were as follows: patients diagnosed with AVM on angiography and who underwent embolization for AVM. The exclusion criteria were as follows: patients in whom angiography did not show an AVM, those who refused to undergo the embolization procedure, patients who underwent surgical resection, and patients who underwent procedures for reasons other than AVMs (e.g., aneurysm coiling and flow diverter). Sessions of liquid embolic agent (Squid) embolization were performed. The procedural outcomes were classified as favorable and unfavorable outcomes. Complications were subdivided into technical, procedural, and clinical. Follow-up angiograms and clinical examination data were assessed.

Results: Majority (n=11) of the patients were older than 50 years. Most common presentation was intracranial hemorrhage. Common presenting complaints were headache, vomiting, loss of consciousness, and seizures. The majority of AVMs were classified as Spetzler-Martin Grades 3 and 4 (66.6%), followed by Grade 2 in seven cases, and Grades 1 and 5 in one case each. Majority of the AVMs were superficial (n=24). Embolization was done in two stages in six patients and in three stages in one patient. In the remaining 20 patients, single-stage embolization was attempted. There was a rupture of the zone of detachment of the detachable tip microcatheter in one patient, and there was leakage of liquid embolic agent in two patients. The most common complication was intraprocedural hemorrhage.

Conclusion: Embolization of AVMs with embolic agents such as Squid and Onyx as treatment option had satisfactory results, with obliteration achieved in most of the patients.

Keywords: Arteriovenous malformations, embolization, Onyx, Squid-12, Squid-18.

Malformations of the central nervous system vasculature consist of developmental arterial anomalies, developmental venous anomalies, and arteriovenous malformations (AVMs).[1,2] Arteriovenous malformations are vascular abnormalities composed of tortuous arteries and veins but lacking an intervening capillary bed.[3] They are congenital lesions that occur sporadically and account for 1.4 to 2% of all hemorrhagic strokes, although familial AVMs are rare.[4-7] The estimated prevalence of AVMs is variable, ranging from 10 to 18 per 100,000 individuals.[7-9] Arteriovenous malformations can be detected incidentally in 0.05% cases using magnetic resonance imaging (MRI).[10] The first report of embolization of a brain AVM was published in 1960. Since then, significant advancements have been made both in embolic materials and microcatheters. Terada et al.[11]

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reported for the first time the use of ethyl alcohol (EVOH) copolymers in AVMs. Later, the "Onyx" was introduced, which is a polyethylene-co-vinyl alcohol copolymer-based liquid embolic agent. The "Squid" is another nonadhesive precipitating liquid embolic agent composed of EVOH in dimethyl sulphonamide (DMSO) solvent with suspended micronized tantalum powder for radiopacity. There is a lack of data from Indian institutes regarding their preliminary experience with liquid embolizing agents. Hence, this retrospective study aimed to present a preliminary experience with liquid embolizing agents from a tertiary care teaching hospital in Northwest Rajasthan.

PATIENTS AND METHODS

The retrospective descriptive study was conducted at the Department of Neurology of the Mahatma Gandhi Medical College and Hospital in Northwest Rajasthan, India, between June 1, 2021, and May 31, 2022. Simple consecutive sampling was used as the sampling method, and 27 patients (16 males, 11 females; mean age: 41.7±8.6 years; range, 15 to 65 years) diagnosed with AVM who underwent embolization within the defined period were included. Data on patients undergoing embolization procedure for AVM was collected from the catheterization lab of the hospital between June 2021 and June 2022. The inclusion criteria were as follows: patients diagnosed with AVMs on angiography and who underwent embolization. The exclusion criteria were as follows: patients in whom angiography did not show an AVM, those who refused to undergo the embolization procedure, patients who underwent surgical resection, and patients who underwent procedures other than those for AVM (e.g., aneurysm coiling and flow diverter). Patients were clinically evaluated for baseline deficits, and a neurological examination was conducted at baseline. Computed tomography angiography was performed in cases suspected for AVMs. The detailed angiographic evaluation was done using digital subtraction angiography, and patients were classified in various grades, as per the modified Spetzler-Martin grading, and embolization was planned accordingly. Institutional ethics committee approval was waived given the retrospective nature of the study. Written informed consent was obtained from all participants. Due to the retrospective nature of the study, approval from the ethics committee was not obtained. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Sessions of liquid embolic agent (Squid and Onyx) embolization were performed under general anesthesia on a monoplane angiography system (Allura Xper FD 20; Philips, Jaipur, Rajasthan, India). Using the right common femoral artery approach, after infiltration of the local anesthetic (1 to 2% lignocaine), the right femoral artery was punctured. A subsequent single-wall puncture with a 21-gauge needle was performed to aid sheath insertion. To achieve an activated clotting time 2 to 2.5 times the normal value, 5000 units of heparin was injected. A 6 French (F) guiding sheath-guiding catheter coaxial system was introduced into the carotid or vertebral arteries through a common femoral artery approach after systemic heparinization. A closed continuous flush system was used. Then the target feeder artery was catheterized with a DMSO-compatible flow directed microcatheters (Detachable tip Sonic 1.2F or 1.5F; Microcatheter, Balt, Montmercy, France) or (Marathon Microcatheter, ev3 neurovascular, Irvine, California, USA) over a 0.007- or 0.008-inch microguidewire (Hybrid Balt, Montmorency, France). Angiographic confirmation of the tip of the microcatheter was performed, and the vascular angioarchitecture was delineated for safe embolization. The decision of using type of Squid depends on feeders of AVM. In cases with small size of feeders or AVM supplied by lenticulostriate perforators, Squid 12 was used. In attempt of complete occlusion of AVM, both Squid 12 and 18 were used. Before Squid injection, the microcatheter was flushed with 10 mL of saline, and its dead space was filled with 0.35 mL of DMSO. The same volume of Squid was injected slowly for 45 sec to substitute the DMSO in the dead space. The Squid was meticulously injected into the lesion under the roadmap. The injection was stopped every 2 to 3 min to reset the roadmap. After some forward penetration, there was a tendency of Squid to reflux into the feeding artery forming a plug. Once a solid plug was formed, forward penetration of Squid into the lesion was noted (plug and push technique). Depending on the degree of shunt in the AVM at the beginning, Squid 12 or 18 was used. After confirming that no Squid escaped into the vein with the first injection, Squid 12 was used for further embolization due to its ability to penetrate more distally within the formed cast. The embolization was discontinued when the reflux reached the detachment zone of the microcatheter or when embolization was completed through the involved arterial pedicle. After complete embolization of the involved artery or lesion itself, the microcatheter was gently removed with the application of gradual backward tension to achieve safe microcatheter removal. All microcatheters were successfully removed without sequela. Originally conceived as a surgical risk assessment tool, the Spetzler-Martin grading system, which is commonly used to describe AVMs in the clinical setting, was used to assign points for AVM size, location, and venous drainage pattern (Table 1).[12]

The procedural outcomes were classified as favorable and unfavorable outcomes. Favorable outcomes included partial or complete obliteration achieved after embolization and no clinical deterioration from baseline or improvement in symptoms after the procedure. Unfavorable outcomes were defined based on complications. Complications were subdivided into technical, procedural, and clinical. Follow-up angiograms and clinical examination data were assessed.

Statistical analysis

The data was segregated and organised in Micrososoft Excel Sheet and data was analysed using descriptive statistics. Categorical variables were presented in number and percentage (%) and continuous variables were presented as mean ± standard deviation (SD).

RESULTS

Of the patients, three were younger than 20 years, five were between 21 and 30 years, four were between 31 and 40 years, four were between 41 and 50 years, and 11 were older than 50 years (Table 2). The most common presentation

TABLE 1
The Spetzler-Martin grading system[12]

AVM features	Points
Size (cm)	
Small (<3)	1
Medium (3-6)	2
Large (>6)	3
Location	
Non-eloquent	0
Eloquent	1
Venous drainage	
Superficial	0
Deep	1

AVM: Arteriovenous malformation.

TABLE 2
Clinical and demographic profile of patients with AVM

	n	%
Total patients	27	100
Sex		
Males	16	59.3
Females	11	40.70
Age (year)		
<20	3	11.11
21-30	5	18.51
31-40	4	14.81
41-50	4	14.81
>50	11	40.74
Presenting complaints		
Headache	17	62.96
Loss of consciousness	7	25.92
Vomiting	6	22.22
GTCS seizures	5	18.51
Focal seizures	2	7.4
Unsteadiness while walking	2	7.4
Visual loss hemibody pain	1	3.7
Paraparesis with bowel bladder involvement	1	3.7
Numbness of one half of face	1	3.7
Partial global aphasia	1	3.7
Spetzler Martin Grade		
1	1	3.7
2	7	25.92
3	9	33.33
4	9	33.33
5	1	3.7
Distribution of AVMs		
Intracranial AVMs	26	96
Spinal AVMs	1	4
Site of AVMs		
Superficial	24	88.89
Deep	3	11.11
Location of AVMs		
Frontal lobe	4	14.81
Fronto-parietal	6	22.22
Parieto-occipital	3	11.11
Parieto-temporal	2	7.4
Temporal	2	7.4
Parietal	2	7.4
Occipital	1	3.7
Cerebellar	1	3.7
Deep capsuloganglionic	4	14.81
Spinal	1	3.7
Cerebellopontine angle	1	3.7
Associated findings		
AV fistula	5	18.51
Aneurysm	6	22.22
Single	1	3.7
Multiple	5	18.51
Meningioma	2	7.4
Embolization stages		
Single stage		
1 stage	20	74.07
Multiple stage		
2 stages	6	22.22
3 stages	1	3.7

AVM: Arteriovenous malformation; GTCS: Generalized tonic-clonic seizures.

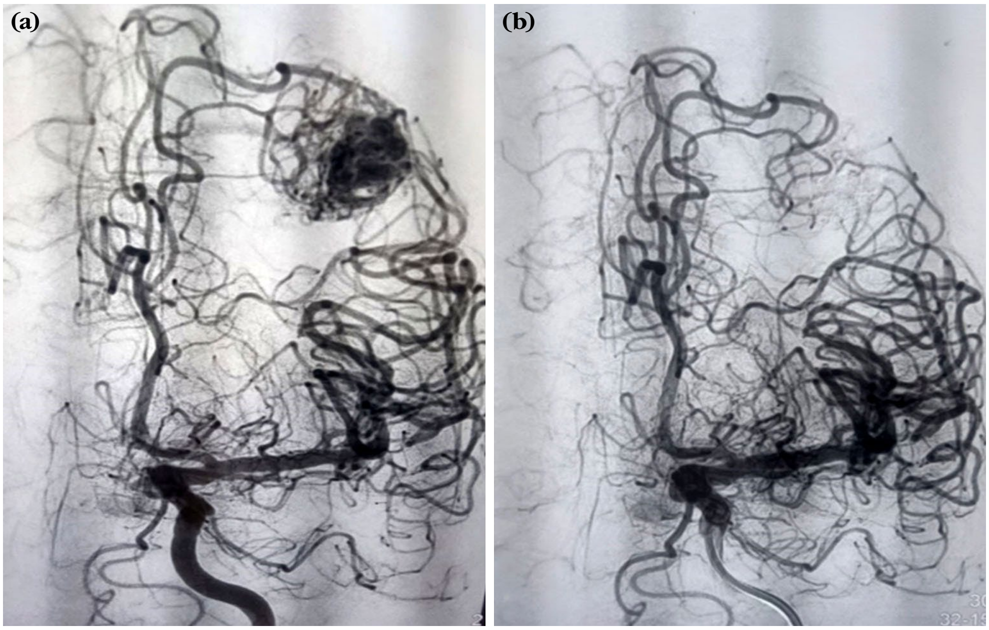

Figure 1. **(a)** Pre-embolization digital subtraction angiography image shows left frontal AVM with feeding arteries from left anterior cerebral artery (pericallosal artery) and left middle cerebral artery (superior division) draining into superior sagittal sinus. **(b)** Showing complete obliteration following endovascular embolization procedure.
AVM: Arteriovenous malformation.

was intracranial hemorrhage. Common presenting complaints were headache (n=17), vomiting (n=6), loss of consciousness (n=7), seizures (focal [n=2], generalized tonic clonic [n=5]), unsteadiness while walking (n=2), hemiplegia (n=4), visual loss (n=1), hemibody pain (n=1), paraparesis with bowel or bladder involvement (n=1), numbness of one half of the face (n=1), and partial global aphasia (n=1), presenting alone or a combination of these symptoms (Table 2). The modified Spetzler-Martin grading results are shown in Table 2. The majority of AVMs were classified as Spetzler-Martin Grades 3 and 4 (66.6%), followed by Grade 2 in seven cases, and Grades 1 and 5 in one case each. Majority of the AVMs were superficial (n=24), and three were deep seated. Associated arteriovenous fistulas were observed in five patients, multiple aneurysms confined to the P2 segment of posterior cerebral artery and left middle cerebral artery in one patient, left posterior inferior cerebellar artery aneurysm in one patient, and tumor in two patients (meningioma).

In six patients, embolization was done in two stages, and in one patient, it was done in three stages. In the remaining 20 patients, single-stage embolization was attempted. Among all patients, eight were treated with Squid 12 alone, eight were treated with Squid 18 alone, and one was treated with both Squid 12 and 18. However, Onyx alone was used in one patient, whereas Onyx was used in combination with Squid 12 and 18 in nine patients. Figures 1 and 2 show an AVM before and after embolization. An AVM rupture, occlusion of the catheter, or thromboembolic phenomenon was not observed during or after the procedure. All

Figure 2. Subtracted image demonstrates the liquid embolization agent (Squid) after the procedure.

TABLE 3
The AVM characteristics, procedures, and postprocedural outcomes

Case no	Age/ Sex	bAVM/ sAVM	Location	Deep/ superficial	Feeder artery/arteries	Draining vein/veins	Modified Spetzler Martin score	Embolization agent used	Embolization sessions	Procedural outcome	Mortality	Length of stay (Day)	Complication
1	30/M	bAVM	Right CP angle AVM	Superficial	Middle meningeal artery, superior cerebellar artery	Right sigmoid sinus	3	Squid-12	1	Complete obliteration	No	7	None
2	56/F	bAVM	Right frontal lobe AVM	Superficial	Right anterior cerebral artery	Superior sagittal sinus	2	Squid-18, Onyx	1	Complete obliteration	No	8	None
3	31/M	bAVM	Left frontoparietal AVM	Superficial	Left middle cerebral artery, left posterior cerebral artery	Superior sagittal sinus, straight sinus	4	Squid 18, Onyx	1	Complete obliteration	No	8	None
4	18/M	bAVM	Right thalamocapsular deep seated AVM	Deep	Right middle cerebral artery	Great cerebral vein of galen	5	Squid-12, Onyx	1	Complete obliteration	No	6	None
5	58/M	bAVM	Left temporal lobe AVM	Superficial	Left posterior cerebral artery, left middle cerebral artery	Superior sagittal sinus	2	Squid-12, Onyx	1	Complete obliteration	No	8	None
6	51/F	bAVM	Dural AVM left frontoparietal region	Superficial	Left posterior cerebral artery, left middle cerebral artery	Left transverse sinus, superior sagittal sinus, great cerebral vein of galen	4	Squid-18	1	Incomplete obliteration	No	6	Leakage of embolic agent proximal to nidus
7	55/M	bAVM	Right parietooccipital AVM	Superficial	Right middle meningeal, right superficial temporal artery	Superior sagittal sinus	4	Squid-18, Onyx	2	Complete obliteration	No	6	None
8	27/F	bAVM	Left capsuloganglionic deep seated AVM	Deep	Left middle cerebral artery	Straight sinus	1	Squid-12	1	Incomplete obliteration	No	12	Early Polymerization of embolic agent (Early termination of procedure)
9	45/F	bAVM	Left parietotemporal AVM	Superficial	Left middle cerebral artery, left callosomarginal artery	Superior sagittal sinus	4	Squid-18	1	Complete obliteration	No	13	Rupture of detachable zone of tip of microcatheter Left frontoparietal hematoma
10	58/M	bAVM	Left temporal lobe AVM	Superficial	Left posterior cerebral artery, left middle cerebral artery	Superior sagittal sinus	2	Onyx	2	Complete obliteration	No	7	None
11	55/F	bAVM	Right frontoparietal AVM	Superficial	Right middle cerebral artery, right anterior cerebral artery	Right transverse sinus, superior sagittal sinus, great cerebral vein of galen	3	Squid-18	1	Complete obliteration	No	14	None
12	31/M	bAVM	Right parietooccipital AVM	Superficial	Right posterior communicating artery, right middle cerebral artery, right posterior cerebral artery	Superior sagittal sinus, basal vein of rosenthal	4	Squid-18, Squid-12, Onyx	1	Complete obliteration	No	7	None
13	16/M	bAVM	Right thalamocapsular deep seated AVM	Deep	Right middle cerebral artery	Great cerebral vein of galen	3	Squid-12, Onyx	2	Complete obliteration	No	8	None
14	45/M	bAVM	Left frontoparietal AVM	Superficial	Left middle cerebral artery, left callosomarginal artery	Superior sagittal sinus	2	Squid-18, Onyx	1	Incomplete obliteration	No	9	Leakage of embolic agent proximal to nidus
15	55/M	bAVM	Right parietooccipital AVM	Superficial	Right middle meningeal, right superficial temporal artery	Superior sagittal sinus	4	Squid-12, Onyx	3	Complete obliteration	No	7	None
16	62/F	bAVM	Ruptured AVM in right parietal region	Superficial	Right middle cerebral artery, right posterior cerebral artery	Superior sagittal sinus	3	Squid-12	1	Complete obliteration	No	6	None
17	54/F	bAVM	Multiple AVMs	Superficial	Right middle meningeal, right vertebral artery	Superior sagittal sinus	2	Squid-12	1	Complete obliteration	No	6	None
18	35/F	bAVM	AVM right caudate nucleus	Superficial	Right middle cerebral artery	Right internal cerebral vein	2	Squid-12	1	Complete obliteration	No	8	None
19	62/F	bAVM	Right occipital region	Superficial	Right posterior cerebral artery	Great cerebral vein of galen	3	Squid-18	2	Complete obliteration	No	4	None

TABLE 3
Continued

Case no	Age/ Sex	bAVM/ sAVM	Location	Deep/ superficial	Feeder artery/arteries	Draining vein/veins	Modified Spetzler Martin score	Embolization agent used	Embolization sessions	Procedural outcome	Mortality	Length of stay (Day)	Complication
20	22/M	bAVM	Left medial frontal micro-AVM	Superficial	Left pericallosal artery	Superior sagittal sinus	3	Squid-12	1	Complete obliteration	No	7	None
21	30/M	bAVM	Left frontoparietal AVM	Superficial	Left middle cerebral artery, left pericallosal artery, left posterior cerebral artery	Straight sinus	4	Squid-18	2	Complete obliteration	No	6	None
22	47/F	bAVM	Left frontal AVM	Superficial	Left middle cerebral artery, left anterior cerebral artery	Superior sagittal sinus	4	Squid-18	1	Complete obliteration	No	6	None
23	22/M	bAVM	Midcerebellar AVM	Superficial	Right posterior inferior cerebellar artery	Straight sinus	2	Squid 12, Squid 18	1	Complete obliteration	No	13	None
24	45/M	bAVM	Left frontoparietal AVM	Superficial	Left middle cerebral artery, left posterior cerebral artery	Superior sagittal sinus, straight sinus	3	Squid 12	2	Complete obliteration	No	14	Subarachnoid hemorrhage
25	65/F	bAVM	Right temporoparietal AVM	Superficial	Right middle cerebral artery, right anterior cerebral artery	Superior sagittal sinus	4	Squid 18	1	Complete obliteration	No	4	None
26	15/M	sAVM	Spinal AVM d7-d12	Superficial	Left d11 intercostal artery, radiculomedullary branch of d7 left intercostal artery	Perimedullary veins extending from l5 to cervical region	3	Squid 12	2	Complete obliteration	No	4	None
27	35/M	bAVM	Left frontal AVM	Superficial	Left callosomarginal artery, left pericallosal artery, left middle cerebral artery	Superior sagittal sinus	3	Squid 18	1	Complete obliteration	No	5	None

bAVM: Brain arteriovenous malformation; sAVM: Spinal arteriovenous malformation; CP: Cerebellopontine angle.

patients were discharged in a hemodynamically stable condition. Table 3 shows patient details in each case.

Entrapment of the microcatheter occurred in none of the cases, including both detachment tip and conventional microcatheters. In one case, rupture of the zone of detachment of the detachable tip microcatheter (Sonic 1.5F; Balt, Montmercy, France) happened during manipulation in parent artery proximal to feeding pedicle. The microcatheter was safely retrieved with the detachable tip without any sequel. In two cases, there was leakage of the liquid embolic agent (Squid) from the detachable zone, leading to occlusion of the feeding pedicle proximal to the nidus. It resulted in incomplete obliteration of the AVM nidus due to occlusion of the proximal part of the feeding pedicle. Fortunately, it did not result in any clinical complications. In one case of deep seated basal ganglionic AVM (supplied by one of lenticulostriate artery), there was early polymerization of Squid into microcatheter which led to formation of plug into microcatheter. This phenomenon resulted in the early termination of procedure. This case was subsequently referred for gamma knife treatment and resulted in complete obliteration of the AVM on follow-up.

Clinical complications occurred in two patients, with the most common complication being intraprocedural hemorrhage. In one patient, during the manipulation of the microwire, there was a perforation of the feeding pedicle. It resulted in left frontal intraparenchymal hematoma; however, it was asymptomatic. The same patient developed large frontoparietal intraparenchymal hematoma after the second stage of embolization. The second stage of the embolization was done successfully with a residual tiny nidus. The patient was extubated uneventfully after the procedure. Thirty minutes after extubation, the patient developed aphasia and right-sided hemiplegia. Urgent noncontrast computed tomography of the brain was performed, which revealed large left frontoparietal intracerebral hematoma with mass effect. Neurosurgery consultation was obtained, and immediate hematoma evacuation with excision of the residual AVM was done. On retrospective assessment, there was seepage of Squid into the draining vein during embolization into the nidus. It resulted in the thrombosis of the draining vein and intraparenchymal hematoma. In the second patient of intraprocedural rupture, there was dissection of the vessel during the manipulation of the microwire proximal to the feeding pedicle, which resulted in subarachnoid hemorrhage. The patient was considered for an urgent ventriculoperitoneal shunt and was discharged from the hospital five 5 days without any residual deficit. Table 4 summarizes the complications experienced at our center.

TABLE 4
Technical, procedural, and clinical complications

Complications	n	%
Procedural and technical		
Perforation or rupture of feeding pedicle	2	7.4
Rupture of detachment zone of tip of microcatheter	1	3.7
Leakage of embolic agent proximal to the nidus causing incomplete obliteration	2	7.4
Early polymerization of agent warranting early termination of procedure	1	3.7
Microcatheter entrapment	0	0
Thromboembolic	0	0
Catheter occlusion	0	0
Puncture site hematoma	0	0
Clinical		
Intracerebral hemorrhage	1	3.7
Subarachnoid hemorrhage	1	3.7

DISCUSSION

Arteriovenous malformations can present with a wide array of clinical presentations. These include intracranial hemorrhage (2-4%), seizures (18-40%), headache (5-14%), and focal neurological deficit (1-40%). The gold standard test for the assessment of the architecture of AVMs is conventional cerebral angiography. Various features such as the feeding arteries, location of the nidus, draining veins, morphology, presence, and location of associated aneurysms, venous varices, and vasculopathic stenotic segments on arteries and veins are assessed, and these features can be used to plan the treatment of these AVMs.[12]

Treatment options for AVMs are microsurgical resection, endovascular embolization, and stereotactic radiosurgery. It is difficult to determine whether to intervene or which intervention is better. More than one modality can be used for treatment. A risk-benefit analysis is required for benefits of treatment against the risks associated with the proposed options.[13,14]

In the present study, we presented our experience with the use of an embolization agent for the treatment of AVM in the form of Squid and Onyx. The first broadly used copolymer-based embolic substance is Onyx, and there is a large amount of data on its safety. On the other hand, Squid is a more recently introduced agent. This substance is extra-low viscous, more stable, and has lower degree of imaging artifacts associated with its use.[15] In our study, Squid was an effective and safe embolic agent for embolization of AVMs. The results are in coherence with the study by Akmangit et al.,[16] in which they observed Squid to be a safer and effective treatment option, with an obliteration rate of 37.5%. There were no direct complications related to Squid as an embolic agent in our study, and the findings were similar to Akmangit et al.'s study.[16] Another study by Gore et al.[17] in 2008 examined 10 patients (4 female, 6 male; range, 11 to 60 years) who underwent preoperative embolization with Onyx before cranial or spinal tumor resection. Tumors included three juvenile nasal angiofibromas, two meningiomas, two hemangioblastomas, two metastases (renal cell and thyroid), and one giant cell tumor. However, in our center, Squid alone or in combination with Onyx was used. Only one patient was treated by Onyx alone, but fewer complications were also observed with this material when used as an embolic agent. In one study, Onyx embolization was performed in 43 vessels over 11 treatment sessions. There were no complications related to the embolization procedures. Potential adverse events, such as premature catheter obliteration and catheter tip stranding, were not observed. The experience was similar to the studies by Arat et al.,[18] Natarajan et al.,[19] and Weber et al.,[20] where no neurologic complications secondary to the embolization procedure were reported. In the current study, three patients had perforation of the pedicle of the feeding vessel leading to hemorrhage, which was managed immediately. No local/introducer site hematoma was observed in the present study. Majority of AVMs (74.07%) were completely obliterated with one session of embolization, only six patients required two sessions, and one (3.7%) needed three sessions.

There were some limitations to this study. The sample size of the study was small. The results of larger scale studies with a larger sample size are required to better understand complications, as well as outcomes, of Squid as a treatment in AVMs. Nonetheless, this study is one of its kind from the region of Indian subcontinent focusing on the preliminary experience with Squid. It adds to the existing literature of treatment of AVMs with Squid.

In conclusion, embolization of AVMs with embolic agents such as Squid and Onyx as a treatment option had satisfactory results, with obliteration achieved in most of the patients. However, safety and efficacy outcomes of these embolic agents should be assessed and compared with surgical treatment in larger scale follow-up studies.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea and concept, design, data collection and processing, references: G.G., H.K.; Control/supervision: G.G., H.K., J.V.J., Y.K.; Analysis and interpretation, literature review, writing the article: G.G., H.K., J.V.J., Y.K., I.C.; Critical review: J.V.J., Y.K., I.C.

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REFERENCES

1. Barut BÖ, Coşkun BE, Türksoy Ö. Choreiform movement disorder secondary to ıntracerebral cavernoma: Case report. 2013;19:60-2. doi: 10.4274/Tnd.71501.
2. Ligha AE, Robert FO. Medusa-like atypical intracerebral vein: A rare case of symptomatic developmental venous anomaly. Turk J Neurol 2017;23:234-238
3. Ren Q, He M, Zeng Y, Liu Z, Liu H, Xu J. Microsurgery for intracranial arteriovenous malformation: Long-term outcomes in 445 patients. PLoS One 2017;12:e0174325. doi: 10.1371/journal.pone.0174325.
4. Kikuchi K, Kowada M, Sasajima H. Vascular malformations of the brain in hereditary hemorrhagic telangiectasia (Rendu-Osler-Weber disease). Surg Neurol 1994;41:374-80. doi: 10.1016/0090-3019(94)90030-2.
5. Laufer L, Cohen A. Sturge-Weber syndrome associated with a large left hemispheric arteriovenous malformation. Pediatr Radiol 1994;24:272-3. doi: 10.1007/BF02015455.
6. Stapf C, Labovitz DL, Sciacca RR, Mast H, Mohr JP, Sacco RL. Incidence of adult brain arteriovenous malformation hemorrhage in a prospective population-based stroke survey. Cerebrovasc Dis 2002;13:43-6. doi: 10.1159/000047745.
7. Perret G, Nishioka H. Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage. Section VI. Arteriovenous malformations. An analysis of 545 cases of cranio-cerebral arteriovenous malformations and fistulae reported to the cooperative study. J Neurosurg 1966;25:467-90. doi: 10.3171/jns.1966.25.4.0467.

8. Berman MF, Sciacca RR, Pile-Spellman J, Stapf C, Connolly ES Jr, Mohr JP, et al. The epidemiology of brain arteriovenous malformations. Neurosurgery 2000;47:389-96. doi: 10.1097/00006123-200008000-00023.
9. Al-Shahi R, Fang JS, Lewis SC, Warlow CP. Prevalence of adults with brain arteriovenous malformations: A community based study in Scotland using capture-recapture analysis. J Neurol Neurosurg Psychiatry 2002;73:547-51. doi: 10.1136/jnnp.73.5.547.
10. Morris Z, Whiteley WN, Longstreth WT Jr, Weber F, Lee YC, Tsushima Y, et al. Incidental findings on brain magnetic resonance imaging: Systematic review and meta-analysis. BMJ 2009;339:b3016. doi: 10.1136/bmj.b3016.
11. Terada T, Nakamura Y, Nakai K, Tsuura M, Nishiguchi T, Hayashi S, et al. Embolization of arteriovenous malformations with peripheral aneurysms using ethylene vinyl alcohol copolymer. Report of three cases. J Neurosurg 1991;75:655-60. doi: 10.3171/jns.1991.75.4.0655.
12. Spetzler RF, Martin NA. A proposed grading system for arteriovenous malformations. J Neurosurg 1986;65:476-83. doi: 10.3171/jns.1986.65.4.0476.
13. McInerney J, Harbaugh RE. Decision analysis for asymptomatic lesions. In: Stieg PE, Batjer HH, Samson D, editors. Intracranial arteriovenous malformations. New York: Informa Healthcare; 2007. p. 123-34.
14. Morgan M. Therapeutic decision making. In: Winn HR, editor. Youmans neurological surgery. Vol 4, 6th ed. Philadelphia: Elsevier Saunders; 2011. p. 4034-48.
15. Vollherbst DF, Chapot R, Bendszus M, Möhlenbruch MA. Glue, onyx, squid or PHIL? Liquid embolic agents for the embolization of cerebral arteriovenous malformations and dural arteriovenous fistulas. Clin Neuroradiol 2022;32:25-38. doi: 10.1007/s00062-021-01066-6.
16. Akmangit I, Daglioglu E, Kaya T, Alagoz F, Sahinoglu M, Peker A, et al. Preliminary experience with squid: A new liquid embolizing agent for AVM, AV fistulas and tumors. Turk Neurosurg 2014;24:565-70. doi: 10.5137/1019-5149.JTN.11179-14.0.
17. Gore P, Theodore N, Brasiliense L, Kim LJ, Garrett M, Nakaji P, et al. The utility of onyx for preoperative embolization of cranial and spinal tumors. Neurosurgery 2008;62:1204-11. doi: 10.1227/01.neu.0000333292.74986.ac.
18. Arat A, Cil BE, Vargel I, Turkbey B, Canyigit M, Peynircioglu B, et al. Embolization of high-flow craniofacial vascular malformations with onyx. AJNR Am J Neuroradiol 2007;28:1409-14. doi: 10.3174/ajnr.A0547.
19. Natarajan SK, Ghodke B, Kim LJ, Hallam DK, Britz GW, Sekhar LN. Multimodality treatment of intracranial dural arteriovenous fistulas in the Onyx era: A single center experience. World Neurosurg 2010;73:365-79. doi: 10.1016/j.wneu.2010.01.009.
20. Weber W, Kis B, Siekmann R, Kuehne D. Endovascular treatment of intracranial arteriovenous malformations with Onyx: Technical aspects. AJNR Am J Neuroradiol 2007;28:371-7.