

Middle Meningeal Artery Embolization for Chronic Subdural Hematoma with Wedging Technique

Qiao Zuo

Changhai Hospital, Naval Medical University

Guanghao Zhang

Changhai Hospital, Naval Medical University

Yuhao Tan

Changhai Hospital, Naval Medical University

Lugang Yin

Changhai Hospital, Naval Medical University

Yi Xu

Changhai Hospital, Naval Medical University

Rui Zhao

Changhai Hospital, Naval Medical University

Pengfei Yang

Changhai Hospital, Naval Medical University

Qiang Li

Changhai Hospital, Naval Medical University

Jianmin Liu

chstroke@163.com

Changhai Hospital, Naval Medical University

Research Article

Keywords: Middle meningeal artery embolization, Chronic subdural hematoma, Liquid embolic material

Posted Date: May 4th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9303489/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at BMC Neurology on August 22nd, 2026.
See the published version at <https://doi.org/10.1186/s12883-026-05256-y>.

Abstract

Background

Chronic subdural hematoma (CSDH) commonly recurs after burr-hole evacuation or conservative management. Middle meningeal artery embolization (MMAE) using ethylene–vinyl alcohol copolymer (Onyx) aims to devascularize the subdural membranes; however, incomplete distal penetration and proximal reflux can limit efficacy and safety. We evaluated a wedging microcatheter technique with large-caliber catheters to enhance distal delivery while minimizing reflux.

Methods

We retrospectively analyzed consecutive adults with CSDH treated with MMAE by Onyx (March–July 2025). Angiographic success was complete occlusion of both frontal and posterior branches of the middle meningeal artery (MMA). Clinical outcomes were recurrent symptomatic CSDH and repeat surgical evacuation. Neurological status by National Institutes of Health Stroke Scale (NIHSS) and functional outcome by modified Rankin Scale (mRS) were recorded at baseline and follow-up.

Results

Thirty patients underwent MMAE (50.0% stand-alone; 43.3% adjunct; 6.7% rescue). Wedging technique succeeded in all cases with 100% dual-branch occlusion; super-selection of the distal frontal branch alone sufficed in 76.7%. Onyx reached the midline in 83.3%, the subdural hematoma membrane in 20.0%, and crossed midline in 6.7%; mean fluoroscopy time was 25 ± 19 minutes. No cranial nerve palsy, vision loss, or ischemic stroke occurred. At 1 month, no symptomatic recurrence or progression was observed; hematoma thickness decreased in 96.7% (-14.4 ± 7.9 mm) and midline shift in 93.3% (-7.4 ± 4.6 mm); 83.3% achieved mRS 0–2 with mean NIHSS improvement of 0.6 ± 2.2 .

Conclusions

Wedging technique with Onyx achieved universal dual-branch occlusion, deep distal penetration into subdural membranes, low fluoroscopy times, and early clinical and radiographic outcomes without ischemic or cranial nerve complications. These findings support the technique as a feasible, safe, and efficacious strategy for CSDH and motivate prospective comparisons with conventional microcatheter approaches.

Introduction

Chronic subdural hematoma (CSDH) has become one of the most common neurosurgical indications in the aging population, while recurrence after burr-hole evacuation or conservative treatment remains as

high as 10–25%^{1–3}. Middle meningeal artery embolization (MMAE) has therefore attracted considerable interest as a pathophysiologically targeted, minimally invasive alternative. Three landmark randomized controlled trials—MAGIC-MT, STEM and EMBOLISE—have independently demonstrated that liquid embolic agents significantly reduce incidence of recurrence or serious adverse events^{4–6}.

Technical success with liquid embolics depends on forming a continuous cast that occludes both the proximal trunk and distal branches of the middle meningeal artery (MMA)^{7–9}. Incomplete distal penetration permits collateral inflow, which may drive neo-membrane revascularization and early failure^{7,10}. Non-target embolization from proximal reflux carries the risk of blindness and cranial neuropathies^{5,11}. Standard Onyx MMAE often relies on prolonged low-rate injection to build a proximal plug before advancing distally, which can lengthen procedure time and increase radiation exposure¹².

Wedged microcatheter–assisted embolization has been described in cerebrovascular malformations as a strategy to limit reflux and enhance distal delivery^{13,14}. However, conventional small-caliber microcatheters, with their limited inner diameter and need for prolonged low-rate plug building, inherently prolong procedure duration, increase cumulative radiation exposure, and elevate the risk of premature cast adhesion and potential microcatheter retention. We report our institutional experience in the safety and efficacy of MMA embolization using Wedging technique with large-caliber microcatheters for deeper penetration of the Onyx.

Methods

Patient Selection

For the purposes of this study, our retrospectively collected institutional cerebrovascular database was reviewed to identify all consecutive patients who underwent MMA embolization for CSDH from March 2025 to July 2025. The inclusion criteria included age 18 years or older, CSDH, MMA embolization using Onyx, and presence of follow-up CT or MR scans in 3 months after intervention. Exclusion criteria were CSDH arising from an underlying cause (idiopathic intracranial hypotension, ventriculoperitoneal shunt overdrainage, brain tumor, cerebrovascular lesions, hemorrhagic arachnoid cysts), and contraindications for angiography. A flowchart of CSDH and patient selection is shown in Figure 1. Institutional review board approval was obtained for the study. Informed consent was waived because of the retrospective nature of the study.

Large-caliber Microcatheter Characteristics

In all cases the same large-caliber microcatheter was used for the embolization: Willskey™ (Ricoton Inc, China). Briefly, this is a large-caliber microcatheter that features a segmented shaft with a proximal stainless-steel braid for push and torque transmission and a distal coil segment with graded polymer stiffness. Two distal softness configurations (soft segment lengths approximately 10 cm [standard] and 20 cm [soft]) and optional pre-shaped distal tips (45°, 90° and J shape) were available. Inner diameter

options relevant to this series were 0.017", 0.021", 0.024" and 0.027" (distal outer diameters approximately 1.7 F, 2.2 F, 2.4 F, and 2.7 F, respectively); all were used as dictated by target vessel diameter, tortuosity and embolic viscosity. The device incorporates dual distal radiopaque platinum–iridium markers (tip and proximal marker) and is rated to a burst pressure of 800 psi. It is compatible with 0.014" - 0.027" guidewires. The catheter is DMSO compatible for delivery of non-adhesive liquid embolic agents.

MMA Embolization Procedure

In brief, a 6-Fr guide catheter was advanced into the proximal external carotid artery. Prior to microcatheterization, several appropriate arterial conduits for flow-arrest delivery were identified based on their size, length, accessibility, tortuosity, collateralization. A Willskey (Ricoton Inc, China) microcatheter over a microguidewire was advanced into the guide catheter. Then, continue advancing the microcatheter until a wedged microcatheter position distally was established and super-selective microcatheter injection was performed to ascertain the lack of dangerous anastomosis. The microcatheter and arterial territory distal to the microcatheter tip was then flushed with DMSO followed by Onyx injecting through the working lumen of the microcatheter. In each case, an attempt was made to achieve distal penetration and, taking care to avoid penetration into collaterals to the orbit as well as the petrosal branch at the skull base (Figure 1).

Outcome Measures

Clinical Outcome

The rate of recurrent symptomatic CSDH and repeat surgical evacuation was defined as the clinical outcome measures. Neurological examination including National Institutes of Health Stroke Scale (NIHSS) score¹⁵ and modified Rankin Scale score¹⁶ at baseline and follow-up evaluations and CT scan imaging information at 1 months after the procedure were extracted for all patients. We defined near-complete resolution of hematoma as 90% or greater decrease in the size of SDH in a 6-month CT scan in comparison with hematoma thickness in the initial CT scan obtained before the embolization. Complete resolution was defined as no evidence of residual chronic SDH in the 6-month scan.

Angiographic Outcome

Complete obliteration of both frontal and posterior branches of the MMA was defined as the angiographic outcome. We also reviewed the rate of Onyx penetration to (1) the midline, (2) past midline to the contralateral side, and (3) the subdural hematoma membrane.

Safety Outcome

The rate of cranial nerve palsy, any thromboembolic events resulting in transient ischemic attack or stroke, or access site complications (hematoma or ischemic complication) were calculated as safety outcomes.

Results

Thirty patients were identified, with a mean ($\pm$ standard deviation) age of 68.5 years (± 10) and 86.7% male. The midline shift median (interquartile range) was 4.7 mm (0–11.4). At presentation, the initial NIHSS score median (interquartile range) was 1 (0 to 3). Fourteen patients (46.7%) were on antiplatelet medications, and 2 patients (6.7%) were taking anticoagulants. A total of 7 patients (23.3%) had bilateral SDH. Approximately half of the MMAE procedures (15 of 30; 50.0%) for CSDH were stand-alone treatments with no prior treatments, while 43.3% (13 of 30) were performed concurrently with surgery and 6.7% (2 of 30) were performed for prior surgical failure (Table 1).

Table 1
Baseline Characteristics

Characteristic	Patients (N = 30)
Age, mean $\pm$ SD	68.5 $\pm$ 10
Sex, No (%)	
Female	4 (13.3)
Admission NIHSS score, median (IQR)	1 (0 to 3)
mRS before symptom onset	
≤ 2	27 (90)
Known head trauma – no. (%)	18 (60.0)
Medications, No (%)	
Antiplatelet	9 (30.0)
Anticoagulation	2 (6.7)
Surgical intervention, No (%)	
Burr hole	10 (33.3)
CSDH location, No (%)	
Bilateral	7 (23.3)
Left side	12 (40.0)
Right side	11 (36.7)
Midline shift, median (mm, IQR)	4.7 (0–11.4)
Maximum thickness (mm, IQR)	17.8 (12.6–22.4)

Technical Evaluation

The embolization procedure was performed through right femoral access and under general anesthesia care in all patients (Table 2). The large-caliber microcatheter was successfully placed into the target location (where the Onyx injection was intended to start) in all cases (Fig. 2). Complete closure of both frontal and posterior branches of MMA was achieved in all patients (Video). Of note, super-selection of only the distal frontal branch was performed in 23 patients (76.7%). Onyx penetrated to the midline in 83.3% (25/30) of the patients, and in 20.0% (6/30) and 6.7% (2/30) of the patients the Onyx cast reached the subdural hematoma membrane and crossed the midline to the contralateral side, respectively (Fig. 3). The average fluoroscopy time was 25 ± 19 minutes. Regarding the safety outcomes, no cranial nerve palsy, vision loss, or ischemic stroke was seen in our cohort.

Table 2
Procedural Characteristics and Details

Characteristic	Patients (N = 30)
Bilateral MMA embolization, No (%)	7 (23.3)
Fluoroscopy time, mean $\pm$ SD	25 $\pm$ 19
Procedure time, mean $\pm$ SD	41 $\pm$ 27
Onyx penetrated to	
Midline	25 (83.3)
Subdural hematoma membrane	6 (20.0)
Crossed the midline to the contralateral side	2 (6.7)
Procedure-related complications, No (%)	
Cranial nerve injury	0
Thromboembolic events	0
Symptomatic recurrence or progression of subdural hematoma within 30 days [§]	
Symptomatic recurrence	0
Symptomatic progression	0
mRS at 90 days	
≤ 2	25 (83.3)
NIHSS at 90 days, median (IQR)	0 (0 to 2)
Imaging outcomes	
Change in midline shift at 90 days	- 7.4 $\pm$ 4.6
Change in subdural hematoma thickness at 90 days	-14.4 $\pm$ 7.9
[§] Symptomatic was defined as one or more of the following neurologic symptoms and signs: headache, cognitive impairment, dysarthria or dysphasia, ataxia or unsteadiness, paresis, sensory loss, and seizures. Recurrence of subdural hematoma was defined as a maximum hematoma thickness exceeding 10 mm at 30 days or reoperation within 30 days among patients who underwent burr-hole drainage. Progression of subdural hematoma was defined as an increase in the maximum hematoma thickness by more than 3 mm from baseline at 30 days or surgical rescue within 30 days among patients who received conservative treatment.	

Follow-Up and Clinical Outcomes

All patients underwent postembolization contrast-enhanced MR scans at 1 month, and no symptomatic recurrence or progression of subdural hematoma was observed in all patients. Overall, 93.3% of patients

demonstrated decrease in MLS on follow-up with a mean $\pm$ SD decrease of 7.4 ± 4.6 mm from initial MLS, and 96.7% demonstrated progressive decrease in CSDH size with a mean $\pm$ SD decrease of 14.4 ± 7.9 mm. NIHSS showed an average improvement of 0.6 ± 2.2 compared to admission. A good functional outcome (mRS 0–2) was documented in 25 (83.3%) patients.

Discussion

In this series of 30 consecutive patients, we demonstrated that MMAE for CSDH using the wedge and surge technique with large-caliber microcatheters achieved high rates of angiographic success, effective distal penetration of Onyx into the subdural membrane, and satisfactory clinical outcomes. Complete occlusion of both frontal and posterior MMA branches was obtained in all cases, with no periprocedural ischemic or cranial nerve complications. The majority of patients demonstrated progressive hematoma resolution with significant reduction of midline shift, consistent with favorable neurological and functional recovery.

Embolic agent considerations

The optimal embolic agent for MMAE in CSDH remains unsettled. The primary controversy lies between particles and liquid agents.^h In a retrospective cohort study by Shehabeldin et al. directly comparing Onyx and PVA particles in 97 embolizations, no significant differences were found in the primary outcomes of embolization failure or the need for rescue surgical evacuation¹⁷. This finding of general equivalence is echoed in a broader meta-analysis by Sioutas et al., which compared liquid agents against particles and found no significant differences in technical success, complications, recurrence, or reoperation in the overall analysis¹⁸. However, their sensitivity analysis did reveal a potential advantage for liquid agents, which were associated with significantly lower reoperation rates when used as an upfront, stand-alone treatment for CSDH.

The potential advantage of liquid agents may stem from their ability to achieve a more comprehensive and permanent devascularization of the subdural membranes. Majidi et al¹⁹. demonstrated the feasibility of n-BCA using the D5W push technique, achieving complete branch obliteration and low recurrence, but also highlighted the technical challenges of using n-BCA, including risks of catheter entrapment and premature polymerization, which limit its widespread adoption. A meta-analysis focused on embolic agent selection in both primary and adjunctive settings and found that liquid agents, particularly Onyx, offered superior hematoma resolution and lower rates of surgical rescue, whereas particle embolization was more frequently associated with incomplete devascularization²⁰. Similarly a systematic review by Mowla et al. demonstrated that three liquid embolic agents—Onyx, Squid, and n-BCA—were effective, but Onyx provided greater procedural control and consistency in penetration of distal MMA branches, which may translate into reduced recurrence risk²¹. More recently, direct comparative analyses have further clarified this trend: Mortezaei et al. recently reported that both Onyx and Squid were associated with superior radiographic and clinical outcomes relative to n-BCA, with Onyx offering particular advantages

in controllability and penetration into pathologic vasculature²². Taken together, the available evidence supports Onyx as a rational, evidence-based embolic choice for MMAE in CSDH.

Limitations of flow-directed microcatheters

The historical approach to MMA embolization often relied on highly flexible, flow-directed microcatheters. While these devices are superbly engineered for navigating the small and tortuous intracranial vasculature to reach high-flow targets such as arteriovenous malformations²³. Additionally, the MMA often undergoes enlargement in CSDH due to the hypervascular membrane^{24,25}. Conventional microcatheters may represent a significant tool-task mismatch for the specific anatomical and hemodynamic demands of dural embolization. A key innovation in our series is the use of a large-lumen microcatheter in a wedged distal position, which addresses several limitations of traditional flow-directed or small-caliber microcatheters. Conventional microcatheters often cannot achieve a stable wedge in the distal MMA, especially in larger diameter or tortuous branches. They rely on slow, flow-directed navigation and require prolonged low-rate injections to build a proximal Onyx plug that prevents reflux^{23,26}. Large-caliber microcatheters (0.017"-0.027", depending on vessel size) allowed a "wedge and surge" injection - once wedged with flow arrested, Onyx could be injected more rapidly in controlled boluses. In our series, the mean fluoroscopy time ($\approx 25 \pm 19$ minutes) was favorable, and no instances of microcatheter sticking occurred despite the use of a non-adhesive liquid embolic. By comparison, smaller microcatheters have a higher risk of the Onyx cast solidifying around the tip if injection is too slow or excessive reflux is induced.

Uncontrolled proximal reflux of liquid embolic is a major safety concern in MMA embolization. The ophthalmic artery or petrosal branch can be inadvertently embolized, risking vision loss or cranial nerve palsies. By wedging the microcatheter tip distal to critical collaterals, we essentially created a flow-arrest situation that naturally limited reflux. This permitted us to use higher injection pressures and larger Onyx volumes confidently, knowing that forward penetration would be favored over proximal reflux. In our cohort we took care to super-select distal branches (most often the frontal branch) beyond any dangerous anastomoses. As a result, no instances of non-target embolization were observed. This aligns with prior reports that microcatheter wedging techniques can reduce the possibility of unintended embolization into off-target vessels^{14,27}.

Technical Considerations

We achieved complete occlusion of both anterior and posterior MMA divisions in every patient, often by wedging and injecting in a single distal branch. This suggests that the wedging technique can embolize both major MMA branches from one access point, as advances of Onyx distally into the arborization tip effectively fills the other branch through the anastomoses between the anterior and parietal branches, thereby achieving complete occlusion of both branches. This obviates the need for separate catheterizations of each branch in many cases, further streamlining the procedure without compromising results. The large-caliber Willskey microcatheter's trackability was sufficient to navigate into distal MMA branches despite its greater outer diameter; there were no instances of vessel

perforation or dissection from catheterization. It is worth noting that wedging a microcatheter in a distal branch raises theoretical concerns of arterial rupture from the injection pressure. Our practice of stopping injection if any resistance or proximal reflux was encountered, and waiting for the cast to solidify before re-advancing, also contributed to safety.

Limitations and Future Directions

While the results of this series are promising, several limitations merit consideration. First, our study is a retrospective analysis from a single institution with a limited sample size (30 patients). There was no direct control group of MMA embolizations performed with conventional microcatheters for comparison. Thus, although we intuitively attribute our high success rate and low recurrence to the large-bore wedged microcatheter technique, we cannot definitively prove its superiority over standard technique in this non-randomized dataset. Second, our follow-up period (3 months for MRI or CT) is relatively short for assessing long-term recurrence risk, so prolonged observation would strengthen confidence in the durability of embolization. We are continuing to follow our patients to evaluate if any late recurrences occur.

Another consideration is the generalizability of the wedge-and-surge technique. Not every MMA anatomy will accommodate a large microcatheter in a distal position. In our series we had the flexibility of using 0.017", 0.021", 0.024", or 0.027" inner diameter microcatheters as needed; we typically chose the largest caliber that the target branch could accept. This tailored approach requires sound judgment—an attempt to wedge an oversized catheter could theoretically injure the vessel.

The learning curve of this technique and the choice of target branch (frontal vs parietal) are additional practical factors that warrant further study. We concur with other operators that the frontal branch is often favorable for distal catheterization, as it is usually larger and less likely to have dangerous collaterals (the risky ophthalmic collateral typically arises proximally, which our distal positioning avoids).

The use of adjunctive techniques such as proximal coil placement was not routine in our practice; we relied on the wedged catheter itself for flow arrest. Whether adding proximal MMA coiling or using dual-lumen balloon microcatheters could further improve safety is an open question—one report suggests these as alternatives to prevent non-target embolization or catheter entrapment^{13,28,29}. Future investigations could explore a standardized approach combining these methods.

Conclusion

In conclusion, our initial experience indicates that large-caliber wedged microcatheter embolization of the MMA is a feasible, safe, and efficacious strategy for CSDH. The ability to rapidly deliver liquid embolic into distal MMA branches appears to confer advantages in achieving thorough embolization of the subdural membranes. This technique yielded a high rate of hematoma resolution and a very low recurrence in our series, without procedure-related complications. Ongoing and future trials of MMA

embolization may consider stratifying or analyzing cases by microcatheter size/technique to determine if the distal wedge approach offers a statistically significant benefit in efficacy or safety.

Abbreviations

CSDH: Chronic subdural hematoma; MMAE: Middle meningeal artery embolization; MMA: Middle meningeal artery; Onyx: Ethylene–vinyl alcohol copolymer; NIHSS: National Institutes of Health Stroke Scale; mRS: Modified Rankin Scale; PVA: Polyvinyl alcohol; n-BCA: N-butyl cyanoacrylate; D5W: 5% dextrose in water; DMSO: Dimethyl sulfoxide; CT: Computed tomography; MR: Magnetic resonance; MRI: Magnetic resonance imaging; DSA: Digital subtraction angiography.

Declarations

Ethics approval and consent to participate: The data analysis and this study were approved by the Institutional Research Ethics Committee of Changhai hospital (CHEC-Y2020-004). All procedures performed in the studies involving human participants were in accordance with the ethical standards of our Institutional Review Board with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. In this retrospective study, the requirement for informed consent was waived.

Consent to Publish declaration: Written informed consent for publication of the clinical details and images in this case series was obtained from all patients. Copies of the consent forms are available for review by the Editor.

Availability of Data and Materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests: The authors declare that they have no competing interests.

Funding: This research was supported by Shanghai Natural Science Foundation (25ZR1401398) and Project from Shanghai Science and Technology Commission (23Y11906700).

Authors' contributions: Qiao Zuo and Guanghao Zhang contributed equally to this work and share first authorship. Qiao Zuo and Jianmin Liu conceived and designed the study. Qiao Zuo, Guanghao Zhang, Yuhao Tan, Lugang Yin, Yi Xu, Rui Zhao, and Pengfei Yang collected the clinical data, performed the procedures, and contributed to data analysis and interpretation. Qiang Li and Jianmin Liu provided overall supervision, technical guidance, and critical revision of the study design and manuscript. Qiao Zuo and Guanghao Zhang drafted the manuscript. All authors reviewed and revised the manuscript for important intellectual content, approved the final version for submission, and agree to be accountable for all aspects of the work.

Acknowledgements: Not applicable.

References

1. Torihashi K, Sadamasa N, Yoshida K, Narumi O, Chin M, Yamagata S. Independent predictors for recurrence of chronic subdural hematoma: a review of 343 consecutive surgical cases. *Neurosurgery*. 2008;63(6):1125-1129. doi:10.1227/01.NEU.0000335782.60059.17
2. Jiang R, Zhao S, Wang R, et al. Safety and efficacy of atorvastatin for chronic subdural hematoma in chinese patients: a randomized ClinicalTrial. *JAMA Neurol*. 2018;75(11):1338. doi:10.1001/jamaneurol.2018.2030
3. Santarius T, Kirkpatrick PJ, Ganesan D, et al. Use of drains versus no drains after burr-hole evacuation of chronic subdural haematoma: a randomised controlled trial. *The Lancet*. 2009;374(9695):1067-1073. doi:10.1016/S0140-6736(09)61115-6
4. Liu J, Ni W, Zuo Q, et al. Middle Meningeal Artery Embolization for Nonacute Subdural Hematoma. *N Engl J Med*. 2024;391(20):1901-1912. doi:10.1056/NEJMoa2401201
5. Davies JM, Knopman J, Mokin M, et al. Adjunctive Middle Meningeal Artery Embolization for Subdural Hematoma. *N Engl J Med*. 2024;391(20):1890-1900. doi:10.1056/NEJMoa2313472
6. Fiorella D, Monteith SJ, Hanel R, et al. Embolization of the Middle Meningeal Artery for Chronic Subdural Hematoma. *N Engl J Med*. 2025;392(9):855-864. doi:10.1056/NEJMoa2409845
7. Ma L, Hoz SS, Doheim MF, et al. Impact of Embolisate Penetration, Type, and Technique on Results After Standalone Middle Meningeal Artery Embolization for Chronic Subdural Hematoma. *Neurosurgery*. 2024;95(6):1395-1406. doi:10.1227/neu.0000000000003023
8. Catapano JS, Ducruet AF, Srinivasan VM, et al. Radiographic clearance of chronic subdural hematomas after middle meningeal artery embolization. *J NeuroIntervent Surg*. 2022;14(12):1279-1283. doi:10.1136/neurintsurg-2021-018073
9. Maciaszek M, Steinfert B, Harrington T, et al. Middle meningeal artery embolization for chronic subdural hematoma. *BMJ Surg Interv Health Technol*. 2025;7(1):e000290. doi:10.1136/bmjst-2024-000290
10. Salem MM, Kuybu O, Nguyen Hoang A, et al. Middle meningeal artery embolization for chronic subdural hematoma: predictors of clinical and radiographic failure from 636 embolizations. *Radiology*. 2023;307(4):e222045. doi:10.1148/radiol.222045
11. Debs LH, Walker SE, Rahimi SY. Newer treatment paradigm improves outcomes in the most common neurosurgical disease of the elderly: a literature review of middle meningeal artery embolization for chronic subdural hematoma. *Geroscience*. 2024;46(6):6537-6561. doi:10.1007/s11357-024-01173-5
12. Giurazza F, Corvino F, Cavaglià E, et al. Arterial embolizations with microvascular plug in extracranial and intracranial districts: technical results. *Radiol Med*. 2017;123(3):236-243. doi:10.1007/s11547-017-0831-x

13. Jang CK, Kim BM, Park KY, et al. Scepter dual-lumen balloon catheter for onyx embolization for dural arteriovenous fistula. *BMC Neurol.* 2021;21(1):31. doi:10.1186/s12883-021-02046-6
14. Nelson PK, Russell SM, Woo HH, Alastra AJG, Vidovich DV. Use of a wedged microcatheter for curative transarterial embolization of complex intracranial dural arteriovenous fistulas: indications, endovascular technique, and outcome in 21 patients. *J Neurosurg.* 2003;98(3):498-506. doi:10.3171/jns.2003.98.3.0498
15. Brott T, Adams HP, Olinger CP, et al. Measurements of acute cerebral infarction: a clinical examination scale. *Stroke.* 1989;20(7):864-870. doi:10.1161/01.str.20.7.864
16. Bamford JM, Sandercock PA, Warlow CP, Slattery J. Interobserver agreement for the assessment of handicap in stroke patients. *Stroke.* 1989;20(6):828. doi:10.1161/01.str.20.6.828
17. Shehabeldin M, Amllay A, Jabre R, et al. Onyx versus particles for middle meningeal artery embolization in chronic subdural hematoma. *Neurosurgery.* 2022;92(5):979-985. doi:10.1227/neu.0000000000002307
18. Sioutas GS, Vivanco-Suarez J, Shekhtman O, et al. Liquid embolic agents for middle meningeal artery embolization in chronic subdural hematoma: institutional experience with systematic review and meta-analysis. *Interventional Neuroradiol.* Published online June 15, 2023:15910199231183132. doi:10.1177/15910199231183132
19. Majidi S, Matsoukas S, De Leacy RA, et al. Middle Meningeal Artery Embolization for Chronic Subdural Hematoma Using N-Butyl Cyanoacrylate With D5W Push Technique. *Neurosurgery.* 2022;90(5):533-537. doi:10.1227/neu.0000000000001882
20. Ku JC, Dmytriw AA, Essibayi MA, et al. Embolic Agent Choice in Middle Meningeal Artery Embolization as Primary or Adjunct Treatment for Chronic Subdural Hematoma: A Systematic Review and Meta-analysis. *AJNR Am J Neuroradiol.* 2023;44(3):297-302. doi:10.3174/ajnr.a7796
21. Mowla A, Abdollahifard S, Farrokhi A, Yousefi O, Valibeygi A, Azami P. Middle meningeal artery embolization with liquid embolic agents for chronic subdural hematoma: a systematic review and meta-analysis. *J Vasc Interv Radiol.* 2023;34(9):1493-1500.e7. doi:10.1016/j.jvir.2023.05.010
22. Mortezaei A, Al-Saidi N, Ghorbi L, et al. Comparative analysis of onyx, squid, and n-BCA in middle meningeal artery embolization for chronic subdural hematoma: a meta-analysis of randomized controlled trials. *Neuroradiology.* Published online May 20, 2025. doi:10.1007/s00234-025-03651-9
23. van Rooij WJ, Jacobs S, Sluzewski M, van der Pol B, Beute GN, Sprengers ME. Curative Embolization of Brain Arteriovenous Malformations with Onyx: Patient Selection, Embolization Technique, and Results. *AJNR Am J Neuroradiol.* 2012;33(7):1299-1304. doi:10.3174/ajnr.A2947
24. Aggipothu B, Deepalam S, Badachi S, et al. Middle Meningeal Artery Embolization for the Management of Chronic Subdural Hematoma. *Cureus.* 2023;15(10):e47293. doi:10.7759/cureus.47293
25. Bastianon Santiago R, Jastrzebski C, Dakwar E, Adada B, Borghei-Razavi H, Obrzut M. Middle meningeal artery embolization for chronic subdural hematoma- pathophysiology and radiological findings. *World Neurosurg: X.* 2024;23:100296. doi:10.1016/j.wnsx.2024.100296

26. Nakagawa I, Kotsugi M, Yokoyama S, et al. Extensive roles and technical advances of middle meningeal artery embolization for chronic subdural hematoma. *Neurol Med Chir (Tokyo)*. 2023;63(8):327-333. doi:10.2176/jns-nmc.2023-0017
27. van Rooij WJ, Sluzewski M. Curative embolization with onyx of dural arteriovenous fistulas with cortical venous drainage. *Am J Neuroradiol*. 2010;31(8):1516-1520. doi:10.3174/ajnr.A2101
28. Park KY, Kim JW, Kim BM, et al. Coil-protected technique for liquid embolization in neurovascular malformations. *Korean J Radiol*. 2019;20(8):1285. doi:10.3348/kjr.2019.0127
29. Campos JK, Meyer BM, Zarrin DA, et al. Immediate procedural safety of adjunctive proximal coil occlusion in middle meningeal artery embolization for chronic subdural hematomas: experience in 137 cases. *Interventional Neuroradiol*. Published online January 2, 2024:15910199231224003. doi:10.1177/15910199231224003

Figures

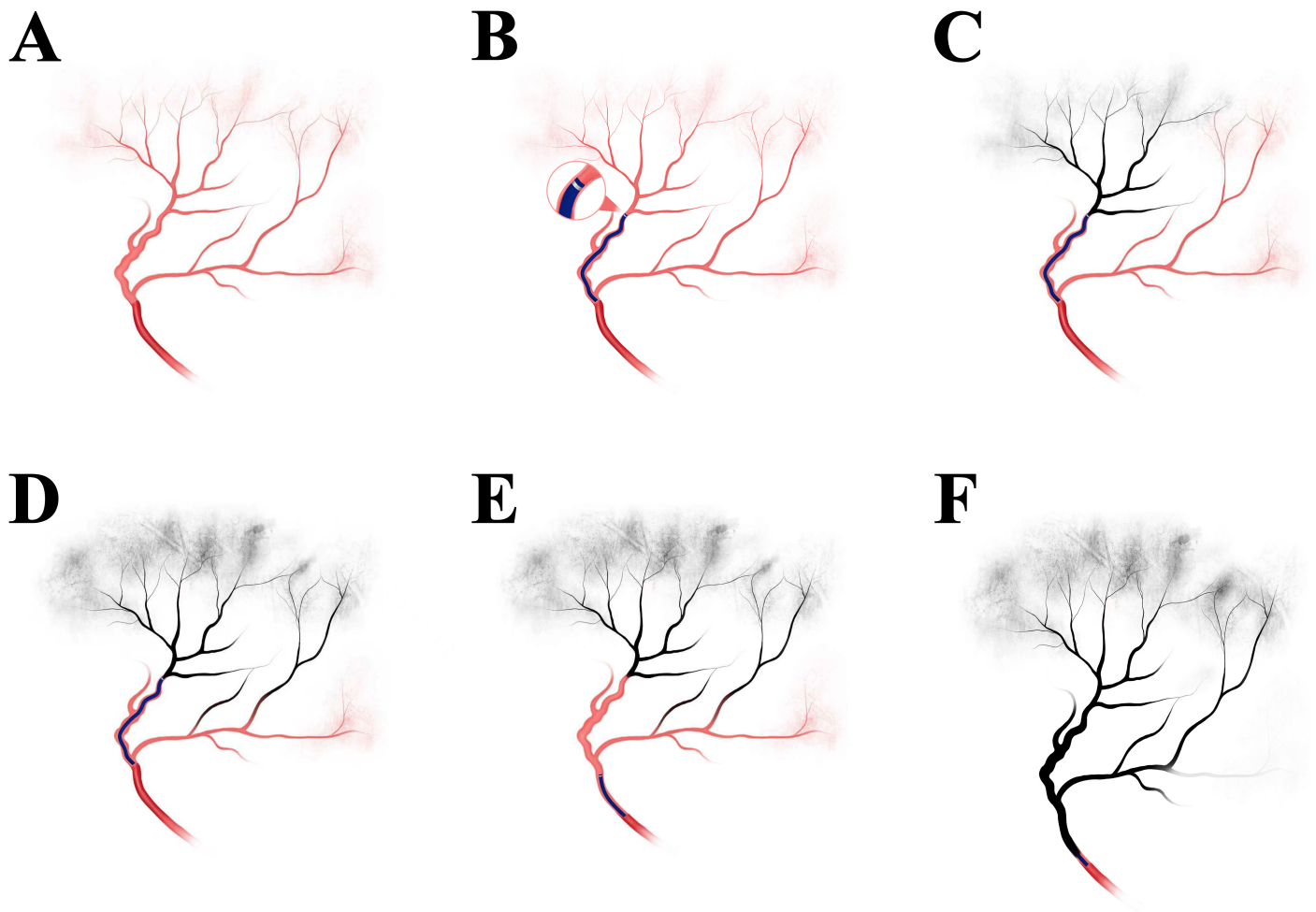


Figure 1

Schematic diagram of the Wedging technique. (A) Baseline configuration of the MMA and dural branches. (B) Navigation of the large-lumen microcatheter to cross the orbital dangerous anastomosis

and establish a wedged tip position distally. (C) Inject Onyx through the wedged catheter to initiate a distal plug and occlude the terminal branch. (D) Sustained injection advances Onyx antegradely through distal collaterals into adjacent MMA territories. (E) Withdraw the catheter to the MMA trunk. (F) Additional Onyx is delivered to extend the cast proximally and complete occlusion of the target division. (G) Immediate post-embolization external carotid DSA demonstrates no residual opacification of the MMA. (H) Final cast shows Onyx filling of the anterior and posterior divisions with distal extension toward the vertex.

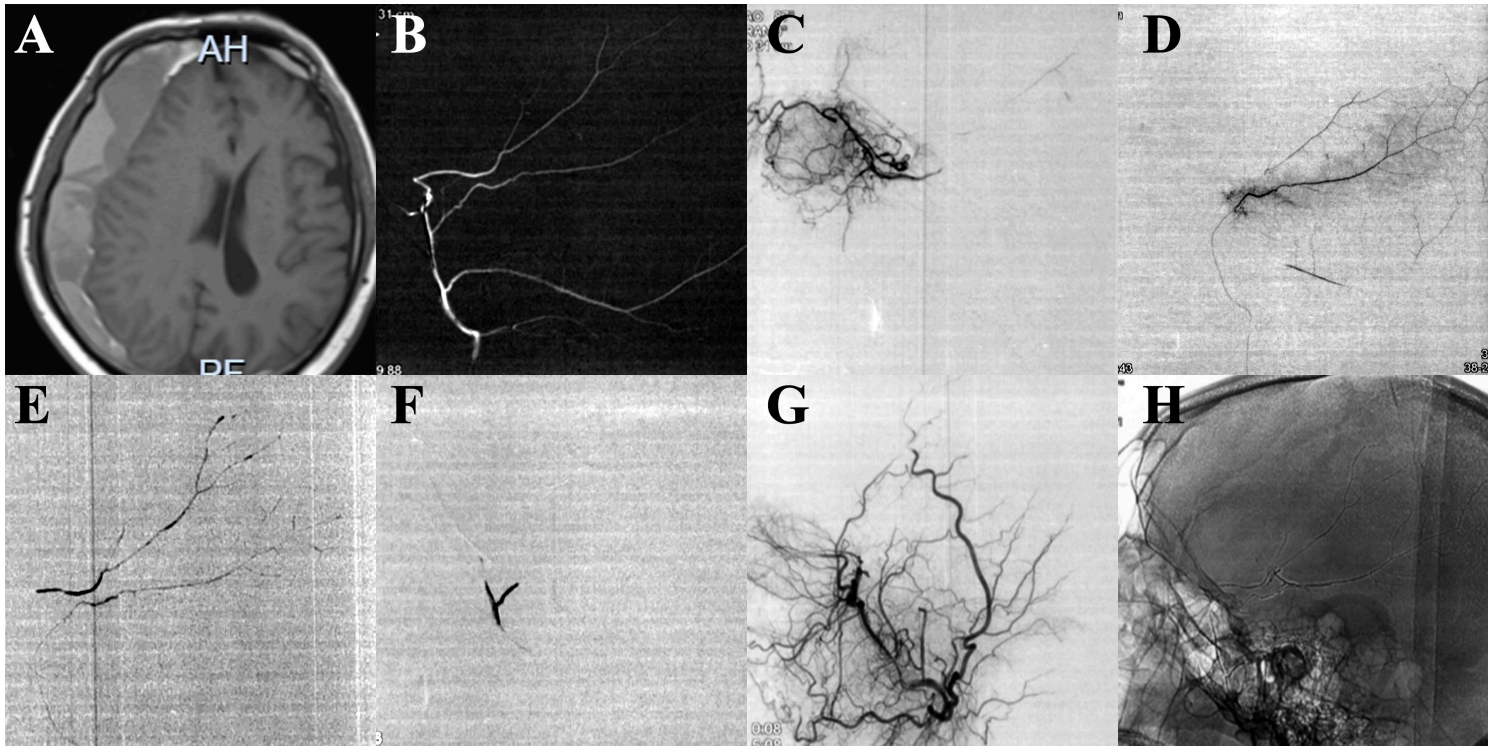


Figure 2

The process of MMAE using wedging technique (A) Contrast-enhanced MRI two days after symptom onset demonstrating right frontotemporoparietal chronic subdural hematoma. (B) Selective angiography shows the branches of MMA prior to embolization. (C) Ophthalmic collateral vessels arising from the anterior division are identified. (D) Contrast injection through a microcatheter wedged in the posterior division confirms effective flow arrest. (E) Sustained Onyx injection achieves complete distal and proximal occlusion of both the anterior and posterior divisions through distal collaterals. (F) The microcatheter is withdrawn to the MMA trunk, and additional Onyx is delivered to complete proximal trunk occlusion. (G) Immediate post-embolization external carotid DSA demonstrates no residual opacification of the MMA. (H) Final cast shows Onyx filling of the anterior and posterior divisions with distal extension toward the vertex.

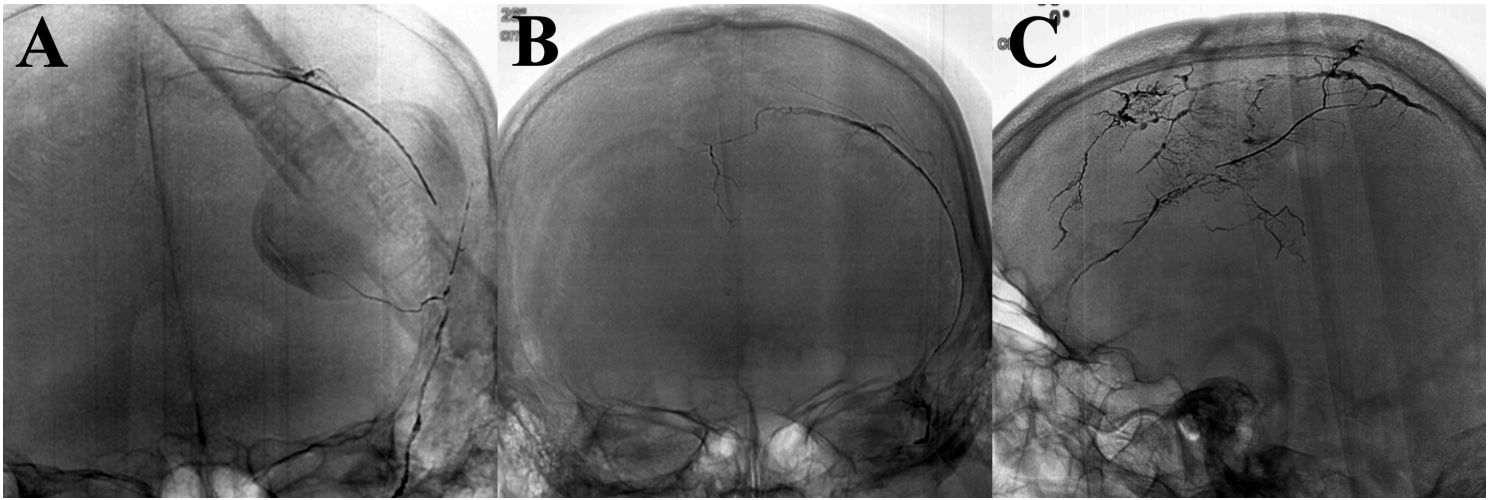


Figure 3

Representative images using the wedging technique after middle meningeal artery embolization. (A) Onyx penetrated to the midline. (B) Onyx extended beyond the midline. (C) Onyx reached the subdural hematoma membrane.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Video.gif](#)