https://doi.org/10.3329/bjns.v14i1.89026

Original Article

Middle Meningeal Artery Embolization: What we Should Know

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Conflict of Interest:

Funding Agency:

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Editorial Formatting: Dr. Md Sumon Rana, Dr. Md Motassimul Hassan, Dr. Md Shafiqul Islam,

Received: 25 October, 2024

Accepted: 26 November, 2024

Abstract

Middle meningeal artery (MMA) embolization has emerged as an effective minimally invasive strategy in the management of chronic subdural hematoma (cSDH), particularly in patients at high risk for surgical intervention or with recurrent disease. Increasing evidence supports the concept that cSDH is a dynamic inflammatory process driven by vascularized subdural membranes predominantly supplied by the MMA. Embolization of this artery disrupts the pathological neovascular supply, promoting hematoma resorption and reducing recurrence rates. This article provides a practical, beginner-oriented overview of MMA embolization, including indications, pathophysiological rationale, relevant vascular anatomy, procedural steps, embolic materials, clinical outcomes, and potential complications. Emphasis is placed on anatomical considerations and technical nuances essential for safe adoption of the technique. As ongoing trials continue to refine patient selection and procedural protocols, MMA embolization is poised to play an expanding role as both a primary and adjunctive therapy for chronic subdural hematoma.

Keywords:
Middle meningeal artery embolization; Chronic subdural hematoma; Endovascular treatment; Minimally invasive neurosurgery; Subdural neomembrane; Embolic agents; Recurrence prevention

Introduction:

Middle meningeal artery (MMA) embolization has emerged as a promising, minimally invasive technique, primarily used in the management of chronic subdural hematomas (cSDH). As our understanding of the pathophysiology of cSDH has evolved, so has the rationale for targeting the MMA—a key vascular supplier of the subdural membrane (Link et al., 2019). This article provides a concise primer for beginners interested in this endovascular technique.

What is MMA Embolization?

MMA embolization involves the endovascular occlusion of the middle meningeal artery to reduce or halt the vascular supply to the fragile neomembranes responsible for chronic subdural hematoma growth and recurrence. It is usually performed via a femoral or radial arterial access and is guided by fluoroscopy (Ban et al., 2018).

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Indications

The most common indication for MMA embolization is:

- Chronic subdural hematoma (cSDH): Especially in patients with high surgical risk or those with recurrence after burr hole evacuation (Ng et al., 2020).

Other emerging indications include:

- Recurrent post-traumatic cSDH
- Prophylactic embolization in patients with subdural effusion at high risk of progression
- Adjunct to surgery to reduce recurrence
- Rarely, tumor embolization (e.g., meningiomas with MMA supply) (Chowdhury et al., 2019)

Rationale and Pathophysiology

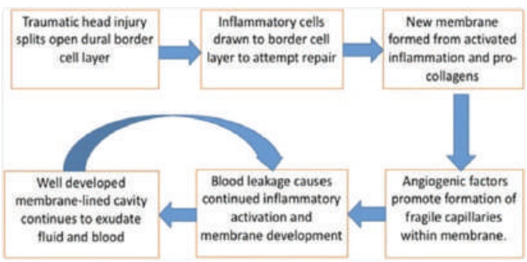

Figure 1: Pathophysiology of Chronic Subdural Hematoma (Edlmann et al., 2017)

Chronic subdural hematomas are not static blood collections; they are dynamic, inflammatory entities with neovascularized outer membranes (Figure 1). These fragile vessels are primarily supplied by branches of the MMA. By embolizing the MMA, the pathological blood supply to the hematoma membrane is disrupted, promoting resorption and reducing recurrence (Kan et al., 2021).

Basic Anatomy: Know Before You Go

The middle meningeal artery (MMA) has always been the workhorse corridor for devascularization of dural-based intracranial lesions and, more recently, has been established as a target for the endovascular management of chronic subdural hematomas. The MMA anatomy is complex and deceitful, and its territory of irrigation (including cranial nerves) is poorly understood. Furthermore, MMA variations and anastomoses are more frequent than expected, which may predispose to procedure-related morbidity (Martínez et al., 2022).

Therefore, understanding the vascular anatomy is crucial:

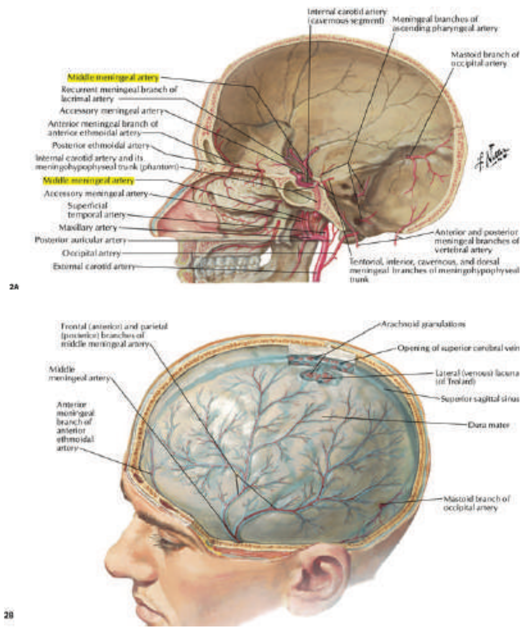

Figure 2: 2A is showing the origin of MMA from the maxillary artery and its entry into the skull through foramen spinosum. 2B is showing branches of MMA(Netter, 2022, Plate 112)

- Origin: MMA typically arises from the internal maxillary artery, a branch of the external carotid artery(Figure 2A).
- Course: Enters the cranial cavity through the foramen spinosum and divides into anterior and posterior branches(Figure 2B).
- Dangerous anastomoses: Be aware of potential anastomoses with:

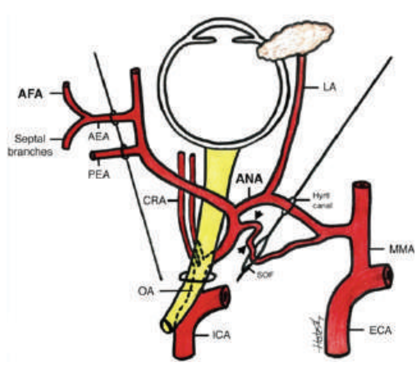

Figure 3: This picture demonstrates dangerous anastomosis of MMA with ophthalmic artery. OA-Ophthalmic artery, ANA-Anastomotic artery, LA- Lacrimal artery, CRA- Ciliary artery, AEA-Anterior ethomoidal artery, PEA-Posterior ethomoidal artery.

- ○ Ophthalmic artery via the recurrent meningeal or lacrimal arteries. There are three anastomoses between the ophthalmic artery (OA) and the middle meningeal artery (MMA): the anastomotic branch with MMA, the recurrent meningeal branch and the anterior falx artery(Martínez et al., 2022).

- ○ Internal carotid via petrosal branches

- ○ Cranial nerves and vasa nervorum

A solid anatomical understanding is essential to avoid serious complications like vision loss (Scoville, Link and Patsalides, 2023).

The Procedure: Step-by-Step Overview

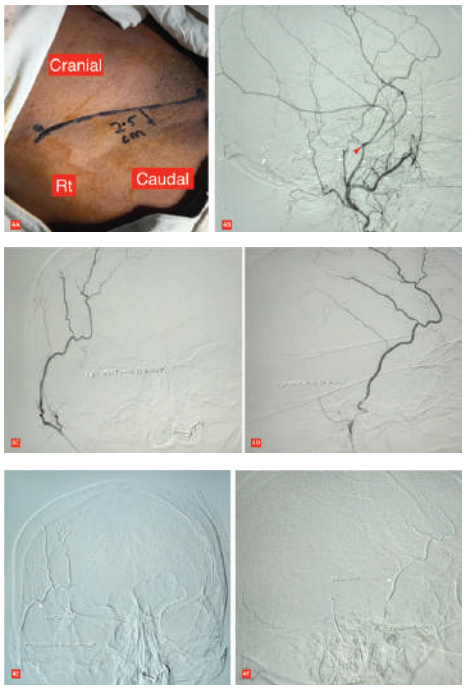

Figure 4: Steps of right MMA embolisation has been demonstrated here. Figure 4A shows the vascular access through the right femoral artery. A 6FR short sheath was used for vascular access. 4B shows Lateral view of selective angiogram of right external carotid artery (ECA). Branches of ECA has been marked here with white arrow. There is a sharp forward turn of MMA after its entrance into the skull base through the foramen spinosum which is marked with a red arrow head. 4C and 4D show AP and Lateral view(LV) of selective right MMA angiogram respectively. There is no dangerous anastomosis here. 4E and 4F shows post-embolized (with n-butyl cyanoacrylate/NBCA glue) AP and LV of Right MMA branches (Frontal and Parietal) respectively. NBCA cast is marked with white arrow. There is complete occlusion of both branches of MMA.

1. Vascular Access:
   - ○ Common femoral (Figure 4A) or radial artery approach.
   - ○ 6F sheath and 5F catheterization of the external carotid artery(Figure 4B).

2. Angiography:
   - ○ Selective injection to confirm MMA anatomy and rule out dangerous anastomoses(Figure 4C and 4D).

3. Microcatheter Navigation:
   - ○ A microcatheter is advanced distally into the MMA branches, often into the anterior division.

4. Embolic Agent Delivery:
   - ○ Particles (e.g., PVA 100–300 μm), n-butyl cyanoacrylate (NBCA), or Onyx can be used.
   - ○ Goal: Achieve stasis in both anterior and posterior divisions without reflux (Shin et al., 2020).

5. Post-embolization Angiogram:
   - ○ To confirm complete occlusion and rule out non-target embolization(Figure 4E and 4F).

Embolic Materials

Each embolic agent has pros and cons:

Embolic Agent	Pros	Cons
PVA particles	Readily available, cost-effective	Risk of recanalization
NBCA (glue)	Permanent, deep penetration	Requires experience
Onyx	Good control, effective penetration	Expensive, longer procedure time

Selection depends on operator experience, anatomy, and availability (Kim, 2017; Chowdhury et al., 2019).

Complications and How to Avoid Them

- ● Ophthalmic artery embolization → Check for dangerous ECA-ICA anastomoses (Scoville, Link and Patsalides, 2023).
- ● Cranial nerve ischemia → Avoid reflux; use precise microcatheter placement.
- ● Allergic reaction or stroke → Meticulous technique and careful agent selection.

Patient Selection: Who Benefits Most?

Ideal candidates:

- ● Elderly or frail patients with recurrent or bilateral cSDH
- ● Patients on anticoagulation
- ● Poor surgical candidates or those refusing surgery

Contraindications include:

- Acute SDH or large symptomatic hematomas needing urgent evacuation
- Significant mass effect with neurological deterioration
- Unfavorable vascular anatomy or inability to cannulate the MMA (Soleman, Nocera and Mariani, 2017)

Clinical Outcomes

- Success Rate: High rates of hematoma resolution or stabilization (80–90%) have been reported (Link et al., 2019; Kan et al., 2021).
- Recurrence: Significantly lower than surgery alone.
- Complications: Rare, but may include cranial nerve palsy, stroke, or vision loss—typically related to non-target embolization (Ng et al., 2020).

Representative Case

A 45 year old female came to us with a headache. Her GCS was 15 and she was neurologically intact. However, the CT scan of the brain shows right fronto-temporo-parietal-chronic subdural hematoma (In Figure 5A it is marked with red arrow head) with midline shifting(MLS). As her neurology was intact and GCS was 15 we performed selective embolisation of her right MMA which has been described in Figure 4A-4F. One month after embolisation there is significant clinical and radiological (Figure 5B) improvement. Hematoma volume was reduced and MLS was corrected. After 3 months there is no blood at all (Figure 5C).

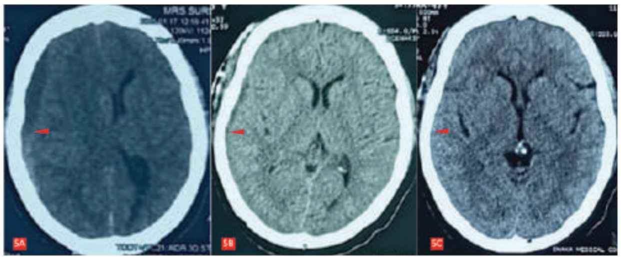

Figure 5: 5A is before embolisation. 5B is after one month of embolisation and 5C is 3 months after embolisation. Red arrow head shows the hematoma.

Future Directions

- Ongoing trials aim to establish MMA embolization as a first-line treatment (Ng et al., 2020).
- Potential expansion into preventive therapy in high-risk trauma patients.
- Technological advancements may allow safer, faster, and more cost-effective interventions (Scoville, Link and Patsalides, 2023).

Conclusion

MMA embolization represents a paradigm shift in the management of chronic subdural hematomas. With growing evidence and technical refinements, this procedure offers a safe and effective alternative or adjunct to surgery—especially in high-risk populations. For the beginner, understanding the anatomy, indications, procedural steps, and potential pitfalls is key to adopting this technique safely.

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