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# Middle Meningeal Artery Embolization for Chronic Subdural Hematoma Using 100–300 Microns Embosphere®: A Technical Overview and Review of Key Concepts

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## Abstract

**Background—** Endovascular embolization of the middle meningeal artery (MMA) has emerged as an excellent alternative to conventional surgery for treating chronic subdural hematoma (cSDH). Previously published case reports/series have mostly used polyvinyl alcohol particles, N-butyl-2-cyanoacrylate (NBCA), gelatin sponge, coils, or onyx for MMA embolization. We successfully performed 20 MMA embolization procedures using 100-300 microns Embosphere® microspheres from April 2019 to September 2019.

**Methods—** All the consecutive MMA embolization procedures performed at our institution from April 2019 to September 2019 were reviewed. Images were selected from MMA embolization procedures in order to illustrate the technique.

**Results—** We describe in detail our technique of MMA embolization using 100-300 µm Embosphere® microspheres for treating cSDH along with pearls and pitfalls to look out for in order to avoid complications. We provide angiogram images demonstrating the MMA anatomy, potential dangerous anastomosis, contrast enhancement pattern of the subdural membranes during angiography and post procedure CT head findings.

**Conclusion—** MMA embolization with 100-300 µm Embosphere® microspheres for treating cSDH is technically feasible and safe.

**Keywords—** Middle meningeal artery, Embolization, Embosphere, Subdural hematoma.

## INTRODUCTION

cSDH is a common neurological disease that develops due to the constant leakage of blood products from the subdural capsule's neo-vasculature fed by the MMA's distal branches.[1-6] Given the high recurrence rate of cSDH and the need for stoppage/reversal of antiplatelet/anticoagulant agents with conservative or surgical treatment, endovascular embolization of the distal branches of the MMA has emerged as an excellent alternative to surgical evacuation or conservative management.[1,2,7-12] Various embolization agents, including polyvinyl alcohol particles (150-250 µm), N-butyl-2-cyanoacrylate (NBCA), gelatin sponge, coils, Onyx (Medtronic, Minneapolis, MN), and 300-500 microns Embosphere® Microspheres (MeritMedical, South Jordan, Utah) have been used for embolization of MMA.[2,10,13-29] 100-300 microns Embosphere® Microspheres have been successfully used for preoperative embolization of skull base meningiomas,[30] prostate artery embolization for treating lower urinary tract symptoms due to benign prostatic hyperplasia,[31] genicular artery embolization for treatment of refractory hemarthrosis following total knee arthroplasty,[32] etc.

We started using 100-300 microns Embosphere® Microspheres for MMA embolization with the hypothesis that smaller particles will provide better penetration in the subdural membrane's distal vessels, resulting in better embolization results. We successfully performed 20 MMA embolization procedures using 100-300 microns Embosphere® Microspheres from April 2019 to September 2019 and continue to practice the same. Through this technical report, we share our technique of MMA embolization using 100-300 microns Embosphere® to treat cSDH, along with the pearls and pitfalls to look out for to avoid complications.

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## TECHNICAL REPORT

### MMA Anatomy and dangerous anastomosis

Middle meningeal artery branches off medially from the first part of the internal maxillary artery (branch of the external carotid artery). It has a typical vertical course before entering the middle cranial fossa through the foramen spinosum. In the petrous temporal bone, it takes a sharp anterior turn and runs anteriorly before dividing into the terminal frontoparietal and squamous/temporal branches (Figure 1). Close attention should be paid to the petrosal arterial branch, which perfuses the seventh cranial nerve, and an orbital/meningolacrimal arterial branch that can supply collateral arterial blood to the ophthalmic artery (Figure 2, 3). Usually, a petrosal arterial branch is small and is not easily visualized on the angiogram. It originates in the petrous temporal bone, where MMA turns anteriorly. The orbital/meningolacrimal arterial branch originates distally, proximal to the bifurcation of MMA into terminal branches or from the proximal portion of the frontoparietal branch of MMA.

### Embolization technique

All MMA embolization procedures are performed in an inpatient setting. If a patient cooperates, the procedure is performed under conscious sedation (midazolam and fentanyl). General anesthesia is required only if the patient feels uncooperative and cannot hold still during the procedure.

The patient is prepped and draped in the usual sterile fashion. The common femoral artery is accessed with a 6 French 24 cm Arrow sheath (Cordis, Miami Lakes, FL). After sheath placement, 30 units/kg of intravenous heparin is administered. A 5 French MPD Envoy (Codman Neurovascular, Raynham, MA) guide catheter is used to select the common carotid artery ipsilateral to the SDH. Biplane angiography of common carotid artery (CCA) bifurcation is performed. If no significant atherosclerotic steno-occlusive disease is noted at the internal carotid artery (ICA) origin, it is selected, and intracranial biplane angiography of the ICA is performed. If a significant atherosclerotic steno-occlusive disease is noted at the ICA origin, intracranial biplane angiography is performed from the CCA. Close attention is paid to the size and flow of the ophthalmic artery. External carotid artery (ECA) is then selected, and biplane angiography is performed.

Under fluoroscopic/road map guidance, the microcatheter (minimum inner diameter of 0.0165 inches) is used to catheterize the MMA over the microwire (0.014 inches) and is positioned proximal to the bifurcation of frontoparietal and squamous/temporal arterial branches and well past the petrous temporal bone on the unsubtracted lateral x-ray. The anterior-posterior view is very helpful in selecting the MMA as MMA branches off medially of the first part of the internal maxillary artery. Biplane angiography is then performed to confirm the position of the microcatheter distal to the origin of the petrosal branch (perfuses the seventh cranial nerve). The orbital/meningolacrimal arterial branch is visualized to confirm that there is no collateral arterial blood supply to the ophthalmic artery. Suppose there is an orbital/meningolacrimal branch visualized. In that case, the microcatheter is navigated distal to this branch into the frontoparietal branch, and great care is taken to avoid reflux into the orbital branch during embolization. If the frontoparietal branch is small, 0.013 inches microcatheter is used to select and embolize. If the frontoparietal branch is too small to catheterize or embolization is considered high risk because of reflux into the meningolacrimal branch, then coil embolization is performed.

A separate clean table is set up for the embolization material/accessories to minimize complications. Each pre-packaged 100-300 microns Embosphere® Microspheres vial (Merit Medical, South Jordan, UT) contains 2 ml of microspheres in 6 ml of pyrogen-free, sterile, physiological saline. 8 ml of contrast (Visipaque 320, Iodixanol, GE Healthcare, Marlborough, MA) is added to this pre-packaged syringe, resulting in a 50% contrast and 50% microsphere/saline solution. A small air bubble (about 1 ml) is drawn in the embosphere syringe, attached to the luer lock three-way stopcock. To evenly suspend the solution, the syringe is gently inverted several times. 1 ml syringe is attached to the three-way stopcock, and the evenly distributed embosphere suspension is advanced into the 1 ml syringe.

Under fluoroscopy and blank roadmap guidance, the embospheres are administered in a slow pulsatile (gentle tapping) manner. The most important aspect of the embolization procedure is to be patient and give enough time for the embosphere to travel distally and embolize the microcapillaries perfusing the subdural hematoma. Continuous injection of the suspension will limit the antegrade movement within the artery, leading to occlusion of the proximal portion of the vessel without appropriate distal penetration, giving a false perception of embolization of distal microcapillaries. Embospheres are administered until stasis of anterograde flow and/or reflux around the microcatheter tip is noted. We clean the microcatheter with heparinized saline after every 2ml of embosphere administration to prevent any clogging of the embosphere within the microcatheter. MMA angiography is repeated after embolization to demonstrate the elimination of the flow into the distal branches of the MMA. Microcatheter is then withdrawn from the body while keeping suction on the microcatheter. Biplane angiography of the external carotid artery is then performed with the guide catheter. The guide catheter is pulled into the CCA and advanced into the ICA. Suppose the baseline angiography was performed from the CCA due to significant steno-occlusive disease in the ICA. In that case, the catheter is positioned in the distal CCA, preferably facing the carotid bulb. Biplane angiography of the intracranial cerebral blood vessels is performed to ensure patency of intracranial vasculature. The capillary phase and venous clearing are visualized to ensure unchanged mean transit time and venous patency. The guide catheter is then removed.

Hemostasis is achieved using a closure device and manual compression. Post-procedure computed tomography (CT) head is repeated to see the penetration of the contrast within the subdural hematoma and the surrounding membranes. The patient is observed overnight in the stroke or neuro intensive care unit and then discharged to home or a rehabilitation facility, as appropriate. Follow-up CT head is obtained in 4 weeks and 12 weeks post-procedure.

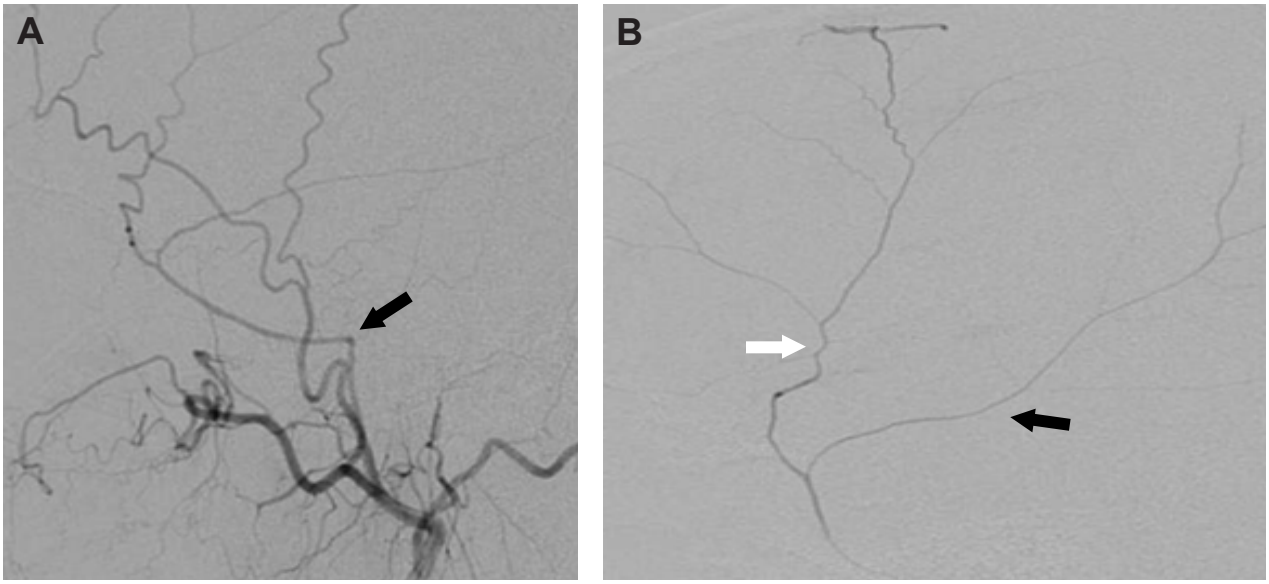


**FIGURE 1: A) ECA angiogram (lateral view) showing the middle meningeal artery (black arrow). B) MMA angiogram (lateral view) showing frontoparietal (white arrow) and temporal (black arrow) branches of MMA. (ECA: External carotid artery, MMA: Middle meningeal artery)**

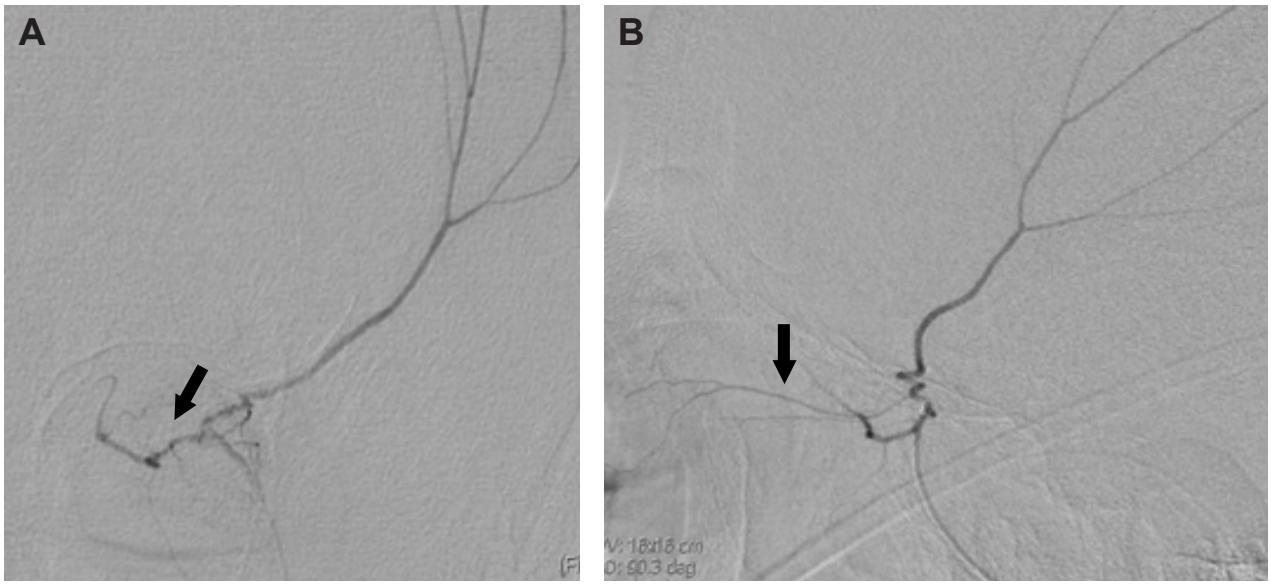


**FIGURE 2: Anterior-Posterior (A) and Lateral (B) views of MMA angiogram showing the prominent meningolacrimal/orbital branch. (MMA: Middle meningeal artery)**

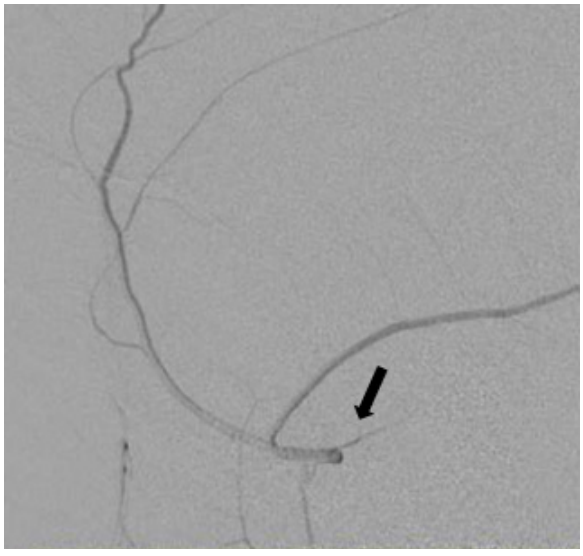

**FIGURE 3: MMA angiogram (lateral view) showing the petrosal branch. (MMA: Middle meningeal artery)**

### Technical pearls

Initially, we used a larger guide catheter (6F MPD, Codman Neurovascular, Raynham, MA) and microcatheter (0.021 inches) for embolization. We noticed limited distal accessibility and higher rates of vasospasm with them. We transitioned to 5F MPD (Codman Neurovascular, Raynham, MA) and 0.0165 inches microcatheter, which provided excellent distal accessibility with no vasospasm.

We recommend not using a microcatheter smaller than 0.0165 inches because of the high chance of clogging the microcatheter from the particles. In cases of prominent orbital/meningolacrimal branch where 0.013 inches microcatheter might be needed for further distal access, we recommend cleaning the microcatheter with saline after every 1ml of embosphere infusion to avoid clogging.

We also recommend using 100-300 microns embosphere over 300-500 for better distal penetration of neovessels of subdural membrane and lower rates of microcatheter clogging.

### Important radiographic findings

**Angiographic Findings:** Prolonged microcatheter runs of the MMA reveal the distal penetration of the contrast in the subdural membrane giving the classic "cotton wool-like" appearance as described in the figure (Figure 4). This pattern of contrast staining is due to leakage of contrast through the immature and fragile neo-vasculature of the subdural membrane.

**Post-procedure CT Head:** Post-procedure CT head usually depicts the enhancement within the SDH and the surrounding capsule, which strongly supports the theory of the arterial origin of the cSDH (Figure 5).

## DISCUSSION

By 2030, cSDH is expected to become the most common neurosurgical disease, with an estimated incidence of around 60,000/year.[1] cSDH develops due to constant leakage of blood products from the fragile neo-vasculature of the subdural capsule. Subdural capsule forms over time from the inflammatory cells and fibroblasts that migrate from the dura due to chronic inflammation from broken-down blood products.[1-5] Histological and angiographic evidence have confirmed MMA's distal branches to be the subdural capsule's main arterial source.[2-4,6]

Conventionally cSDH was treated based on the size of the subdural hemorrhage and the patient's presenting symptoms. Asymptomatic or patients with minor symptoms, with cSDH measuring less than 10 mm in greatest thickness with less than 5 mm midline shift, were generally managed conservatively. In contrast, patients with severe symptoms or larger cSDH would undergo surgical evacuation with a burr hole or craniotomy.[1] Surgical evacuation requires stoppage and reversal of antiplatelet or anticoagulant agents that put these patients at high risk for thromboembolic complications depending on the underlying pathology. Also, a high recurrence rate of subdural hemorrhage (2-37% based on various observational studies) is seen post surgical evacuation.[1,2,7-12]

Given these surgical challenges, endovascular embolization of the MMA has emerged as an excellent alternative to surgical evacuation or conservative management. Multiple case reports/series have strongly demonstrated the safety and efficacy of MMA embolization for treating cSDH.[2,10,13-29] Various embolization agents, including polyvinyl alcohol particles (150-250 μm), N-butyl-2-cyanoacrylate (NBCA), gelatin sponge, coils, Onyx (Medtronic, Minneapolis, MN), and 300-500 microns Embosphere® Microspheres (MeritMedical, South Jordan, Utah) have been successfully used for embolization of MMA.[2,10,13-29] Very limited data exists on the feasibility and safety of 100-300 microns Embosphere® Microspheres usage for embolization of MMA.[33]

We achieved successful angiographic outcomes in all 20 consecutive MMA embolizations using 100-300 microns Embosphere® Microspheres with a tailored, consistent technique without technical failures or clinical complications. 60% (n=12) of our patients were female, with a mean age of 71. cSDH was located on the left in 9 patients, right in 8 patients, and bilateral in 3 patients. All the patients tolerated the procedure very well. A recent large multicenter study of 154 MMA embolization procedures using particles, liquid embolic agents and coils reported technical success rate of 97.4% with complication rate of 9.4% that included increase in SDH size, facial palsy, MMA rupture and seizure.[34] Major limitation of our study is small sample size (n=20).

We believe smaller embosphere particles (100-300 microns) provide better distal penetration in the arterial neovascularization of the subdural membrane (compared to other embolization agents or larger particles), resulting in better angiographic embolization outcomes. Smaller particles enable the usage of smaller microcatheter, which allows for better distal access without causing vasospasm in small terminal branches of MMA. Smaller particles also have lower rates of microcatheter clogging. Thus, we prefer 100-300 microns Embosphere® Microspheres for MMA embolization.

In this paper, we describe in detail our technique of MMA embolization using 100-300 microns Embosphere® Microspheres for treating cSDH. To avoid complications, we discuss several technical pearls, including MMA anatomy and dangerous collaterals. We also discuss the key radiographic findings during MMA embolization and post-procedure CT head. We hypothesize our rationale of using 100-300 microns Embosphere® Microspheres over liquid embolic agents, coils, or bigger particles.

## CONCLUSIONS

MMA embolization has recently emerged as an excellent alternative to conservative or surgical management of cSDH. Various embolization agents have been used successfully for MMA embolization, but limited data exist on embolization with 100-300 microns Embosphere® microspheres. Based on our experience, we conclude that MMA embolization with 100-300 microns Embosphere® microspheres for cSDH is technically feasible and safe. We describe in detail our technique of MMA embolization using 100-300 microns Embosphere® microspheres, along with key technical pearls, including MMA anatomy, dangerous collaterals,

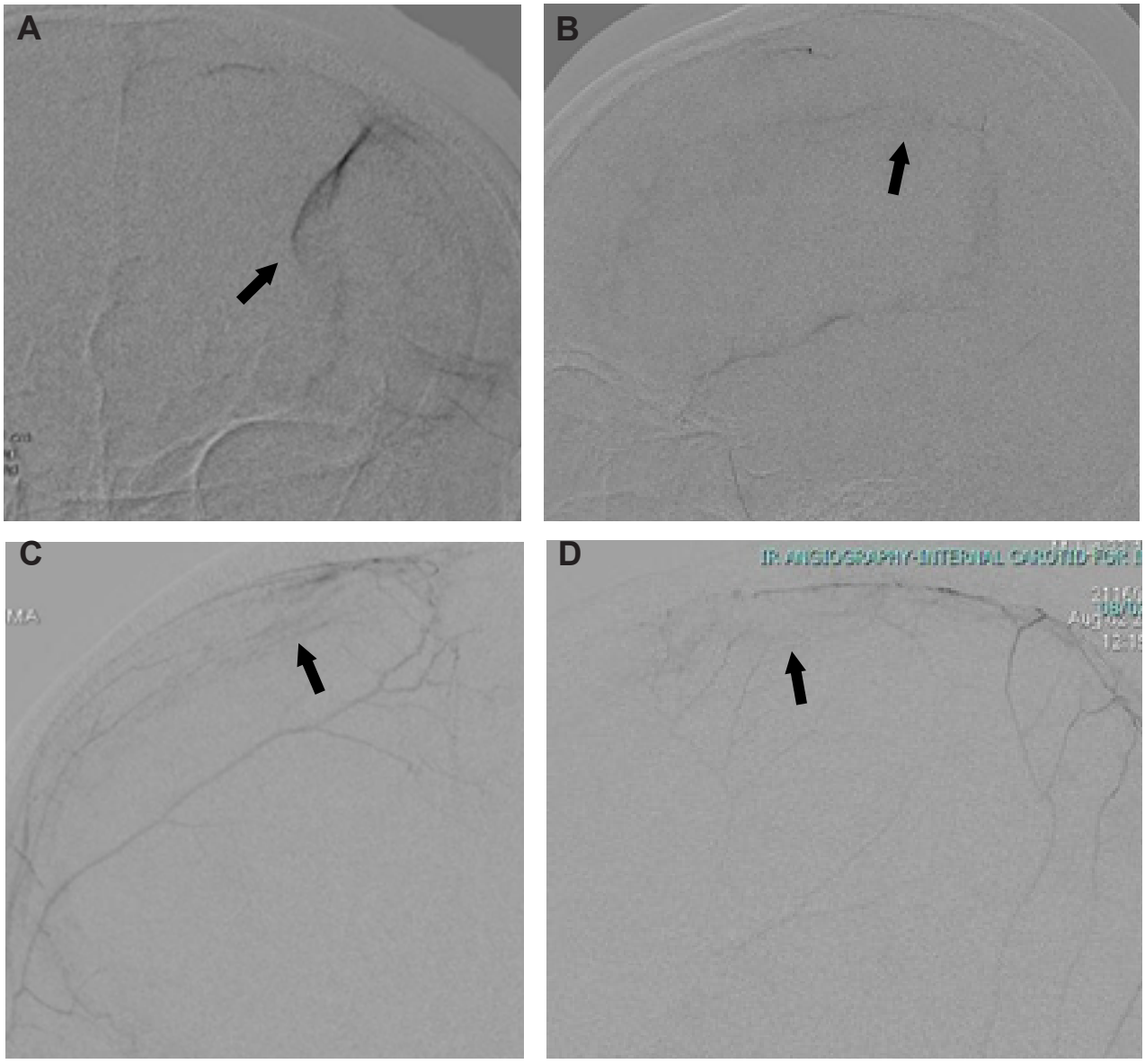


**FIGURE 4: Anterior-Posterior (A, C) and Lateral (B, D) views of MMA angiogram from two different patients show the classic "cotton wool like" appearance of the contrast penetration in the subdural membranes. (MMA: Middle meningeal artery)**

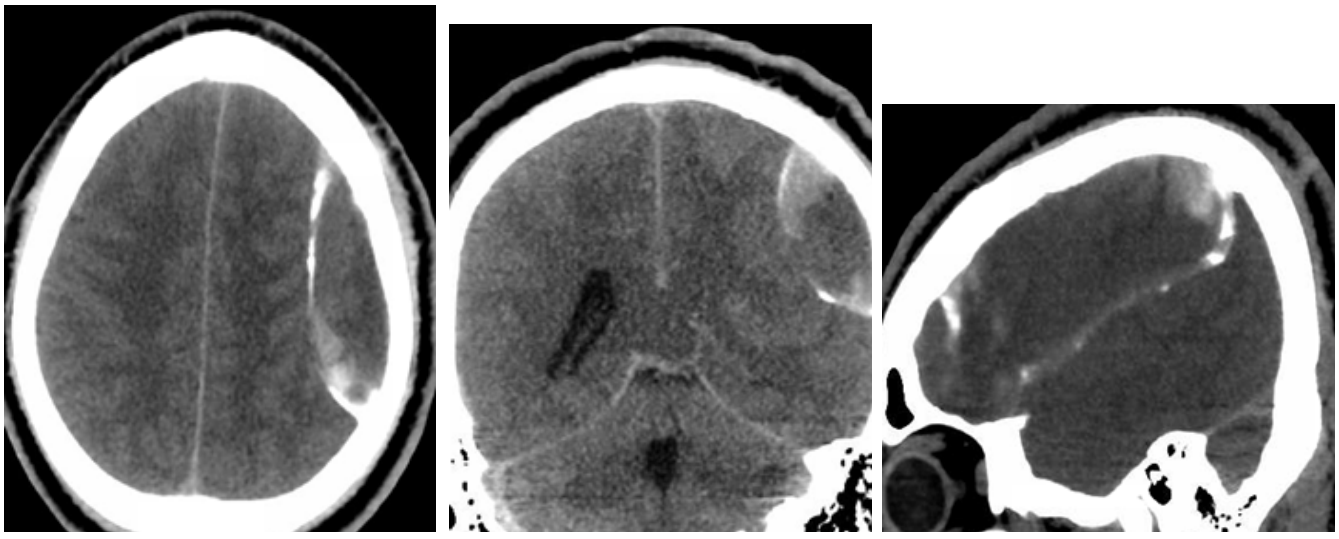

**FIGURE 5: Post-procedure CT head (axial, coronal, and sagittal views) depicting the contrast enhancement of the subdural hematoma and the capsule. (CT: Computed tomography).**

and radiographic findings during embolization and post-procedure CT head.

## DECLARATION OF CONFLICTING INTEREST

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