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RESEARCH HIGHLIGHT

# Middle meningeal artery embolization and subdural evacuating port system placement for chronic subdural hematomas: how I do it

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## Abstract

**Background** Chronic subdural hematoma (cSDH) is a common neurosurgical pathology causing significant morbidity and mortality, yet optimal management and intervention remains controversial.

**Methods** We describe embolization of the middle meningeal artery (MMA) and placement of subdural evacuating port systems (SEPS) by a dual trained open and endovascular neurosurgeon. Both procedures are done in sequence in the interventional radiology suite, and real time radiographic results are demonstrable with Xper-CT.

**Conclusions** MMA Embolization followed by evacuation of cSDH with a SEPS is a valuable strategy to mitigate perioperative risk factors and patient comorbidities, through a minimally invasive evacuation with subsequent embolization minimizing recurrence.

**Keywords** Middle meningeal artery embolization · Subdural evacuating port system · Chronic subdural hematoma · Minimally invasive neurosurgery · Neurointerventional radiology · Hematoma recurrence prevention

## Relevant surgical anatomy

The middle meningeal artery (MMA) emerges as a branch of the maxillary artery and supplies blood to the meninges [10]. The MMA enters the skull through the foramen spinosum and runs between the inner table of the bone and the outer layer of the dura. This anatomical positioning explains its involvement in the formation of epidural hematomas and the grooves seen on the inner table of the skull that accommodate its path. Distally, its branches are embedded between the two layers of the dura [6]. Of notable anatomical importance is that the MMA sits deep in the pterion region, which is a common access site for interventions involving the MMA, such as an MMA embolization procedure [10].

MMA embolization is done in a neuro-interventional radiology suite. Pertinent anatomy for this procedure includes diagnostic catheter access via the radial or femoral artery [4]. Once vascular access is obtained, a catheter is advanced into the common carotid artery, followed by the external carotid artery, leading to the branch of the maxillary artery, and ultimately reaching its destination in the proximal MMA [4]. ECA-ICA anastamoses are evaluated and branches avoiding the skull base and orbit are avoided.

After the MMA embolization, unilateral or bilateral SEPS drains are placed depending on the laterality of the pathology. The SEPS drain utilizes trephination and fastening of a titanium port between inner and outer cortices of the calvarium, perforation of the underlying dura, and subsequent attachment of drainage tubing and suction bulb. Pertinent anatomy for this procedure can include localization of the parietal boss, which is a bony prominence found on the posteromedial portion of the skull. The burr hole can also be created at the location of the hematoma's maximal thickness. Performance of the burr hole after embolization utilizes the hemostatic effect of the embolization and can allow for optimal burr hole placement due to use of IR guided fiducials.

## Description of the technique

### MMA embolization

The accompanying photos and video illustrate the combined MMA embolization and SEPS procedural technique.

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The MMA contributes to the blood supply of the fibrocellular neo-membranes which develop throughout the cSDH [7]. Therefore, embolization of the MMA has been shown to augment spontaneous hematoma resorption, and reduce the risk of recurrence [1].

After diagnosis of an amenable cSDH and preoperative optimization where patients are typically not prescribed steroids, the patient is then taken to the interventional radiology (IR) suite for MMA embolization and SEPS placement during a single anesthetic period [2]. Embolization of the MMA is performed prior to SEPS deployment and can be done under local or general anesthesia [2]. This is done to create a safer environment for the subdural drainage as potential vascular supply has been embolized. Standard femoral or radial artery is used for vascular access [2]. Once a catheter is advanced to the bifurcation of the frontal and parietal branches of the MMA, polyvinyl alcohol particles (45–150 µm) are used to occlude the vascular distributions or embolic material of operator's choice (Fig. 1) [2]. Although this period of time is precious for drainage of the hematoma, the embolization portion of the procedure had a mean operation time of 1.27 h (±0.71).

Although rare, complications from the MMA embolization procedure can occur, including access site issues such as groin or wrist hematomas and vessel injury (e.g., dissection), as well as more serious complications including stroke, cranial nerve dysfunction or visual deficits secondary to non-target embolization such as via meningo-ophthalmic collaterals [8].

## SEPS placement

With the patient still under local/conscious sedation or general anesthesia in the IR suite, radiopaque fiducial markers (EKG leads) are placed on the scalp (Fig. 2) [2]. An Xper cone-beam CT (Philips Healthcare, Netherlands) of the head is then performed on the IR table, to utilize the fiducials in localization of SEPS placement, generally at area of maximum hematoma thickness [2]. A 1 cm incision is made in the scalp down to the outer table of the calvarium. A handheld twist drill is then used for trephination at the selected location [2]. This is followed by perforation of the dura with a sharp instrument, attachment of the SEPS port to the skull, and connection of the tubing and suction drain reservoir in an airtight fashion (Fig. 3) [2]. A final CT head is performed to confirm the absence of acute hemorrhage and evaluate the level of decompression (Fig. 4) [2].

After the MMA-SEPs procedure, patients are kept flat for about 4 h in cases where transfemoral access is utilized. If radial access is utilized, patients are not required to remain bedridden. At this point, post-operative medications such as steroids are not typically prescribed as decompression is happening through the drainage of the hematoma. Usually

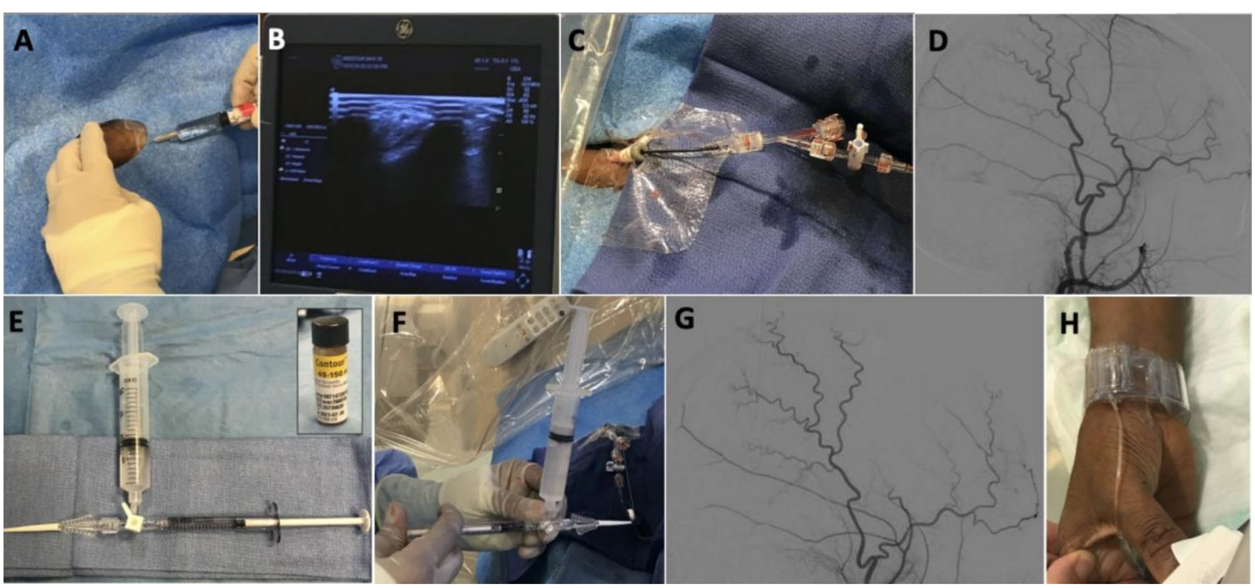


**Fig. 1** Middle Meningeal Artery (MMA) Embolization via transradial approach. **A**. Injection of local anesthetic (1% lidocaine) near the radial artery at the wrist. **B**. Ultrasound-guided access of the radial artery. C. Radial artery with 5-French sheath placed over a microwire. **C**. A 5-French Sim 2 and 035 Glidewire was used to obtain access to the common carotid artery. **D**. Lateral working projections of the left ECA. Microcatheter and microwire were then selectively coaxially navigated at the bifurcation between the anterior and posterior segments of the MMA. E. 45–150 um PVA particles were prepared with contrast in a syringe which was connected to the catheter and a 1-cc syringe via 3-way connector. F. PVA particles injected under direct fluoroscopic guidance until stasis was achieved in the target vessels. G. Lateral projection post-embolization of left ECA. H. Patent hemostasis and closure obtained with a TR band.

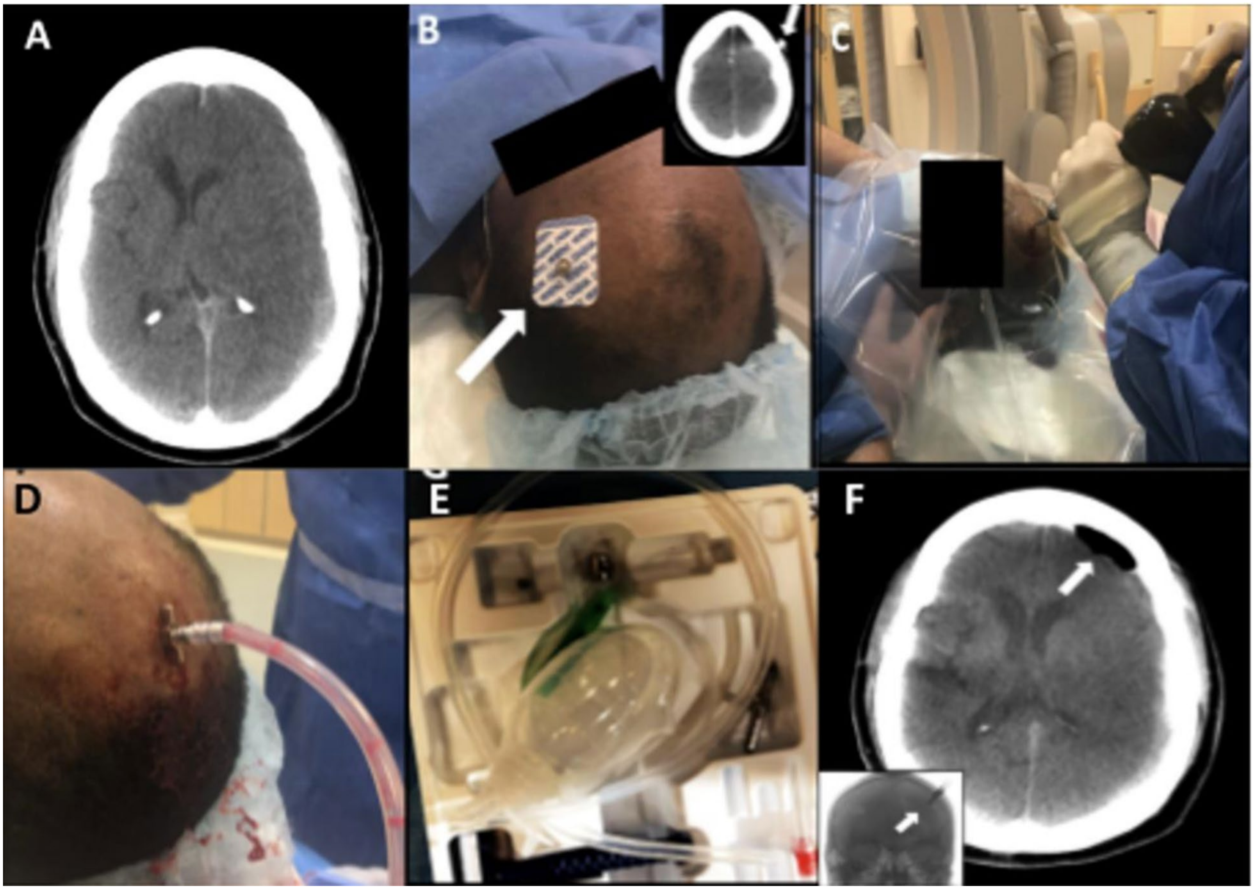


**Fig. 2** Pre- and post-placement of SEPS in the IR suite [2]. (**A**) Preoperative axial CT scan demonstrating a chronic subdural hematoma. (**B**) Placement of radiopaque fiducial markers on the scalp, with an inset showing the corresponding CT localization. (**C**) Intraoperative setup for SEPS placement in the IR suite under fluoroscopic guidance. (**D**) SEPS drain secured in place after burr hole trephination. (**E**) Close-up view of the SEPS reservoir system. (**F**) Postoperative axial CT scan demonstrating SEPS placement and reduction in hematoma size, with an inset highlighting the location of the drain

within 48-h post-operatively, proper drainage of the hematoma has occurred and the SEPs system is then removed.

## Indications

MMA embolization and SEPS placement protocol is recommended for cases of cSDH is symptomatic and being considered for evacuation. Typical indications include: neurologic compromise, subdural hematoma with associated midline shift, a hematoma greater than 10 mm in size [2, 5, 9]. When a patient's cSDH is not causing significant mass effect or the patient is on antiplatelet/anticoagulant therapy that cannot be held/reversed, patients still undergo the embolization, but not the SEPS placement [3].

## Limitations

Placement of a SEPS confers the standard operative risk of surgical site infection, as well as creation of acute subdural or intraparenchymal hemorrhage. There is variable presence of fibrous membranes throughout the cSDH which may limit the ability to effectively drain all components of the hematoma. These fibrous capsules can demonstrate high levels of neovascularization and can bleed acutely when perforated during the drainage of the existing chronic hematoma. [7]. The immediate CT scan after a SEPS procedure demonstrates reduction of the cSDH but rarely shows complete evacuation. The combination of the SEPS with the MMA embolization allows for synergistic reduction of hematoma volume size, increased reabsorption of residual hematoma with protection against recurrence in a single operative/anesthetic setting.

## How to avoid complications

Performing a safe MMA embolization is paramount to a safe overall procedure. The embolization should only be

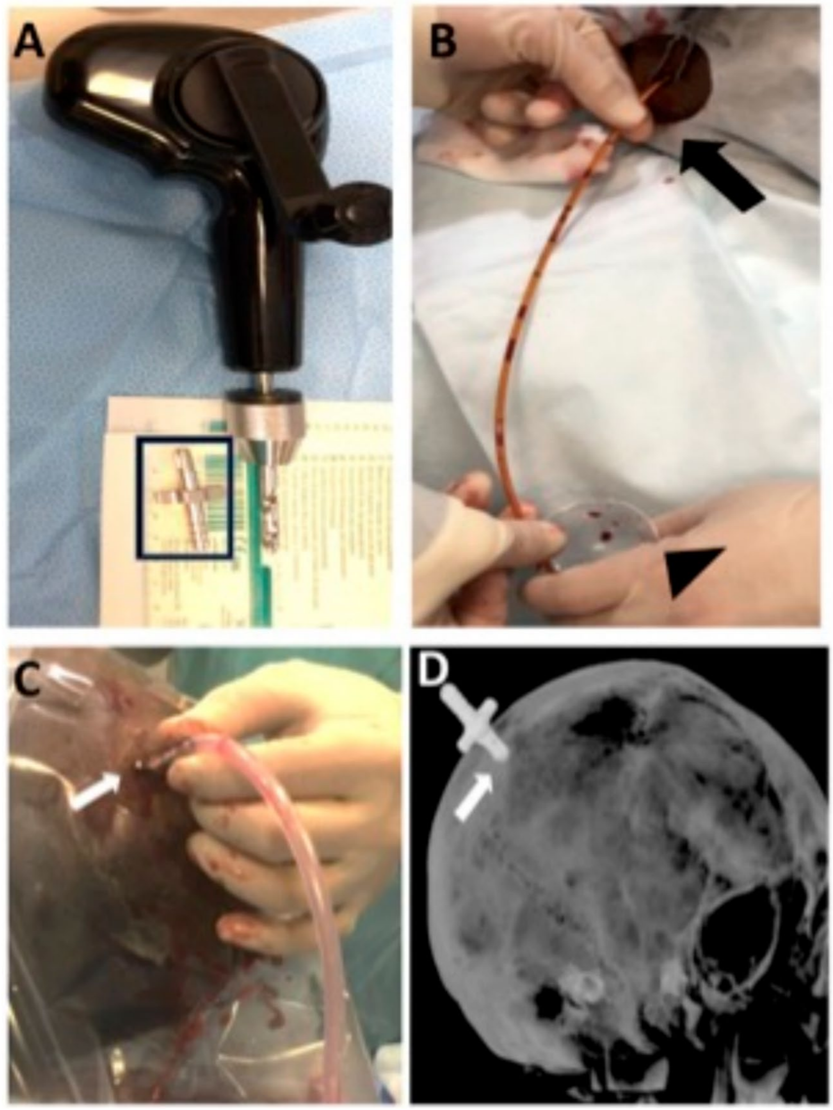


**Fig. 3** Illustration of SEPS anatomy [2]. (**A**) The handheld twist drill used for trephination, with an inset showing the SEPS placement guide. (**B**) Insertion of the SEPS catheter through the burr hole, with the black arrow indicating the port and the arrowhead highlighting the attached drainage tubing. (**C**) Securing the SEPS in place, with white arrows indicating the port and tubing. (**D**) Postoperative lateral skull X-ray demonstrating the SEPS placement, with the white arrow pointing to the external port and tubing

entertained after careful evaluation of the MMA branches and appropriate selective catheterization of the MMA is done to ensure that inadvertent embolization of ICA collaterals is not done.

The nuance of this particle procedure is performing the SEPS after embolization to create a safer environment for hematoma evacuation. The SEPS on its own has been shown to have a high recurrence rate related to suboptimal placement of the drain. Doing the procedure in the IR suite allows for fiducial placement and allows the operator to identify the optimal bur hole placement.

We have found that an immediate reduction of the hematoma is generally obtained with minimal pneumocephalus. Because of contrast staining within the dura and the subdural membranes correlates with a successful MMA embolization, the subsequent CT can be misinterpreted as an acute component.

## Specific information for the patient

It is vital to explain to patients our institution's extensive experience with the MMA/SEPS procedure. Our most recent study, published in 2022, underscores the safety and efficacy associated with this minimally invasive procedure. In the 250 patients who received the MMA/SEPS procedure versus the conventional approach of a craniotomy, the MMA/SEPS group had substantially shorter hospital stays ($p < 0.05$) with a significant majority of them going home after the procedure [2]. In that same study, the MMA/SEPS procedure did not increase mortality rates, readmissions, or postoperative complications [2]. MMA embolization with SEPS offers a safe and effective minimally invasive alternative to traditional craniotomy for cSDH and may be more appropriate for patients with significant comorbidities.

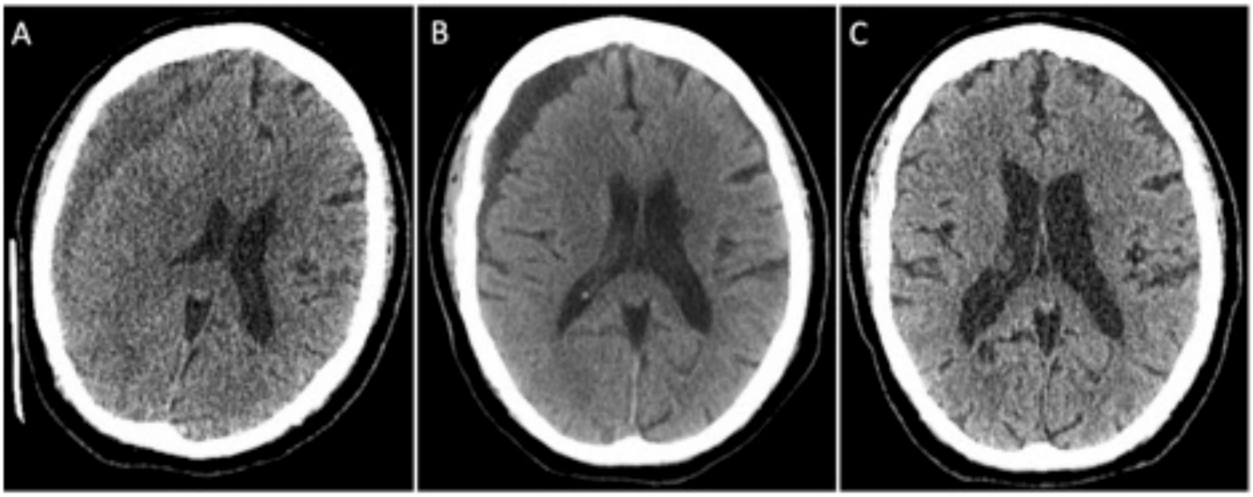


**Fig. 4** Panel (**A**) shows the CT head of an 83-year-old male who presented to his PCP complaining of mild headaches. The patient was referred to MWHC for head CT, which revealed a right chronic subdural hematoma (cSDH) 2 cm in thickness with a 1 cm midline shift. The patient underwent simultaneous SEPS drain placement and MMA embolization on the day after admission. Panel (**B**) shows a follow-up head CT 9 days after presentation, demonstrating a reduction in hematoma size and decreased midline shift. Panel (**C**) shows a follow-up CT head at a 5-month interval, indicating complete resolution of the cSDH and associated mass effect. [2]

It is the combination of both an endovascular procedure with a bedside procedure that allows for hematoma decompression with subsequent reabsorption and recurrence protection. Performing both in a single anesthetic session allows minimizing exposure to repeat procedures in a potentially frail patient with multiple comorbidities while reducing the risk of recurrence.

## 10 Key points

1. **MMA-SEPS Combined Approach**: Describes the combined MMA embolization and SEPS placement for cSDHs.
2. **Single Anesthetic Session**: MMA embolization is performed first, followed by SEPS placement, during the same session.
3. **IR Suite Guidance**: Procedures are minimally invasive and performed in the IR suite using cone-beam CT for real-time imaging.
4. **Indications for cSDH**: Recommended for cSDHs with significant mass effect, midline shift, or hematomas > 10 mm.
5. **MMA Anatomy**: Highlights the importance of the MMA's path and fiducial-guided SEPS placement.
6. **PVA Embolization**: Embolization is achieved using PVA particles through radial or femoral artery access.
7. **Twist-Drill SEPS Placement**: SEPS involves burr hole creation, dural perforation, and airtight drainage confirmed by CT.
8. **MMA-SEPS Benefits**: Demonstrates reduced recurrence, faster recovery, and shorter hospital stays compared to craniotomy.
9. **Complication Avoidance**: Ensures precise MMA embolization and optimal SEPS placement to minimize risks.
10. **Minimally Invasive cSDH Management**: Combines MMA embolization and SEPS for effective decompression and recurrence prevention.

**Authors contributions** R.G. wrote the main manuscript text, prepared figures 1–3, edited the video, prepared the citations. G.F.K. conceived and designed the study, narrated the video, and edited the manuscript. C.G. performed the procedures. E.D. provided the figures and captions. D.R.F. conceived and designed the study. All authors reviewed and approved the final manuscript.

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**Data availability** No datasets were generated or analysed during the current study.

## Declarations

**Ethical approval** Consent to participate and consent to publish were obtained from all individual participants included in the study.

**Competing interests** The authors declare no competing interests.

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